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OF
CHEMISTRY:

EMBRACING THE MOST
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AND THE OUTLINES OF
ITS APPLICATION TO AGRICULTURE AND THE ARTS.

CONTAINING, ALSO,

A TREATISE ON THE NEW CHEMICAL PHILOSOPHY AND NOMENCLATURE,
WITH THREE HUNDRED AND THIRTY ILLUSTRATIONS EXHIBITING PARLOR AND LECTURE-ROOM EXPERIMENTS.

DESIGNED FOR THE USE OF COLLEGES AND SCHOOLS.

BY JOHN A. PORTER, M.A., M.D.,
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PREFACE.

In the revision and enlargement of the "Principles of Chemistry," the Author has made it his especial care to retain those peculiar features of the work to which it owes its distinctive character as a text-book, and which have secured for it, among teachers, such wide approval.

Especially designed for beginners in the science, whether in schools or colleges, great effort was made in the original volume to simplify the study of Chemistry, and to save teachers much explanation which would otherwise be required. To this end, the facts were more carefully classified than is usual, many details of interest only to the professional chemist were omitted, great simplicity of statement was uniformly observed, and chemical phenomena were described in ordinary, as well as in symbolic language. In pursuance of the same general design, a large number of experiments were devised, of the utmost simplicity, extending over a wide field of the science, and bringing the illustration of the subject within the reach of every pupil. A series of new and original designs were also introduced, illustrating to the eye the groupings of organic chemistry. All of these characteristic features have been retained in the revised edition.

While a new class of cuts have been introduced, illustrative of lecture experiments, and adapting the book more completely to college use, all of the more simple experiments with the figures describing them, have been preserved in the present edition. This course has been pursued, first, because of the great advantage which it gives to the student, who with limited means at his command, still entertains the ambition to become an experimenter, and secondly, because the figures referred to, serve, in proportion to their simplicity, as object-lessons of the most effective character, and take the place of experiments where the experiments themselves cannot be performed. This is, however, according to the testimony of teachers, but a small part of the end which they serve. The reduction of the experiment to its very simplest form is found to simplify greatly to the learner the apprehension of the subject which it illustrates.

In pursuance of the leading object of the revision, viz., to bring the work up to the present condition of the science, considerable portions have been entirely rewritten, and every page carefully revised.

The Chapter on Animal Chemistry has been so expanded as to include a presentation of the more interesting topics in Human Physiology, and will be found amply illustrated by cuts introduced for the first time in this edition.

The revision has necessarily resulted in a considerable enlargement of the work, and it will now be found to contain quite as extensive a survey of the science of Chemistry as can with advantage be pursued in an ordinary college course.

So large a number of authorities have been consulted in the preparation of the new edition, that special acknowledgment of each cannot be attempted.

The author would, however, express his especial indebtedness to the articles of Professor Graham, on "Crystalloid and Colloid Substances," and to Professor Tyndall's lectures on "Heat considered as a Mode of Motion." It has not been deemed advisable to modify the language employed in the Chapter on Heat, or the mode of presenting the subject, in view of the recent more perfect development of the dynamical theory. To carry out any such purpose consistently, would have been impracticable, inasmuch as the new theory has not as yet provided itself with an adequate vocabulary.

It has been deemed the wiser course to hold strictly to the material theory in the description of phenomena, and the statement of principles, and to indicate in connection with each important topic the difference of conception which the dynamic theory requires.

It remains for the author to express his great obligations to Dr. M. C. White, of New Haven, and Professor Seely, of Middlebury College, for important aid rendered in the revision of this work. He would also embrace this opportunity of expressing his acknowledgments for the favorable reception accorded to former editions of the work, and his hope that the effort to make the present revised edition still more worthy of approval, may not have been altogether unsuccessful.

JOHN A. PORTER.

New Haven, Conn.,
Aug., 1st, 1864.

PUBLISHER'S NOTICE.

To meet the demand for a text-book containing the later theories of Chemical Philosophy, the publishers have extended the former edition so as to embrace a new part giving a complete exposition of the modern theories, together with numerous exercises in the new nomenclature.

New York, July, 1868.

TABLE OF CONTENTS.

PART I.

PHYSICS

PART II.

CHEMICAL PHILOSOPHY.

Laws of Combination.

PART III.

INORGANIC CHEMISTRY.

NON-METALLIC ELEMENTS.

PART IV.

ORGANIC CHEMISTRY.

PART V.

CHEMICAL PHILOSOPHY.

INTRODUCTION.

According to the most ancient view of the constitution of matter, the earth and all material things are but modifications of one and the same original substance. Fire, water, and air, were each in turn asserted to be the primitive element, according to the arbitrary conjecture of philosophers who were bold enough to speculate upon the subject. At a later date, the views of all seemed to be harmonized in ascribing the same dignity to the three contending elements, and including earth among the original varieties of matter. Earth, Air, Fire, and Water, were assumed to be the original materials out of which all forms of matter are produced.

Modern chemistry has dethroned each of these elemental monarchs of the world, and distributed their prerogatives among a larger number. Earth, air, and water, are all excluded from the list of elements, and fire appears in the modern view as only the transient attendant of chemical combination.

Each one of the acknowledged elements has its own specific properties, affinities, and capacity of combination. These peculiarities, and all resulting phenomena, it is the province of chemistry to investigate and explain. Light, heat, and electricity, stand in intimate relation to all chemical action, either as cause or effect, or unfailing attendant, and are, therefore, briefly considered in the earlier part of the present work.

The study of science has not for its object the mere gratification of an idle curiosity. Looking at the subject from a material point of view alone, chemistry is one of the great agents in the transformation of nature, and its subjugation to the wants of man. The earth yields her treasure to its skillfully conducted processes, and even the trodden clay becomes converted in its crucible into shining metal. The arts draw from it, with every succeeding year, increased advantage, and the condition of mankind is elevated, and the world advanced by its progressive triumphs. Agriculture also is indebted to its discoveries. It opens to us mines of agricultural wealth in what would otherwise have passed for worthless refuse. It clothes exhausted fields with new fertility, by the addition of some failing constituent whose absence its subtle processes have detected. It carefully investigates the laws and conditions of vegetable growth, by which earth and air are converted into food for man and beast, and thus places us on the highway of sure and rapid improvement.

These practical results, which are the basis of that material prosperity in which taste, and literature, and the graces of life find their natural growth, are by no means to be disregarded. But this is not all. The study of chemical science reveals to the mind a beauty and harmony in the material world, to which the uninstructed eye is blind. It shows us all of the kingdoms of nature contributing to the growth of the tiniest plant, and feeding the nascent germ, by the inter-revolution of their separate spheres. It shows us how through fire, or analogous decay, all forms of life are returned again to the kingdoms of nature, from which they were derived. Without encroaching upon the domains of the astronomer, it reveals to us still more wonderful relations of distant orbs, which affect not only the outward sense, but supply the very forces which we employ in our contest with the powers of nature. It unveils to us a thousand mysteries of cloud and rain, of frost and dew, of growth and decay, and unfolds the operation of those silent yet irresistible forces which are the life of the world we inhabit.

But the study of nature is worthy of being pursued with a still nobler aim. The glory of the Deity shines in every crystal and blooms in every flower. Every atom is instinct with a life which the Creator has imparted. The laws that govern the minutest particles, as well as the grander revolutions of the heavenly spheres, are but the expression of His will. The reverent study of nature is therefore a contemplation of Deity. Vague and unsatisfactory without the aid of another, and written revelation, it unfolds to the mind thus enlightened, new and exalting evidences of the infinite wisdom and beneficence of the Creator of the world.

INTRODUCTORY.

1. The Science of Chemistry is of the widest range. Air, Earth, Fire, and Water, all belong to its domain.

It informs us of the composition of the rocks which make up the mass of the Earth, and of the soil which forms its surface. It tells us of what Air is made, and how it supplies the wants of animal and vegetable life. It separates Water into gases, and reproduces it again by uniting them. It informs us of the nature of Fire, and of the changes which take place in combustion.

2. It tells us of what plants are formed, and what becomes of them when they decay and disappear. It tells us how to produce metals from ores, wines from fruit, liquors from grain, and shows us the changes which take place in the formation of all these substances. Almost all transformations which occur in the materials around us—as, for example, of iron into rust, of wood or coal into gas, of food into flesh—it belongs to Chemistry to describe and explain.

Questions.—1. What does Chemistry tell us of earth, air, fire, and water? 2. What of metals, plants, and wines?

3. As all of these changes result from the action of the minute particles of matter on each other, it is necessary first to consider the subject of Atoms.

4. As the most of them depend on changes of temperature, it is necessary, in the first part of the work, to consider the laws and effects of Heat. As these laws are best understood from their analogy to the laws of Light, and as Light has an important influence in many chemical processes, a brief chapter on Light precedes the chapter on Heat and its various effects.

5. As many, and perhaps all chemical changes, are accompanied by electrical phenomena, it is also important to dwell briefly on the subject of Electricity before proceeding to what is more strictly the science of Chemistry. The first part of this work is, therefore, devoted to the consideration of these subjects; or, in other words, to the Science of Physics.

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3. Why does it treat of atoms? 5. Why of heat and light? 5. Why is electricity introduced?

Youmans New Chemistry
good for Old System

good to outline
knowledge of subject

good for class-room - refer-
ences &c.

PART I.

PHYSICS.

CHAPTER I.

ATOMS AND ATTRACTION.

1. Atoms.—All matter is supposed to be composed of exceedingly minute spherical or spheroidal particles, which are held together by their mutual attraction, and are never themselves subdivided. These particles are commonly called atoms. There is reason to believe that the atoms of different substances differ from each other in weight and perhaps in size. The belief that they are never subdivided is not based on their extreme minuteness, but on other grounds, to be mentioned hereafter.

2. Minuteness of Atoms.—Their minuteness is illustrated by the fact that a single grain of musk will fill a room with its fragrant particles for years, without suffering any considerable loss of weight. The number of atoms it gives off during that time is beyond computation.

Questions.—1. Of what is matter composed? What is said of atoms? 2. How is the minuteness of atoms shown?

3. Elements.—There are at least sixty different kinds of matter. Each kind which cannot be separated into other kinds is called an elementary substance, or simply an element. Iron and carbon or charcoal are elements. Iron rust, on the other hand, is a compound. There are, of course, as many different kinds of atoms as there are of elements.

4. Cohesion.—The force which binds together atoms of the same kind is called the attraction of cohesion, or simply cohesion. In the more tenacious substances, such as iron or copper, the force of cohesion is immense. The strength of a horse is insufficient, for example, to break an iron wire one-fourth of an inch in thickness, because in every section of the wire the atoms attract each other with a superior force. As we may imagine innumerable sections in every inch of the wire, we see that there is in every inch a force of attraction exerted, which in its sum total is inconceivably great. Attraction between unlike atoms in contact with each other, as between glue and the wood to which it is applied, is called *adhesion*.

5. Gravitation.—Unlike the force of attraction mentioned in the preceding paragraph, gravitation is an attractive force which acts at all distances. The weight of all bodies is due to gravitation; one body weighs twice or three times as much as another, because it has twice or three times the quantity of matter to attract and be attracted by the earth.

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3. Define and illustrate an element? 4. What is cohesion? Illustrate the subject? What is adhesion? 5. How does gravitation act?

The attraction of gravitation causes terrestrial bodies to fall to the earth, and the same force extending to celestial bodies retains the planets in their orbits.

6. Chemical Attraction, or Affinity.—The force which unites unlike atoms to form compounds possessing new properties is called *chemical attraction*, or *affinity*. Thus iron and oxygen unite by chemical attraction to form iron rust, a substance different from either. The gas chlorine and the metal sodium unite, as will be hereafter seen, to form common salt. When substances become thus united by chemical affinity, the resulting compound is not a mere mixture, with properties of both constituents, as when salt and sugar are mixed; it is, on the contrary, a new substance, with properties of its own.

7. Distance of Attraction.—The forces of attraction above mentioned, with the exception of gravitation, act only at immeasurably small distances. The attraction of two plates of glass an inch apart is too feeble to be perceptible, and when brought into apparent contact they exhibit but little cohesive attraction. But if two plates of glass, well polished and perfectly clean, are pressed together with great force, the atoms are brought within the range of cohesive attraction, and they unite so firmly that fracture takes place in any other direction quite as readily as in the line of union. So iron and oxygen will not attract each other

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6. What is chemical attraction or affinity? 7. Do the forces of cohesion and chemical affinity act at great distances?

from a distance, but when brought together, they unite in consequence of their chemical attraction.

8. The three kinds of attraction are perfectly illustrated in a falling drop of water. Affinity holds together the atoms of oxygen and hydrogen which make up each particle of water. Cohesion unites the particles of water thus formed, to make the drop, and gravitation causes the coherent drop to fall.

9. Three States of Matter.—There are three distinct states or conditions of matter—the solid, the liquid, and the gaseous. Almost all substances may be made to assume each of these states. Thus, a piece of solid sulphur, if heated up to a certain point, melts and becomes liquid. If the liquid sulphur be exposed to a still higher temperature, it passes off in the form of a vapor or gas.

10. Contact of Atoms.—The atoms of matter are not supposed to be in absolute contact in either solids, liquids, or gases. This is inferred from the fact that all substances may be diminished in bulk by pressure. But in solid bodies the attraction of cohesion between the atoms is strongest, and they are more nearly and firmly bound together. In liquids, cohesion is less than in solids, and the atoms are free to roll and glide around each other. In gases, cohesion is entirely overcome, and but for gravity, the atoms would separate themselves indefinitely.

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8. Illustrate the three different kinds of attraction. 9. What are the three states of matter? 10. Are atoms in contact? What is the cause of the difference of cohesion in bodies?

Heat is the main cause of this difference in cohesion. This subject will be more fully considered in the chapter on Heat, or Caloric.*

CHAPTER II.

LIGHT.

11. Light is the Source of Vision.—We ascribe the phenomena of vision, by which we obtain our principal knowledge of the material world, to a mysterious agent called light.

12. Chemical Action of Light.—Daguerreotype pictures are produced by the chemical action of light. So, light acts chemically in converting water and the carbonic acid of the air into vegetable matter. The action of light in these cases will be explained hereafter. The present chapter is devoted to the consideration of its nature and more important laws.

13. Light is without Weight.—While the effects of

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11. To what agent do we ascribe the phenomena of vision? 12. In what cases does light act chemically? 13. Has light weight?

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* The subject of Crystallization belongs to Physics, and in a strictly scientific arrangement, would be considered in this place. The student will find the most convenient illustrations of this subject in the Salts, which are considered later in the work, and it has therefore been introduced in the chapter which treats of these compounds. It is to be borne in mind that what is there said of crystallization, relates to other compounds and to elementary substances, as well as to salts.

light, and the laws according to which they take place are well understood, philosophers have differed widely with respect to its nature. It is, however, agreed that light is imponderable, or without weight, this being inferred from the fact that an illumined object weighs no more than the same object when unillumined.

14. NEWTON'S THEORY.—Newton maintained that light is a material substance, thinner or more subtle than air, or any gas, but composed, like these, of minute particles, constantly given off from the sun and all luminous objects. He supposed that it is this substance passing into the eye that produces the sensation of sight, as the fine particles of fragrant matter, passing off from flowers, produce the sensation of smell.

15. UNDULATORY THEORY.—Another view is that a very subtle fluid pervades all space, and serves as a medium for producing the sensation of light, as the air does for producing sound. This view is now generally accepted.

16. When a bell is struck its vibrations are communicated to the air, and thence to the ear, producing the effect of sound. So, according to the undulatory theory of light, vibrations are caused by some means in the sun and certain other bodies, which being rapidly transmitted through the fluid above mentioned, produce, when they fall on the eye, the sensation of light.

17. EXISTENCE OF THE SUPPOSED FLUID.—Such a fluid

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14. What was Newton's theory? How is the sensation of sight produced? 15. What is the other view of the nature of light? 16. Illustrate this view. 17. How is this fluid known to exist?

as this theory requires is known to exist in the spaces between the heavenly bodies, by the influence which it exerts on their motions, and is supposed to pervade all substances, whether solid, liquid, or gaseous, occupying the spaces between their particles. It is called *ether*, but has no relation to the chemical and medicinal liquid of the same name.

18. For the explanation of the leading phenomena of light, it matters little which of the views above mentioned is adopted. Thus, in the study of the laws of reflection, it matters little whether we regard light as a subtle fluid whose particles rebound from polished surfaces as a ball does when thrown against a house, or whether we suppose it to consist of ethereal vibrations which take a new direction from impact upon certain surfaces, as do the vibrations of the air in the case of echoes.

19. The definitions and laws of light are stated in the language of the Newtonian theory, because they are thus more easily understood. We employ this language without adopting the theory, just as astronomers say that the sun rises and sets, though it is well known that the sun is fixed in the heavens, while the earth revolves on its axis from west to east once in twenty-four hours.

20. Ray, Pencil, Beam, and Medium, defined.—Light moving in a single line is called a ray of light.

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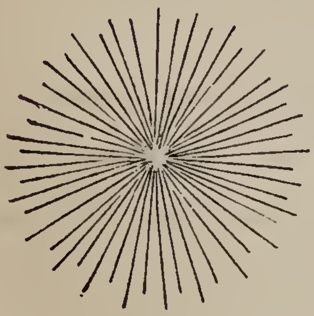
18. How does either view explain reflection? 19. Which theory is used in stating the laws of light? Why? 20. What is a ray of light? a pencil of light? a beam of light? a medium?

In such rays or lines light is constantly passing off from all visible objects. From every part of the book before the student, for example, it passes into the eye, enabling him to know the nature of the object. If the book is taken into a dark room it is no longer visible, because it obtains no light which it may afterward reflect to the eye. A collection of rays proceeding from a point is called a pencil of light. A collection of rays moving in lines parallel to each other is called a beam of light. Rays of light coming from the sun are parallel, while rays from a lamp or candle come to us in pencils of diverging rays. A medium is any space or substance through which light passes.

21. Laws of Light.—The more important laws of the radiation of light are the following:

1.



1. Rays of light proceed from every point of luminous objects in every direction. They proceed, for example, from every point of the sun's surface.

2. They proceed in straight lines. Light, for example, comes to us in straight lines from the sun.

3. They diverge as they proceed. This is illustrated in the figure, the central point being supposed to be a star, or other source of light.

22. Divergence of Light.—By the divergence of rays of light is meant that they spread themselves over

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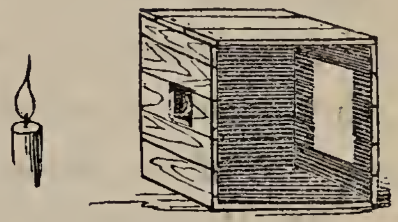
21. Give the laws of light? 22. Explain the divergence of rays of light?

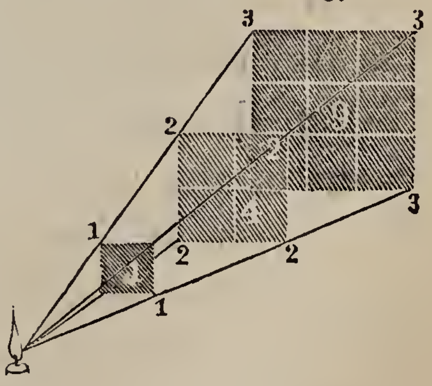
more space the further they proceed from their source. This is illustrated in the figure, where the light of a candle is represented as passing through a window, and illuminating a larger space on the opposite wall.

2



23. Law of Divergence.—When the distance is doubled, the surface that light will cover is quadrupled. This is also illustrated in the figure. The wall being twice as far from the candle as the window, the light covers four times the surface. If the distance of the wall were three times that of the window, the surface covered would be nine times as large as the window; if four times, the surface covered would be sixteen times as large. It is evident from these figures that the surfaces covered increase as the squares of the distances. The light, of course, diminishes in intensity in the same proportion, as it is thus spread over greater surface. At four times the distance, it has only one-sixteenth the intensity, and so on.

3.



If a square board is placed at a distance of one foot, and a screen at the distance of two feet from a candle, the shadows on the screen will cover a space four times as large as the board which intercepts the light. If the screen is at the distance of

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23. Give the law of divergence, and illustrations?

three feet, the shadow will be nine times as large—that is, three times as broad and three times as high, and multiplying the breadth by the height, we see that the space covered by the shadow increases as the square of the distance as shown in the figure.

24. Reflection of Light.—If a ball of ivory or other material is thrown perpendicularly against any hard plane surface, it will return in the same line; if it is thrown obliquely, it will glance off with the same degree of obliquity in the other direction. Light is reflected from plane surfaces in the same manner.

4.

This reflection is illustrated in the figure, which represents a mirror, and a ray of light falling upon it and again reflected.

25. Apparent Place changed by Reflection.—As we always seem to see an object in the direction from which its rays enter the eye, a mirror which changes the direction of the rays will change the apparent place of the object. This is shown in Fig. 5, where the image of the candle is seen by reflection as far behind the mirror as the real candle is in front of it. The image is thus seen in the direction which the rays of light take after reflection.

26. Concave Mirrors.—By considering that rays are reflected from plane surfaces with the same degree of obliquity with which they fall upon them, we shall be

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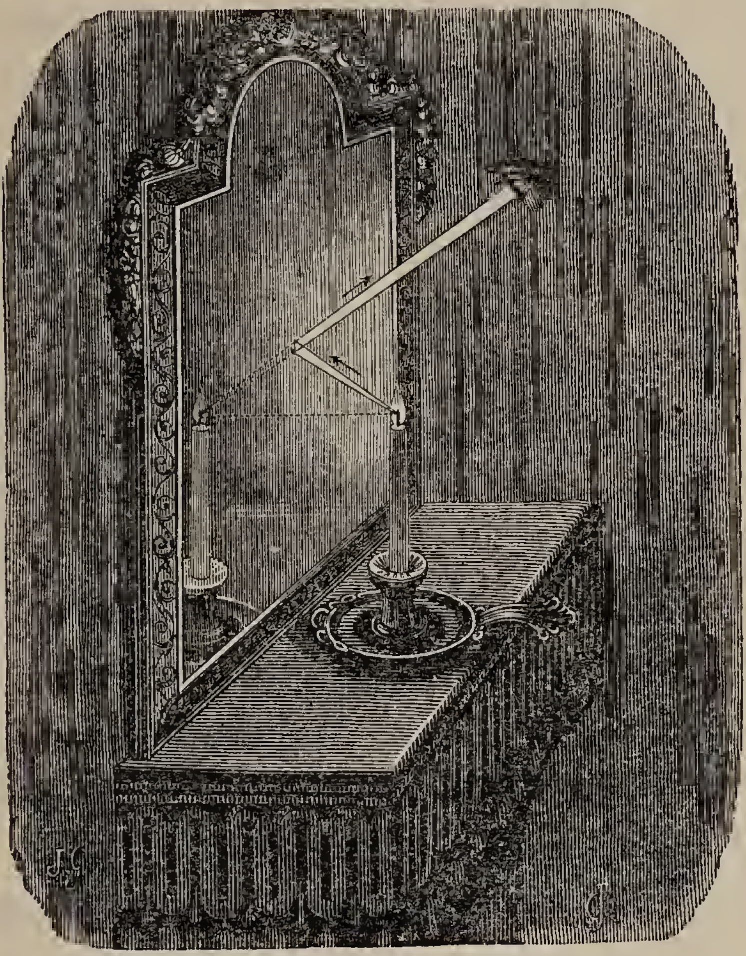
24. Explain the reflection of light? 25. Explain the change of apparent place by reflection? 26. Why do concave mirrors converge rays of light?

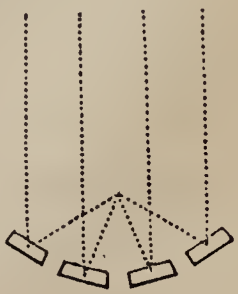
able to comprehend how it is that concave mirrors have the property of converging rays of light, or bringing them together in a point.

5.



A number of small plane mirrors, situated obliquely toward each other, as represented in the figure, and as they might be arranged in a bowl or saucer, would evidently have this effect. As a concave mirror may be regarded as made up of innumerable plane mirrors, similarly arranged, it would obviously be productive of the same effect.

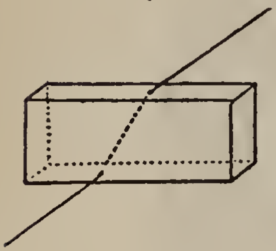
6.



27. REFRACTION.—Refraction is the change of direction which a ray experiences in passing obliquely from a rarer into a denser medium, or the reverse.

28. The figure represents a block of glass, and shows the direction which a ray of light would take on entering and emerging from it. On entering, it makes a bend, and passes on through the glass less obliquely; that is, more nearly in the direction of a line drawn perpendicularly to the surface of the glass, and continued through it. On passing out again it would be bent away from such an imaginary perpendicular line, and resume its previous course.

7.



29. ANOTHER STATEMENT OF THE LAW.—As the perpendicular has only an imaginary existence, it is perhaps easier to fix in the mind the changes of direction of rays passing in and out at regular surfaces thus: A ray, on entering a denser medium, pursues within it a course further from the nearest portion of the surface than its original course would be if continued. And a ray entering a rarer medium takes a course nearer the nearest portion of the surface than its original course would be if continued. These statements are true for all plane or uniformly curved surfaces.

30. ILLUSTRATION.—A coin placed in a tea-cup, as represented in Fig. 8, so as to be barely concealed from

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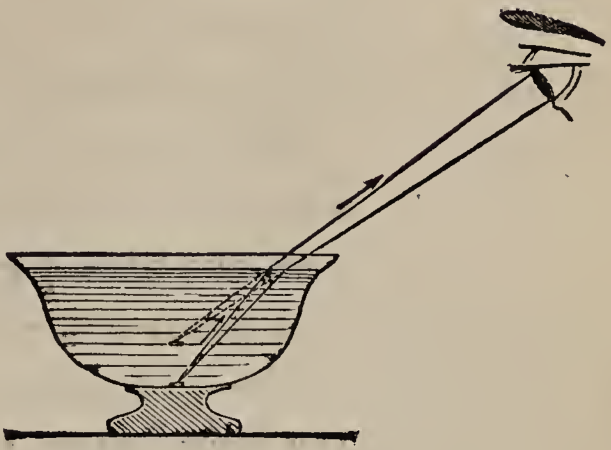
27. What is refraction? 28. Explain the figure? 29. Give another statement of the laws of refraction? 30. Illustrate by a coin?

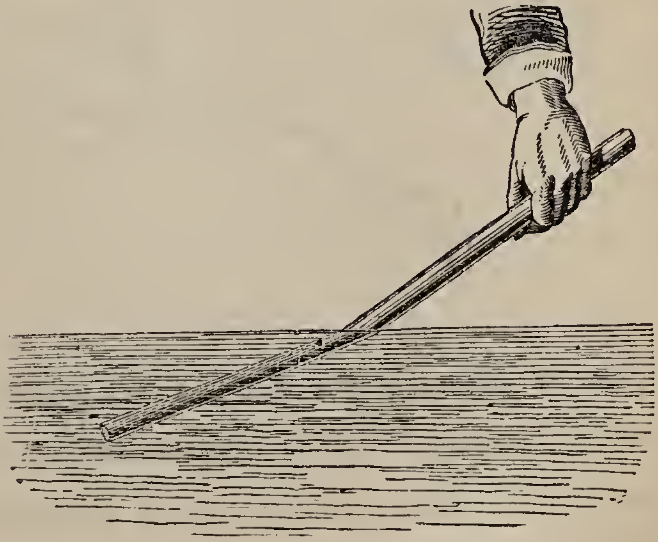
the eye, will be rendered visible by filling the cup with water.

8.



The surface of the water furnishes a point of transition from a denser to a rarer medium, and the direction of the ray is thereby changed in accordance with the law above stated. It is thereby enabled to turn a corner, as it were, and come to the eye.

9.



A stick thrust obliquely into the water seems to be broken at the surface, because every part below the surface appears, in consequence of refraction, more elevated than it really is. For a similar reason, water never appears more than three fourths its true depth.

31. Triangular Prism.—Bearing in mind the rules last given, it will be readily seen that the course of a ray

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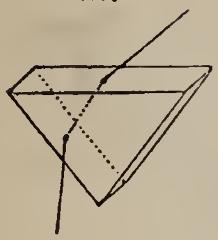
30. Why does a stick thrust obliquely into the water appear broken where it enters the water? 31. What effect has a prism on a ray of light?

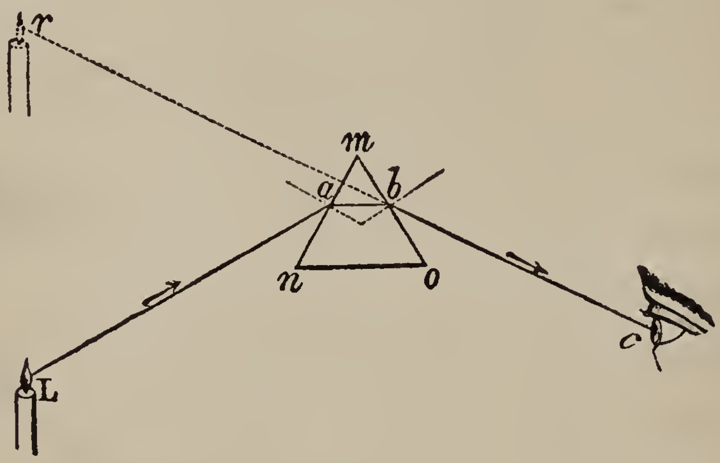
of light passing through a prism must be such as is represented in the figure. The ray may be supposed to start from below or above the prism. The line of its passage through the glass will be the same in either case.

10.



32. Let *m*, *n*, *o*, represent a section of a prism, L, a candle placed before it, and *c*, an eye placed behind the prism; then the light from the prism will pass in the direction L, *a*, *b*, *c*, and the candle will appear to be at *r*, or in the direction that the light enters the eye. A glass luster from a chandelier forms an excellent prism for these experiments. This experiment may be made equally well with the water prism described in the next paragraph.

11.



33. For optical experiments the student may readily construct a water prism as represented in Fig. 12. A strip of window glass is to be scratched with a file and

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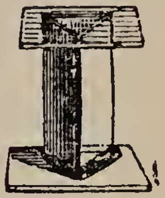
32. Illustrate the effect? 33. How may a prism be constructed?

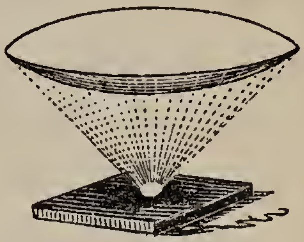
broken into three pieces of equal length. These are set up, as represented in the figure, upon another bit of glass previously warmed and thickly covered with sealing wax. When the wax is cooled, and the bits of glass which it holds will stand alone, the corners where they meet are also closed with sealing wax. The prism is then filled with water, taking care not to moisten the upper edges, and a glass top is afterward attached.

12.



34. A Lens is a transparent body having one or more spherical surfaces, acting on the same principle as the prism, and it is used to concentrate or disperse rays of light and heat. Spectacle glasses are lenses used so to modify the light as to improve the vision. Sun-glasses, called also burning-glasses, are lenses used to concentrate rays of heat so as to produce fire. The sun's rays are brought to a focus or point, as shown in figure 13, and paper, or other dry substances, are readily set on fire by this means.

13.



35. Action of the Lens.—The surface of a convex lens may be regarded as composed of a great number of plane surfaces, and each plane surface considered will correspond to one side of a prism, as shown in figure 14, where plane surfaces A, B, *a*, *b*, correspond to the same points on the curved surface of the lens, which

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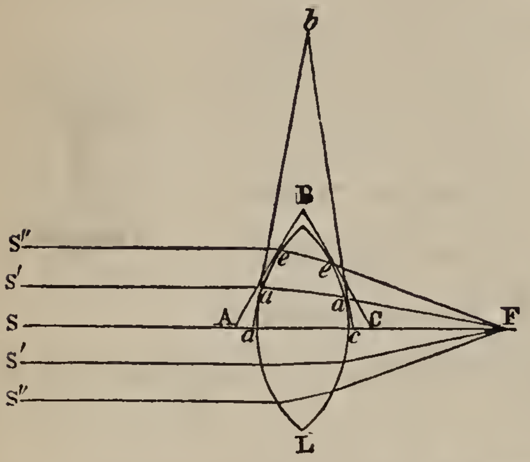
34. What is a lens? State its uses? 35. Explain the action of the convex lens?

receives and reflects the sun's rays, s, s′, s″, to a point F. All of the rays which fall upon the surface of the lens are bent, as shown in the case of the prism; but, owing to its shape, they are bent in different degrees and directions, so that they all meet in a point. This point is intensely bright if brought on a dark object, and is called the focus.

14.



36. The shape of the lens causes the rays to bend in different degrees and directions, as above stated, in accordance with a law of refraction according to which the more obliquely a ray falls upon any surface the more it is refracted or bent out of its course. And it is a consequence of the shape of the lens, and its greater steepness toward the edge, that of all the parallel rays which fall upon its surface, those which fall furthest from the center fall most obliquely, and enter the air again more obliquely. In proportion, therefore, as they need to be bent to be brought to the focus, they are thus bent by the action of the lens.

37. Analysis of Light.—It has, up to this point, been assumed that light is simple in its nature, but it may be proved by experiment that every beam of white light such as we receive from the sun is made up of rays of different colors.

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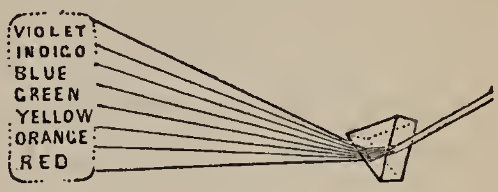
36. Explain another law of refraction. 37. How is light composed?

38. This may be done by holding a prism in the sun and allowing the light to pass through it and fall upon an opposite wall or screen. A beautiful parti-colored spot will be produced, called the solar spectrum. The beam of light which enters the prism is separated by it into rays of seven different colors. The experiment, if performed in a dark room, into which light is admitted through a very small opening, is extremely beautiful.

15.



39. The rays, before entering the prism, passing along together parallel with each other, form white light; but on entering the glass and emerging from it, each of them is refracted or bent out of its course in a different degree, and they are thus separated, and made to appear with their own colors.

40. It has been proved by mathematical calculations, that if light consists of vibrations of ether of very great rapidity, the shortest vibrations would be most refracted or bent out of their course by passing obliquely through transparent substances. It has, therefore, been inferred that the different colored rays of light are formed by vibrations of different rapidity. This is one among many other reasons for adopting the undulatory theory of light.

41. RED, YELLOW AND BLUE ARE CALLED PRIMARY

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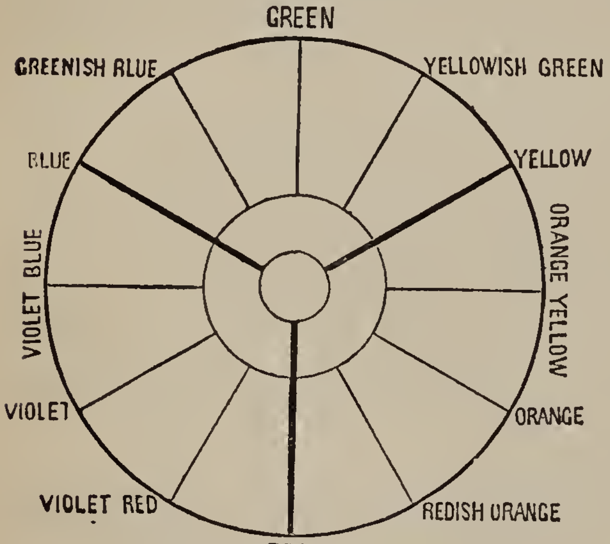
38. How is its composition proved? 39. How does refraction decompose light? 40. What theory of light serves to explain the phenomena of colors? 41. Which are the primary colors?

Colors, because all other colors may be obtained by suitable mixtures of these three.

42. The relations of various colors to each other will be easily understood by the diagram figure 16. A circle is divided by three dark lines into arcs of 120 degrees each, and by other lines into smaller arcs; the names of the primary colors are placed at the extremities of the darker lines, and the names of the intermediate colors opposite the lighter lines.

16.



CHROMATIC DIAGRAM.

43. Complementary Colors.—If we take any two colors at opposite extremities of the same diameter, in this diagram, they will together produce white light. Thus red and green when mixed will produce white; and the same is true of yellow and violet, or of blue and orange. In the arrangement of colors the most pleasing effect is produced when one color is placed near another of which it is complementary. The study of these principles will aid the development of correct taste.*

44. Lenses decompose White Light.—This separa-

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42. How are colors arrayed in the chromatic diagram? 43. What are complementary colors? 44. Do lenses decompose light?

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* A full development of these principles will be found in a small work by Chevreul on Colors.

tion of white light into colored rays always occurs when light passes through a prism; but for the sake of simplicity, this fact was left out of consideration in paragraph 29, the object in that place being simply to show the general direction of the light as it passes through the prism. Such separation also occurs when light passes through a lens, but the different colored rays are so slightly separated as to cause but little inconvenience in spectacles and burning glasses. The consideration of the means of correcting such defects belongs to Natural Philosophy.

45. FRAUNHOFER'S DARK LINES.—When a ray of sunlight, after entering a dark chamber by a very narrow opening, is allowed to pass through a prism, as in paragraph 38, and then is examined by means of a telescope, certain dark lines are seen in different parts of the spectrum, varying in number and distinctness with the purity of the prism and the excellence of the telescope employed. The most conspicuous of these lines have been named from the first letters of the alphabet. The dark lines B and C are found in the red portion of the spectrum, D in the orange, E between the yellow and green, F in the blue, G in the indigo, and H in the violet.

46. SPECTROSCOPE, SPECTRAL ANALYSIS. — In the spectrum produced by artificial light bright lines are seen instead of the dark lines of the solar spectrum. These lines vary in color and position with

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45. What are Fraunhofer's dark lines? 46. What lines are seen in the spectrum of artificial light? To what practical use have they been applied?

the kind of light employed. Thus soda imparts to flame the power of producing a double yellow line in the spectrum, potassium gives a pale red line, lithium an intensely red line, lime a deep orange and also a green line. The number, positions and appearance of the bright lines in the spectra produced by flames in which different substances are burning are so peculiar, and the quantity of material required to produce the effect is so small, that chemical analysis is readily affected in that manner. A smaller quantity of any elementary body can be detected by this process than by any other method. Three new metals, caesium, rubidium and thallium, have been discovered by this method of analysis. This method is called *spectral analysis*, and the instrument employed is called a *spectroscope*. § 612.

CHAPTER III.

HEAT.

SECTION I.

NATURE AND SOURCES OF HEAT.

47. NATURE OF HEAT.—It was remarked in the commencement of the chapter on light, that philosophers, although acquainted with its facts and laws, have differed widely in opinion as to its nature. The same

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47. Has heat weight?

is true of heat. It is agreed, however, that heat, like light, is imponderable, or without appreciable weight; this being known from the fact that a heated body weighs no more than a cold one.

48. If the end of a bar of iron is heated, the other end soon becomes hot. There is no doubt as to the effect, and it would seem that something must have passed from the fire, along through the rod to produce it. But we do not certainly know that any substance has been thus transmitted. It may be that heat is analogous to sound, and produced by vibrations. As in the case of light the opinion of philosophers has been divided upon the subject.

49. MATERIAL THEORY.—One view is that a very subtle fluid coming from the fire has actually passed along through the mass of metal, and from that into the hand, and so caused the sensation of warmth or heat. This supposed substance is called heat, or caloric.

50. THE DYNAMICAL THEORY.—Another view, corresponding to the second view of light, is, that heat is not a fluid, but, like light, the result of vibration in the ether which is every where present. The vibrations which occasion in us the sensation of heat differ, of course, from those which produce light, as the movements of the air which produce heavy sounds are different from those which produce sharp sounds; and as the vibrations of different instruments, sounding the same note, are so different as to be readily distinguished. The intimate relation that subsists between light and

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49. State the material theory. 50. What is the theory of vibration?

heat renders it probable that they are different effects of the same cause. Great as is the apparent difference in their effects, it is assumed that both are the result of vibrations of some kind acting upon different organs of sense.

51. ILLUSTRATION.—When a bell is struck its vibrations are communicated to the air, and so to the ear, producing the effect of sound. So, according to this view, vibrations of a peculiar kind are caused by some means in the sun, and all sources of heat, and being rapidly transmitted through the ether, produce, when they fall upon our bodies, the sensation of heat. The bar heated at one end becomes hot at the other, because certain vibrations, originated in the fire, are gradually transmitted through the ether, and the iron which it pervades, to the other end.

52. THE FACTS ARE DEFINITELY KNOWN.—It is not to be assumed in view of the doubt which has existed as to the nature of heat, that a corresponding uncertainty belongs to the *facts* connected with the subject, or to the principles which have been derived from a study of the phenomena. The most positive knowledge of effects may exist in the presence of utter ignorance as to their cause. In physiology, for example, we know that muscle and bone and other parts of the body are produced from the blood, and that life or vital force are essential to their production. But as to the mode of operation of the vital force we are entirely ignorant.

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51. Give the illustration. 52. Show that the facts may be known where the nature of the cause is not understood.

But it can scarcely be said that any doubt exists among philosophers of the present day as to the nature of heat. Lord Bacon long ago suggested that "it is in its essence motion and nothing else." Locke defined it as "a very brisk agitation of the insensible parts of the object which produces in us that sensation from whence we denominate the object hot." Davy subsequently supported the same view by conclusive experiments. It has since been most ably sustained and developed in the writings and experiments of later philosophers, among whom Mayer and Joule may be mentioned as especially prominent. The evidence in its favor has long been sufficient to satisfy the leading writers on chemical science. But this has not prevented their retention of the material theory as a medium of instruction. The same course is pursued in the present volume, while in connection with each important topic a statement is made of the difference of conception which the dynamical theory requires.

54. Definition of Cold.—Cold is a relative term signifying the comparative absence of heat. But the coldest bodies which we know of, as ice, for example, contain heat, and may be made colder by its withdrawal.

55. Sources of Heat.—The principal sources of heat are the sun and fixed stars, chemical action, electricity, and friction. It is by no means certain that these should be distinguished as different sources; for the heat of the sun may be due to chemical action, and

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53. Give Bacon's definition of heat. Locke's. 54. What is meant by the term cold? 55. State the principal sources of heat.

electricity is, as we know, excited both by chemical action, and by friction.

56. QUANTITY OF HEAT THE SUN SENDS TO THE EARTH.—The sun sends enough heat to the earth every year to melt a shell of ice enveloping the earth a hundred feet thick. This may be ascertained by observing what thickness the average heat of the sun will melt per minute, and then calculating the quantity for a year. The method actually pursued is slightly different from this, but the same in principle. The sun, in fact, sends a larger amount of heat to the earth than is above stated, but forty per cent. of it is absorbed by the atmosphere. The quantity above given is the remaining sixty per cent.

57. TOTAL QUANTITY OF HEAT THE SUN GIVES OUT.—Knowing how much comes to the earth and its atmosphere, it is easy to calculate how much starts from the sun. It is just in proportion to the extent of the whole visible heavens, as seen from the sun, compared to the space occupied by the earth, as seen from the same point. By making the calculation it is ascertained that a quantity of heat is given out from the sun in a year, which, if it all came to the earth, would melt a crust of ice nearly four thousand miles thick, or a quantity which would melt every minute a crust nearly thirty-seven feet in thickness. To effect this a heat is required possessing seven times the highest intensity of the glowing surface of metal in a blast furnace.

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56. How much heat does the sun send to the earth? 57. How much heat is given out by the sun and its atmosphere?

58. Other Sources of Heat.—It is estimated that the *fixed stars* give us four-fifths as much heat as the sun, and that without this addition to the sun's heat, neither animal nor vegetable life could exist upon the earth. Illustrations of the production of heat by chemical action and electricity will be given hereafter.

59. Percussion.—If a leaden ball is allowed to fall from a height to the ground its temperature is raised. Its mechanical motion has, according to the dynamic theory, been transferred to the atoms of the mass and now exists as heat. Retardation of motion without contact also produces heat as when a diamagnetic body (255) is drawn back and forth through the region of repulsion between the poles of an electro-magnet. It is estimated that the simple stoppage of the earth in its orbit would develop sufficient heat to vaporize it.

60. Heat from Friction.—The heat produced by slight rubbing is sufficient to set on fire a phosphorus match. Sir Humphrey Davy produced heat by friction between two pieces of ice. Count Rumford caused water to boil by boring a cannon beneath its surface. Other examples will occur to the student. The production of heat by friction is strong evidence in favor of the view that heat is a mode of motion. The unlimited quantity which may be produced by continuance of friction cannot possibly be stored up in the bodies submitted to the process, as the material theory would seem to require.

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58. What is said of the heat of the fixed stars? 59. Give an example of heat produced by percussion. 60. By friction. State the inference.

SECTION II.

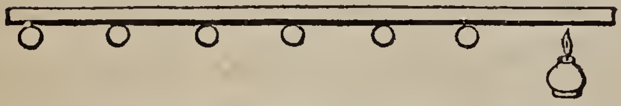
COMMUNICATION OF HEAT.

61. HEAT is communicated by *conduction*, *convection*, and *radiation*. These three modes of communication will be considered in the order in which they are named.

Conduction.

62. Conduction is the passage of heat through a body by communication from particle to particle. An iron wire, one end of which is held in a flame, soon grows hot at the other, by conduction of the heat of the flame. The progress of heat along a wire may be shown by fastening marbles to it with wax, as represented in the figure, and then heating one end by a lamp. The marbles drop off successively, as the heat in its progress melts one bit of wax after the other. According to the dynamical theory conduction consists in the communication of vibratory motion from one atom to another. § 51.

17



63. WHEN CONDUCTION CEASES. — Conduction proceeds toward the cooler portions of a body until all its particles become equally hot, just as the absorption of water by a sponge continues until all its pores are filled.

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62. Explain the conduction of heat. 63. When does conduction cease?

This point being reached, there is no tendency to further motion within the heated body.

64. The Metals are the best Conductors.—The earths and wood conduct very slowly; fine fibrous substances, like wool, cotton, fur, and feathers, slowest of all. Liquids and gases, as will be hereafter seen, are non-conductors of heat. The superior conducting power of metals is shown in the rapidity with which an iron wire, one end of which is held in the flame of a lamp, grows hot at the other end. A splinter of wood, or a pipe-stem, is heated from end to end much less rapidly, while scarcely any heat would be communicated along a roll of cotton cloth, one end of which was inflamed. Wood conducts heat most rapidly in the direction of its fibers, and least rapidly across its fibers.

65. Illustration. — The difference of conducting power in metals and earths may be illustrated by fastening together by a wire, as represented in the figure, an iron nail and a bit of pipe-stem of equal length, and heating them over a spirit lamp. The end of a match having been fastened with thread to each, it is found that the heat will travel along the nail and inflame the match at its end long before the other match is ignited.

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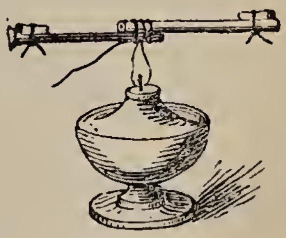

66. Protection from the Central Fire of the

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64. What substances are the best conductors? 65. How may the conducting power of metals, &c., be illustrated? 66. How are we protected from the central heat of the earth?

Earth.—We are protected from the central heat of the earth by the non-conducting power of the rocks and soil which form its outer crust. So a crust forms after a time over the streams of lava which flow from volcanoes; but, owing to its non-conducting power, the lava below remains liquid for years.

67. Conduction from one Body to another.—This takes place more rapidly the more perfect the contact between the two. Conduction from air or a gas to a solid is slow, because the gas contains comparatively few atoms, and therefore furnishes few points of contact. Between a liquid and a solid it is more rapid, because there are more points of contact. A cannon ball would grow hot much more rapidly in boiling water than in air of the same temperature. Between solid and solid, again, conduction is less rapid, because the surfaces cannot adapt themselves to each other like liquid and solid so as to bring all their atoms together. This paragraph refers solely to the passage of heat from the atoms of one surface into those of the other. The further conduction of heat depends on the substance into which it has passed.

68. Heating Water.—Water is sooner heated in an iron pot, or other metallic vessel, than in one of porcelain, glass, or earthenware, because the metal conducts the heat through from the fire more rapidly. Cooling, or the passage of heat outward when the vessel is removed from the fire, goes on more rapidly in the case

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67. When does conduction take place most rapidly? 68. Why is water heated sooner in an iron than in a glass vessel?

of the metallic vessel for the same reason. These statements have reference only to vessels which are not polished. In the case of bright surfaces, another principle is involved to be considered hereafter.

69. Clothing.—Fibrous substances, such as wool, and furs, are best adapted for clothing both because they are poor conductors, and because they contain air shut in between their fibers, which is a non-conductor, as will be hereafter shown. The object of clothing is not to impart heat, but to prevent its escape from the body. It escapes more or less through all substances, but less rapidly through the fibrous materials just mentioned, and therefore their superiority for winter clothing. "Cold feet" may be prevented by inserting one or two folds of brown paper in the boot or shoe. The paper is a bad conductor of heat, and so prevents its escape through the leather of the sole. If we lived in an atmosphere hotter than our bodies, the object of clothing would be to exclude heat, and the same non-conducting materials now used would be best adapted for this purpose also. Sometimes it is actually the object of clothing to keep out heat, as, when workmen enter hot furnaces in certain manufacturing processes. Thick clothing, of non-conducting materials, is obviously best in this case also. In summer, coarser fiber of linen, which is a better conductor than cotton or wool, is more used, because it conveys away the heat of the body more rapidly, as is desirable in the warmer season.

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69. Explain the subject of clothing and its relation to heat.

70. Furs of Animals.—We see, in what has been stated, the reason why the Deity has clothed animals inhabiting cold climates with fine furs. While the elephant of the torrid zone has but a few straggling hairs, the polar bear has a thick coat of fine fur to keep in his vital heat, and enable him to endure the extreme rigor of a northern climate. So the sea-fowl has a thick covering of soft down to protect him from the cold of the ocean, while the ostrich has an open coat of scanty feathers.

71. Warmth of Snow.—Snow keeps the earth warmer in winter than it would otherwise be, not because of any heat it imparts, but because, by reason of its low conducting power, and that of the air which it contains, it prevents the escape of the heat which is stored in the earth from the previous summer. But for this protecting influence of the snow, the cold of a single winter would be sufficient to kill whole races of plants. Thus, the cold of the winter weaves a garment to protect the earth from its own influence.

72. Building.—In building, the same principles apply as in the case of clothing. Bad conductors, when suitable in other respects, are the best materials for walls, making a house cooler in summer and warmer in winter. Wood and brick, for example, are in this respect better than iron. They keep out the heat in summer, and, though they have the same effect to exclude the heat

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70. Why has the Deity varied the covering of animals? 71. Why does snow tend to keep the earth warm during winter? 72. How do the principles of conduction apply in the case of buildings?

of the sun's rays in winter, they more than make up for this by preventing the escape of the larger quantity of heat produced by the fires inside. The inhabitants of the Arctic regions build their winter huts of snow, and thus make practical use of its low conducting power. Double doors and windows have more than a double effect in preventing the escape of heat in winter, because of the non-conducting wall of air between them.

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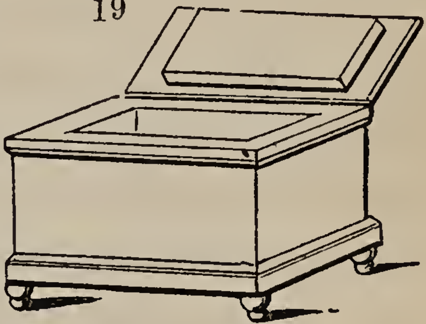

73. Refrigerators.—These are double-walled wooden boxes, used to preserve articles of food from the heat of the summer. The space between the double walls and top is filled with pulverized charcoal, which has in itself very little conducting power, and again is non-conducting because of the air between the particles.

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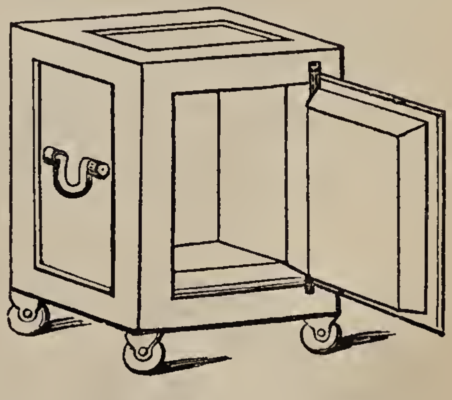

74. Fire-proof Safes.—These are constructed on the same principle, the space between the double walls being filled with gypsum, alum, or some other non-conducting material. They are used as repositories of valuable papers and other property, for greater security in case of fire.

75. Sensation of Heat.—A metallic door-knob feels colder than the wood to which it is fastened, although

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73. What is the principle involved in the construction of refrigerators? 74. How are fire-proof safes constructed? 75. How does conduction influence the sensation of heat?

it cannot actually be so. It is because the metal is the best conductor, and carries off the heat of the hand more rapidly. If a piece of metal and wood be placed in a hot oven until both become equally hot, as they must by long exposure to the same heat, the metal will feel hotter than the wood. It is because the metal, by its greater conducting power, supplies heat more rapidly to its own surface to be taken away by the hand.

76. Simple Test of Conducting Power.—As a general rule, the colder a body feels, the better conductor it is. That this is usually the case is evident from the last paragraph. On applying this test, we find the metallic lamp-stand cooler, and therefore a better conductor than the table cover on which it stands. In an oven, or other place where the heat is greater than that of our bodies, the inference is reversed. For the flow of heat would be in this case into the hand, from this highly heated object, and the body that brought it fastest, or felt hottest, would be thereby proved to be the best conductor.

77. Liquids Non-conductors.—Water in a test-tube may be boiled at the top while ice frozen into the bottom will remain unmelted. If a bar of metal with a cavity at the bottom for the ice were heated in the same way, the heat would be conducted downward so rapidly that the ice would soon disappear.

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76. Give a simple test for determining the conducting power of a body? 77. How can it be proved that liquids are non-conductors?

When a blacksmith immerses a red hot iron in a tank of water, the water becomes boiling hot around the iron, yet the water at a little distance from the iron remains quite cold. These experiments prove that water has but a feeble power of conducting heat.

78. Fire on Water.—Fire may be kindled on water by pouring a little ether upon its surface and inflaming it. But the flame will be found to have slight effect on the temperature of the water. And, what little effect it has, is principally due to the fact that the glass or metal of the containing vessel carries the heat downward and distributes it to the liquid. When water is heated by a fire beneath it, it is not by conduction, but by another process, explained in a subsequent paragraph. The above experiment may be made in a tin cup very nearly filled with water. A tea-spoonful of ether having been poured on the water, the bottle is to be corked and set away, for fear of explosion, from the kindling of the ether which it contains. The experiment, as described, is not in the least degree dangerous.

22

Convection.

79. It has been already shown that liquids and gases are non-conductors. This implies that they cannot be heated, like a mass of metal or other solid, by commu-

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78. Explain the experiment with ether to prove that liquids are non-conductors of heat. 79. Explain how liquids become heated.

nication of heat from particle to particle. Each particle, on the contrary, receives its heat directly from the source of heat, and conveys it away, making room for others. Hence the term *convection.* In the process of boiling water, for example, the vessel of water being placed over the fire, the first effect of the fire is to heat the lower layer of liquid, and thereby to expand and make it lighter. It then rises as a cork would in water, and gives place to another portion, which becomes heated and rises in its turn. Thus a circulation is commenced, the warmer portions ascending and the cooler descending, which continues until the water boils. Before this happens, each particle will have made many circuits, accumulating heat with each return, but not communicating it to others. Air and gases become heated in the same way.

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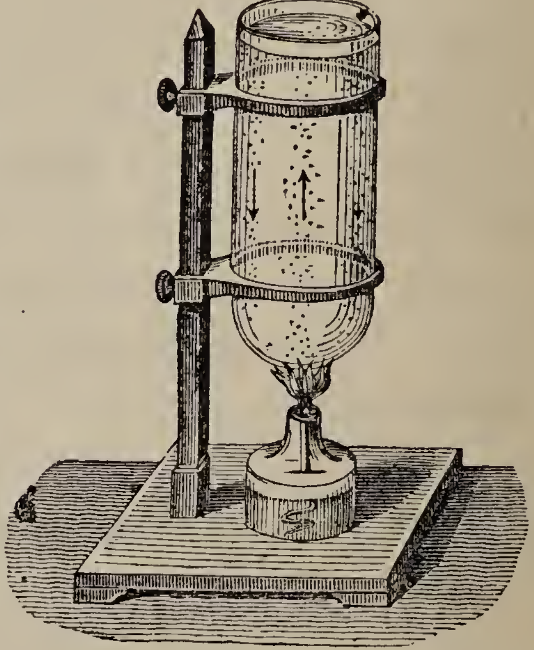

80. Convection made visible.—The circulation above described may be rendered visible by adding a little of the "flowers of sulphur" to water, and then heating it in a test-tube over a spirit lamp. The suspended particles will be found to move in the direction indicated by

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80. How can the circulation produced in liquids by heat be rendered visible.

the arrows, showing that the water has the same motion. The upward current is not, it is to be remembered, because of any tendency of heat to rise. Heat, on the contrary, travels in one direction as well as another. But it is, as before explained, because hot water is lighter than cold. Dust of bituminous coal answers the purpose in this experiment still better than "flowers of sulphur." It is necessary to have something that will neither sink nor swim, but remain suspended in the water.

Convection of heat is impeded by any thing that makes the fluid viscid; hence porridge or starch requires to be stirred when boiling, to keep it from burning to the bottom of the over-heated vessel.

81. HEATING ROOMS.—The same principle explains in part how a room is heated by a stove. The air in immediate contact with the hot surface becomes heated and rises. Cooler air comes in from all sides to take its place, grows warm, and rises in turn. A circulation is thus established precisely similar to that which occurs in the tube, as represented in the figure. Any light object, as a feather, or a flock of cotton-wool, held over a stove or an open flame, will prove by its ascent the existence of the upward current.

A considerable portion of heat is also communicated to the air of the room by direct radiation from the stove or other heated body, and by reflection and reradiation from the objects which first receive it. In

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81. How does a room become heated?

the case of an open fire-place, radiation is the principal source of heat.

82. CONVECTION IN HEATING THE ATMOSPHERE.—Heat is distributed through the earth's atmosphere in the same manner. At the equator, where the surface is hottest, the air heated by contact with it rises and flows off toward the poles, while colder air from the polar regions flows in to take its place, to be heated and rise in turn, continuing the circulation. But for this arrangement, the equatorial regions, which are constantly receiving excess of heat from the sun, would soon become uninhabitable from its accumulation, and the polar regions, from extreme cold. The currents or winds thus produced are subject to great irregularities, which are considered in works on Natural Philosophy.

Radiation.

83. When we stand before a blazing fire, or near any hot body, we become warm because heat emanates from the hot body and comes to us through the air. This is called radiant heat, because it proceeds in all directions from the hot body as rays of light pass from a luminous object.

The general laws of radiation are the same for heat as for light. According to the dynamical theory radiation consists in the communication to the ether and transmission through it of the peculiar vibrations which constitute heat.

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82. How is the atmosphere heated? 83. What is radiant heat? What are the laws of the radiation of heat?

This theory supposes that the atoms of the body on which the ethereal pulsations fall themselves acquire a corresponding motion, and that the body is thus warmed.

84. Heat is Radiated from all Bodies.—It is to be observed that while light proceeds only from certain bodies, heat proceeds from all points of all bodies without exception. If the mercury in a thermometer were frozen by extreme cold, and then hung in a cavity made for the purpose in a block of ice, radiation of heat from the ice would melt it, even if there were no air in the cavity to help melt it by conduction.

85. Proportion of Radiation to Temperature.—The hotter a stove is the more heat it gives out. This is obvious, and we might naturally suppose that a stove twice as hot as another stove, compared with other objects about it, would give out heat just twice as fast. It gives out heat, in fact, more than twice as fast, the rapidity of radiation being at high temperatures more than in proportion to the temperature.

86. Polish is unfavorable to Radiation.—A coffee-pot of well brightened metal will keep its contents hot much better than a dingy, blackened one, thus rewarding the housewife for her pains. The brightness is not the cause of this effect. It is owing to the increased density of the outer surface which accompanies high polish. For it is satisfactorily proved by experiment, that by adding to the density of a surface, its radiating

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84. Illustrate the fact that heat is always being radiated from bodies.
85. What can be said of the proportion of radiation to temperature?
86. What of the influence of composition on radiation?

power is reduced. Hot air flues are best made of smooth tinned iron which is a poor radiator, while rough sheet-iron makes the best stove pipes, because it has a great power of radiating heat to the room through which it passes. It is the *outer surface* of a body exclusively which influences radiation. Thus, a gilded globe of glass, radiates as poorly as solid metal, and the polished coffee-pot, used as a previous example, becomes a good radiator, and cools quickly, if covered over with paper or cotton cloth.

Chemical constitution would seem to have an influence on radiation. The elements are less effective radiators than compounds. The dynamical theory suggests that the atoms of heated compounds vibrating as they must in groups, would naturally communicate their motion more completely to the ether which is the medium of radiation.

87. COLOR DOES NOT AFFECT RADIATION.—A black coat wastes no more of the heat of the body by radiation than a white one. But the former absorbs and imparts to the body more of the heat which comes to it associated with intense light, as is the case with the heat of the sun, and therefore its advantage as an article of winter clothing.

88. ABSORPTION OF HEAT.—Bodies differ greatly in their power of absorbing heat. The atmosphere is but little heated by the rays of the sun which pass through it, for we find the air grows colder as we

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87. What effect has color on radiation? 88. How is it shown that different bodies vary in their power of absorbing heat?

ascend. Brick and stone walls and almost all solid objects exposed to the rays of the sun become much hotter than the surrounding air in consequence of their greater power of absorbing heat. A tube filled with ether may be held in the focus of a burning glass without becoming sensibly hotter; but the moment absorption of the rays is caused in any way, as by introducing a bit of charcoal into the liquid, the ether boils and is quickly dissipated in vapor. Standing before a fire our clothes become much warmer than the intervening air. "A joint of meat might be roasted before a fire with the air around the joint as cold as ice."

89. ABSORPTION OF HEAT VARIES WITH THE COLOR.—Dark clothing is warmer than that of light color, for the reason, that heat associated with light seems to follow the laws of the latter and undergo absorption or reflection with it. Now we know that dark objects owe their dark color to the fact that they absorb much light, and reflect but little to the eye. Experiment shows that they absorb much heat also. Dr. Franklin proved what has been stated, by the observation that when different colored cloths are spread upon snow, it melts most rapidly under those which are darkest.

The radiating power of bodies as before remarked is not influenced by color, but the power of bodies to absorb the heat of the sun's rays depends almost entirely upon their color. The heat from a lamp or candle is absorbed by differently colored objects with nearly equal

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89. What effect has color on the warmth of clothing?

facility. Heat of low intensity is more readily absorbed by all bodies than heat from bodies intensely heated.

90. Transmission. — The heat of the sun passes through all transparent bodies with but slight diminution. But heat from less intense sources is absorbed, and in large part stopped by many substances which allow light to pass; such are water and alum, and glass to a less extent. Thus, a glass plate will serve as a fire screen but not as a sun screen. For the same reason a glass lens fails to concentrate the heat of a fire.

Dry air and simple gases allow heat from all sources to pass readily. But all compound gases and vapors absorb in large measure heat of low intensity. Many substances which stop the light, transmit heat very perfectly. Such are black glass and smoked quartz crystal. Rock salt allows heat to pass so completely that it has been called the *glass of heat.*[*]

91. Reflection of Heat.—Polished metallic surfaces are the best reflectors. Coffee takes longer to boil in a bright coffee-pot, because the heat is reflected from the bright surface and does not enter the liquid. If it were desired to heat a liquid as rapidly as possible, and keep it hot as long as possible in the same vessel, it would be wise to take a dingy one for the rapid heating of the liquid, and then to polish it in order to fasten the heat in. Bright tea-kettles and coffee-pots with rough copper

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90. What is said of the transmission of heat through bodies? 91. What bodies are the best reflectors of heat? Illustrate the subject.

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[*] According to Knoblauch even rock salt absorbs certain of the rays of heat more freely than the others.

bottoms admit the heat readily from below, and prevent the escape of heat at the top and sides.

Glass mirrors do not reflect heat so well as those of uncovered metal, because of the absorbing power of the glass, mentioned in the last paragraph. But this absorbing power is very slight for heat which comes from an intense source like the sun, so that such mirrors reflect the solar heat quite perfectly.

92. REFLECTION AND ABSORPTION COMPARED.—The power of a body to reflect heat is in inverse proportion to its absorptive power. Both these properties depend only upon the surface. A sheet of gilded paper will reflect or absorb heat nearly as well as a plate of burnished gold. The heat of the sun's rays is reflected much more perfectly than the heat from a lamp or a candle.

93. EQUILIBRIUM OF TEMPERATURE.—It has been already stated that heat is constantly radiated from all bodies. Absorption of heat, is also universal. If any number of bodies are equally hot, they remain so, each according to its surface, imparting to the rest and receiving from all the others, taken together, the same quantity of heat. If one is hotter than the rest, it gives faster than it receives, until the equilibrium is reached. If, while they are thus coming to the same temperature, one is a good reflector, and therefore slow to receive the heat which comes to it, it is also slow to part with what it gets; thus the difference of reflecting power is without influence.

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92. How are reflection and absorption related to each other? 93. How is equilibrium of temperature maintained?

94. COOLING OF THE EARTH.—Were it not for the sun, the heat of the earth would waste away very rapidly into space. It is, in fact, radiated into space now, as truly as if there were no sun or stars, but these make up for the loss. At night, when the sun is below the horizon, the waste by radiation takes place very rapidly, and the earth and air grow colder in consequence. It is not simply because of the absence of the direct heat of the sun, for this is removed at once when the sun sets, while the cooling proceeds until morning. As the earth, being solid, is a better radiator than the air, it cools more rapidly, sending out its heat through the air into space. Even in the absence of visible moisture a portion of this heat is returned by the aqueous vapor of the air. This vapor probably absorbs within ten feet of the surface one-tenth part of all the heat that is radiated from the earth. A part of the heat thus absorbed is again radiated toward the earth.

95. ICE IN TROPICAL CLIMATES.—To produce ice in some parts of India, where the temperature in winter is seldom below 40° Fahrenheit, excavations are made one or two feet deep, and loosely filled with straw, which is a bad conductor of heat, and upon the straw are placed shallow pans of porous earthenware filled with water to the depth of one or two inches. Radiation from the surface of the water during the clear nights rapidly reduces the temperature below the freezing point, and thin plates of ice form which at day-light are removed to ice-houses

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94. What is said of the cooling of the earth? 95. How is ice produced in the tropics.

and kept for use in the hot season. That the water is not frozen by evaporation, is evident from the fact that it does not freeze in windy nights, when evaporation is greatest.

96. THE FORMATION OF DEW.—Dew does not "fall," but is deposited from the air in contact with colder surfaces. Its deposition is another consequence of the cooling of the earth and the objects upon its surface by radiation. The air, however transparent, always contains moisture, absorbed and invisible. Cold causes the air, like every thing else, to contract, and presses out of it, as it were, the water which it contains. Now, when at night the earth has become cooled by radiation, the warmer air which comes in contact with it is cooled, and thus made to deposit its moisture in the form of dew. When the temperature is sufficiently low, the dew takes the form of frost.

97. WHY CLOUDS PREVENT DEW.—Clouds send back the heat radiated from the earth, by a new radiation, and thus prevent the cooling which is essential to the production of dew. No dew is found therefore, on cloudy nights, when, if it came from above, like rain and snow, we should expect most.

98. ARTIFICIAL PREVENTION OF DEW AND FROST.—It is only necessary to substitute for clouds the artificial canopy of a muslin handkerchief, or any other covering, at a little distance from the earth, to prevent the depo-

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96. Explain the formation of dew. 97. Why do clouds prevent the formation of dew? 98. How can the formation of dew be prevented artificially?

sition of dew and frost. Gardeners practised this method of protecting their tender plants from frost long before philosophers explained it.

99. Absence of Dew on polished Surfaces.—Dew does not form on polished surfaces, because they are poor radiators, or, in other words, do not allow their heat to escape and thereby produce the degree of cold which is required to form dew. Leaves and grass receive most dew, because they are the best radiators.

100. Supposed Radiation of Cold.—If a piece of ice be held before a thermometer, it will cause the mercury to sink. It is not because cold has been radiated from the ice, but because the thermometer, in common with all other bodies, is constantly giving out heat, and when the ice is near, it does not get its due portion in return. The ice cuts off the heat that would have come to it from other objects behind it, and gives it but little in its place.

101. Refraction of Heat.—Rays of heat from the sun and other objects, are refracted or bent out of their course, on passing from one medium to another, similarly to rays of light. By ordinary glass prisms most of the heat rays are refracted in a less degree.

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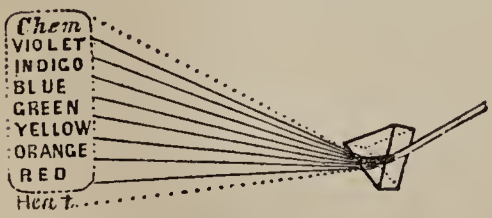

102. Heat Rays and Chemical Rays.—The light

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99. Why is dew not deposited on polished surfaces? 100. Why does the thermometer fall when brought near ice? 101. How are rays of heat refracted? 102. What is said further of heat rays and chemical rays?

which proceeds from the sun, is accompanied by rays of heat and others called chemical or *actinic* rays. In the analysis of light by a prism, the chemical rays accumulate principally in the region of the violet color of the spectrum, while the most of the heat rays are thrown into the region of the red, and below it. By varying the source of heat which is employed the position of maximum temperature in the refracted beam is found to vary; the less intense the source of heat the smaller is the refrangibility of the heat radiated. The naked flame of a lamp emits rays of heat of all degrees of refrangibility, its greatest intensity being found about the middle of the spectrum; the greatest heat from ignited platinum falls nearer to the red, and from copper at 750° nearer still, while the heat radiated from a surface at the temperature of boiling water contains scarcely any of the more refrangible rays.

103. Neither the place of the heat rays nor of the chemical rays is visible to the eye, but a delicate thermometer proves that from the sun's rays there is most heat just below the red, and a piece of paper covered with chloride of silver, (a substance very sensitive to the chemical rays of light,) grows black most rapidly in the region of the violet. The place of the chemical and heat rays is thus shown, although neither can be seen. It is not to be understood that they are confined to the points indicated, but only that they are accumulated there in largest proportion. The positions in the

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103. How are the positions of the heat rays and chemical rays determined?

spectrum where the greatest amount of heat rays and chemical rays accumulate, vary with the nature of the substance of which the prism is made.

104. Burning Glasses.—The collection of rays of heat from the sun by ordinary burning glasses, depends on the fact that they are refracted, or bent out of their course on passing from one medium to another, precisely as in the case of light. A lens made of two watch-glasses, filled with water, answers for heat as well as light, and may be used as a burning glass. As glass absorbs a great part of the heat from any artificial source, lenses and prisms made of glass are not suitable for conducting experiments on artificial heat, but instruments made of rock salt should be used.

105. Method of using a Burning Glass.—In using any lens, it is first to be placed near the object to be ignited, and then withdrawn till the spot of light which it casts is round and very small. The focus to which all the rays of light converge is thus found. The heat focus is a little beyond, but so near that the difference need not be taken into account.

106. Different Heat Rays.—There are different kinds of heat rays, as there are of light rays; some will pass through one substance best, and some through another. Thus a piece of smoked rock salt allows the blue heat ray of the spectrum to pass, while alum lets the lower or red heat ray pass.

107. Analysis of heat.—The analysis of heat is

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104. Explain the action of burning-glasses. 105. How is a burning glass used? 106. Are all the rays of light alike? 107. How is the analysis of heat effected?

effected by the same means as that of light. Rays of the sun are passed through a prism just as if light were to be analyzed, a dark colored glass being previously placed before the prism, to absorb the light and allow the heat only to pass. Emerging from the prism, it forms an invisible spectrum of rays beyond. These rays correspond to the different colored rays of light, and have different capacities of passing through different substances, as before stated. But strictly speaking, they have no color; they were called blue and red, simply to designate their relative position. Heat from very intense sources is more refracted than heat of less intensity, and it passes more readily through most substances. This accounts for the fact that the heat of the sun is not stopped by glass. For the analysis of heat from other sources other material must be employed for the prism.

108. EFFECT OF DIFFERENT HEAT RAYS IN MELTING SNOW.—Snow melts comparatively slowly in the heat of the sun, because the crystalline texture of the snow and its white color are very unfavorable to absorption, but exactly suited to reflect light and heat very perfectly. But near a fallen tree melting proceeds more rapidly, because the dark color and dense structure of the tree enable it to absorb the rays of the sun very perfectly, and becoming heated it radiates heat to all bodies around it, so that an additional amount of heat falls upon the snow near the tree. Besides this the

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108. What is said of the melting of snow?

heat radiated from the tree is more readily absorbed by the snow than the heat of the sun's rays.

109. Burning Glass of Ice.—A lens may be made of ice sufficiently powerful to concentrate the rays of the sun so as to ignite gunpowder.

110. Change of Refrangibility of Heat.—When heat from a source of great intensity is absorbed and again radiated it assumes a degree of refrangibility depending solely on the temperature of the radiating body, retaining no relation to the temperature of the source from which it originally came. When such heat is concentrated by lenses, or by mirrors, the temperature of the focus of heat rays never exceeds the temperature of the surface from which the heat was last radiated.

In some cases heat of low refrangibility may be changed to heat of great refrangibility: for example, a jet of mixed oxygen and hydrogen gases produces a heat nearly as intense as any which art can command; yet such heat has a low refrangibility, and will not pass through glass in any considerable quantity even though concentrated by a lens of rock salt. But if the jet of burning gases falls upon a cylinder of lime it produces a light too brilliant for the eyes to endure, and the heat rays acquire the property of passing through glass and are highly refrangible.

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109. How can gunpowder be ignited by ice? 110. By what means may the refrangibility of heat be changed?

SECTION III.

CHANGES EFFECTED BY HEAT.

111. Expansion, Melting and Vaporization are the principal changes effected by heat, while *contraction*, *freezing*, and *condensation of vapor* are produced by its withdrawal. But before these changes are explained, it will be well to consider certain remarkable differences in the heating effects of heat, in the case of different substances.

112. The heating Effect of Heat is different for different Substances.—It might naturally be supposed that the same quantity of heat actually imparted to different substances would make them equally hot; but this is not the case. If two heated cannon balls, of the same size and temperature, are cooled, the one in mercury and the other in an equal weight of water, the mercury will be made much hotter than the water, by reception of the same heat. It does not simply feel hotter, as it might do if it were not really so, from the superior conducting power of the mercury, but it is actually so, as may be ascertained by testing the temperature by the thermometer.

113. Specific Heat.—If the above experiment were varied, by cooling in mercury a bullet of one-

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111. What changes are effected by heat? 112. Are the effects of heat equal in different bodies? 113. What is specific heat?

thirtieth the bulk of that used for the water, the two would be brought to the same temperature. Mercury requires but one-thirtieth as much heating as an equal weight of water, to make it equally hot. It fills up, as it were, with heat, more rapidly. Iron absorbs about one-tenth as much heat as water. The comparative quantity required by any substance to produce an equal elevation of temperature, is called its *specific heat.*

The specific heats of different bodies compared with water as a standard are given in the Appendix.

114. Atomic Heat.—If in the above experiment elementary bodies are taken in the proportion of their atomic weights the heat required is, in most instances, the same. Notwithstanding some apparent exceptions, the inference is justified that the elementary atoms possess the same capacity for heat. See Appendix.

115. According to the dynamical theory, the specific heat of a body is the comparative amount of heat required to produce in it the same degree of that vibration which occasions in us the sensation of heat.

116. Relation of Heat and Density.—The specific heat of any substance is diminished as its density is increased. Less is required to indicate the same temperature. The surplus raises the temperature. This is one source of the heat which is produced in hammering metals. In the case of gases, the diminution is nearly proportioned to the increase of density. In the

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113. What is the specific heat of mercury? Of iron? 114. What is atomic heat? 115. What explanation does the dynamic theory give? 116. What relation exists between density and capacity for heat?

case of liquids and solids it has been less carefully investigated. In the comparison of different substances, no inference as to specific heat can be made from the degree of density. A substance more dense than another may at the same time have a greater specific heat.

117. THE OCEAN A RESERVOIR OF HEAT. — In hot weather the ocean absorbs the heat of the sun and air. If it were an ocean of mercury, it would soon grow as hot as the air, and therefore cease absorbing; but as water is a bad conductor and its capacity for heat is so much greater than that of mercury this does not occur. Again, in cold weather it is constantly giving out the large quantity it has absorbed, but at the same time itself grows cool, though very slowly. It is thus a reservoir of heat and a regulator of climate.

118. FIRE BY COMPRESSION. — The fire syringe, represented in the figure, is an instrument designed to produce fire by the compression of air. On forcing the piston suddenly down, a piece of tinder attached to the lower end of the piston is ignited. According to the material theory this is a result of the condensation of the air. The specific heat of the air being reduced by condensation the surplus is forced out and ignites the tinder. According to the dynamical theory this case is another instance of the conversion of force into heat.

25

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117. How does the ocean serve as a reservoir and regulator of heat? 118. Explain the principle of the fire syringe.

Expansion.

119. Expansion universal.—All bodies, solid, liquid, and gaseous, expand by heat, and contract to their original dimensions on cooling. An iron wire lengthens by heat; the mercury in a thermometer expands and rises by heating; air partially filling a bladder expands and fills it by the operation of the same cause.

120. How Heat expands Bodies.—All particles may be regarded as surrounded by spheres of heat. On imparting additional heat to any substance, the sphere of each atom is enlarged, and general expansion is the consequence. According to another mode of viewing the subject, heat produces repulsion between particles in some unknown way, and this occasions expansion. According to the dynamical theory the vibrations of the atoms of the heated body require more space to be occupied by each atom than when it does not vibrate, just as a buzzing bee, a spinning top, or the cord of a violin or piano appears larger when in a state of vibration than when at rest.

121. Expansion of Solids.—The expansion of solids by heat is comparatively small. Among solids, the metals expand the most; but an iron wire increases only $\frac{1}{802}$ in length on being heated from zero up to 212°. Expansion in general bulk is about three times as great as in length. Thus, a cannon ball heated to

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119. What effect has heat on the size of bodies? 120. How does heat operate to expand bodies? 121. Among solids which expand the most?

to 212° would occupy about $\frac{1}{270}$ more space than when cooled down to zero.

122. ILLUSTRATION.—The expansion of metals may be illustrated by arranging a brick, a knitting-needle, and a shingle, as in the figure. On heating the needle with a spirit lamp, the shingle, if before carefully poised, will be overturned.

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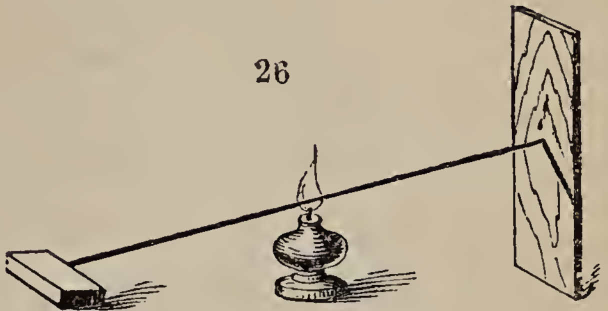

123. WHEEL-TIRES, RIVETS, ETC.—Important application of even this small degree of expansion is made in the arts. The tires of carriage wheels, for example, are made originally too small for the frames they are to surround. They are then heated red hot and applied in a state of expansion. The contraction which afterward takes place, on sudden cooling by cold water, binds the wooden frame-work together with the greatest firmness. So in making steam-boilers, the rivets are fastened while hot, that they may by subsequent contraction unite the plates more firmly.

124. HOT-WATER PIPES.—In certain uses to which iron is applied, the consequences of expansion have to be carefully guarded against. A cast-iron pipe for the conveyance of steam or hot water, must not be so laid that its ends touch two opposite walls, lest by

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122. How may the expansion of metals be illustrated? 123. What application of this expansion is made in the arts? 124. What disadvantages arise from the expansion of metals?

its ex-pansion when heated, the walls should be overturned.

125. Clamps in Walls.—If the two ends of a piece of metal are so fixed that they cannot move, and contraction takes place by cold, the metal must break. Cast-iron clamps in walls are frequently thus broken. If they are of wrought iron, they often crush the stone, and thus loosen themselves in their sockets.

126. Lifting Walls.—Walls of buildings, in danger of falling, have been restored to their perpendicular position by taking indirect advantage of expansion. This is effected, by connecting the walls to be lifted into place, by iron rods fixed firmly in one wall and passing loosely through holes in the other. The whole length of every alternate rod is then heated by lamps or pans of burning charcoal, whereby the heated rods are caused to expand and project beyond the wall; the nuts with which the rods are provided are then screwed up close to the wall, when the fires being removed, the rods contract and draw the walls together. While they hold the walls in this position, the other rods in the series are heated in the same manner and the nuts upon them are screwed up, when the rods cool the walls are drawn still nearer together. The same process is repeated alternately, with one-half of the rods at a time, until the walls are drawn toward each other to any position required.

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125. What effect has cold upon clamps in walls? 126. How are walls straightened by expansion and contraction?

127. Fracture of Glass Vessels.—Glass expands less than iron by heat, yet sufficiently, when expansion is unequal on opposite surfaces, to occasion its fracture. Thus if hot water is poured on a thick glass plate, it cracks. The first effect is to expand the upper surface, while the under one is but slightly affected. The obvious tendency of this unequal expansion, is to warp the plate, and curve it inward toward the under side. But, as the glass cannot bend, it breaks.

128. How to cut Glass by hot Wire.—In consequence of the same unequal expansion, a crack once commenced in glass may be made to follow the heated end of a rod of iron or pipe-stem drawn over its surface. Broken vessels of glass may be thus cut into useful shapes. A glass vial may be cut evenly in two, by encircling it with a ring of iron heated to redness, and afterward plunging it into cold water. The glass beneath the ring becomes expanded through and through, and the subsequent immersion in water, causes a sudden contraction in the exterior, and consequent fracture, on the principle above stated.

129. Wood and Marble expand little.—Wood and marble expand but little by heat, and are therefore sometimes used for pendulum rods, where careful provision must be made against change of length by change of weather.

130. Liquids expand More than Solids.—A column

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127. Explain the fracture of glass vessels by heat? 128. How can heat be used to cut glass? 129. Why are wood and marble used for pendulum rods? 130. What is the relative expansion of water and iron?

of water inclosed in a glass tube, will expand $\frac{1}{23}$ in length on being heated from freezing to the boiling point of water, while a column of iron will expand only $\frac{1}{802}$.

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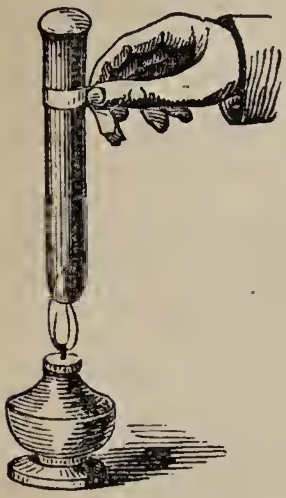

131. Illustration.—The overflow of water from full vessels before boiling commences, so often observed in the kitchen, is in consequence of expansion by heat. To illustrate the expansion of liquids, a test-tube full of water may be heated over a spirit lamp, as indicated in the figure. The water will be found to heap itself into a convex surface over the mouth of the tube, and even to run over, long before boiling commences.

132. Cold Water expands by Cold.—There is an important exception to the general law of expansion of liquids by heat and contraction by cold, or withdrawal of heat. Very cold water (39°F.) expands by further cold before it freezes. Again, on conversion into ice it undergoes still further expansion.

133. Illustration. — Expansion by these combined causes may be shown by burying a test-tube full of water in a mixture of snow and salt. Before the water is completely frozen it will rise at least a quarter of an inch, above the tube.

The greater part of this expansion is owing to the latter of the causes above mentioned. The freezing

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131. Illustrate the expansion of liquids by heat? 132. What effect has cold on water at 39°F? 133. How may expansion by cold be illustrated?

mixture employed is made of two parts snow to one part salt, brought into the cup alternately in small portions. It is well to wrap the cup in flannel, or other cloth, to prevent loss of heat. From ten to fifteen minutes are required for the experiment. If the water is perfectly frozen, the tube will be found cracked by its expansion.

28

134. Cold Water floats on warmer Water and protects it.—It was shown in the last paragraph that very cold water (below 39°) is in an expanded condition, and occupies more space than warmer water. It follows that it is lighter, and will float on warmer water. At A, B, and C, are shown water in successive stages of cooling. At A the warmer water is on the surface; at B the water is of uniform temperature throughout, and at C the colder water floats upon the surface.

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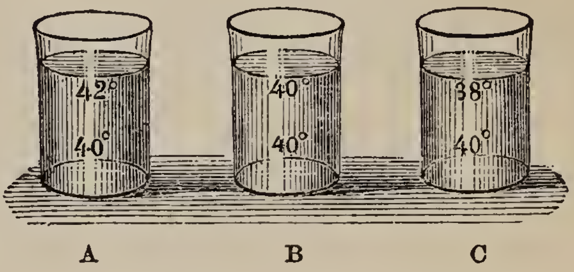

The maximum density of water saturated with salt is at a temperature below its freezing point; hence the phenomena in question is not conspicuous in sea-water. When ice forms upon sea-water it contains no salt except as portions of water containing salt become entangled in the forming ice.

135. Consequences of the Lightness of very cold

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134. Why does cold water float on warmer water? 135. What consequences result from the expansion of water by cold?

WATER.—But for the remarkable fact that more cold makes very cold water lighter, and not heavier, and thus enables it to exert the protecting influence just explained, the cold of a single winter would be sufficient to kill all the fishes inhabiting our lakes and rivers. Another consequence would be change of climate, as a necessary result of the formation of immense masses of ice, which the heat of the summer would be insufficient to melt. The temperate regions of the earth would thus become uninhabitable. Such are the consequences which are obviated by this remarkable exception to a general law of expansion. The whole realm of nature furnishes no more remarkable evidence of design on the part of the CREATOR.

As the weather grows colder each winter and the time approaches for the formation of ice in rivers and lakes, the cold water is found to float on the warmer, and protect it from the cold air. The body of water being thus protected, ice never forms many feet thick. The case would be very different if water grew constantly heavier by cold. The surface water would then constantly sink, until all was reduced to the freezing point. Cooling does, in fact, proceed in this way until the temperature sinks to 39°; then the exception comes in play, and the surface water, as before stated, retains its place and exerts its protecting influence. When ice is subsequently formed it has the same effect.*

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* Recent observations by Dr. Harrison of Wallingford, Conn., show that a quiet lake covered with ice in winter receives heat from the earth below, and that the water at the bottom acquires a temperature of 40° or 42°, while the temperature of 39.2°, or temperature of maximum density, may not be more than 6 or 8 feet below the sur-

136. Anchor Ice.—A curious formation of ice at the bottom of some clear and rapid streams is sometimes produced by the influence of radiation in clear frosty weather. Ice thus formed is termed *anchor ice*, or *ground ice*. The water cools down as usual to 40°, but below this point the colder water no longer forms a protecting layer, as in still sheets or in streams moving gently; the agitation produced by the passage of the water through its precipitous and irregular channel makes the temperature uniform throughout, until it arrives at the freezing point. Radiation at the same time proceeds through the water from the weeds and rocky fragments in the bed of the stream; these become now the coldest points, and to them the ice attaches itself in silvery, cauliflower-shaped, spongy masses, sometimes accumulating in quantity sufficient to dam up the stream, and cause it to overflow. This ice sometimes increases in bulk and buoyancy until it floats and raises to the surface portions of rock and even iron itself; it has indeed been productive of serious inconvenience by lifting and transporting to a considerable distance the heavy masses of iron which are used to prevent the removal of buoys employed to indicate the navigable channels of rivers.

137. Law of Expansion for Gases.—Gases expand

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136. What is anchor ice? 137. State the law of expansion for gases.

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face. The waters attain a condition of instability and when the ice begins to melt so that the wind can agitate the water the warmer water from below soon rises and completes the melting of the ice in an incredibly short space of time.—*Amer. Jour. Sci.* (2) XXXV., p. 49.

$\frac{1}{491}$th of the bulk which they possess at 32°, for every degree above that point, and contract in the same proportion for every degree below it. Thus, 491 cubic inches at 32° would so expand as to occupy an inch more space at 33°, still another inch at 34°, and at the same rate for higher temperatures. And the same quantity would contract by cold, or withdrawal of heat, so as to occupy an inch less space at 31°, and two inches less at 30°, and so on for lower temperatures. The law is the same for steam and other vapors.

Measurement of Temperature.

138. THE THERMOMETER.—The thermometer is an instrument in which expansion is made use of to show changes of temperature. A straight wire, which would grow regularly and perceptibly longer in proportion to the increase of temperature, would form the most convenient thermometer. But solids do not expand enough, or with sufficient regularity, for this purpose. The liquid metal mercury, is therefore employed instead, being inclosed in a glass tube and bulb.

139. CONSTRUCTION OF THERMOMETERS.—In making thermometers the mercury being first introduced into the bulb is boiled so as to expel all air and moisture, and fill the tube with its own vapor. The end of the tube is then closed by fusion. As the metal cools, it

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138. What is a thermometer? 139. How are thermometers manufactured?

contracts and collects in the bulb and lower part of the tube, leaving a vacuum above. The instrument is now complete, with the exception of graduation. Used in this condition, the mercury would be observed to rise and fall with changes of temperature, but we should not be able to say how much or how little.

140. GRADUATION OF CENTIGRADE THERMOMETER.—To obtain a fixed point from which to count, the instrument is immersed in melting ice, and the point to which the mercury sinks scratched on the glass. This point is called *zero*. Another fixed point is obtained by immersing the thermometer in boiling water, and when the mercury has risen, noting this height also on the glass, and marking it 100°. The space between the two points is next divided into one hundred equal parts, by scratches on the glass, and numbered from one up to a hundred. The upper and lower portions of the tube are marked off into divisions of the same length, for very high and low temperatures.

A thermometer graduated as above is called a Centigrade thermometer, from the fact that the space between "boiling" and "freezing" is divided into one hundred degrees. This is by far the most rational method of graduating, and these thermometers are in general use on the continent of Europe, and by scientific men all over the world.

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140. How are thermometers graduated? Describe the Centigrade thermometer.

141. Fahrenheit's Thermometer.—This is the thermometer in common use in this country. The instrument itself is precisely the same as the centigrade. The difference is only in the graduation. In graduating it, the space between the freezing and boiling points having been marked on the glass is divided into one hundred and eighty parts, and the rest of the tube, above and below, into similar spaces.

Fahrenheit adopted for the zero of his scale the lowest temperature known in his time, produced by mixing snow and salt. The same degree of cold had been previously observed in Holland in 1709. This temperature was then supposed to indicate an entire absence of heat, but as a much lower temperature has since been observed by arctic travelers, and a still greater degree of cold can now be produced by artificial means there ceases to be any propriety in placing the zero point where it was established by Fahrenheit. The reasons which induced Fahrenheit to make 180 divisions between the freezing and boiling points have no scientific importance, and therefore the Centigrade graduation is much to be preferred; but as the scale of Fahrenheit is much better known in this country it is generally used in elementary books.

If a thermometer of each kind were immersed in boiling water, the mercury would rise in the Centigrade to the point marked 100, and in the Fahrenheit to the point marked 212. In the same way, *zero* Cen-

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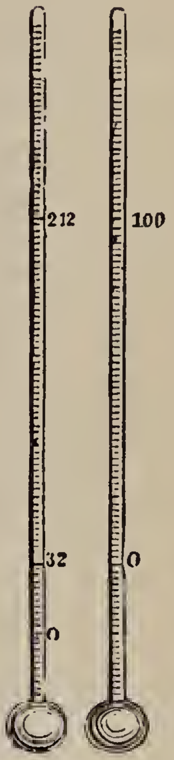
141. Describe Fahrenheit's thermometer.

tigrade corresponds to 32° Fahrenheit. The two thermometers are compared in figure 31.

142. Extreme Cold, how measured.—As the temperature is lowered, the mercury of the Fahrenheit thermometer sinks, until by sufficient cold it reaches 39 degrees below zero. More intense cold has no further effect, for at this point the mercury freezes. How much colder it is than—39° cannot be told, therefore, by the mercurial thermometer. Thermometers containing alcohol instead of mercury are used for this purpose, because alcohol never freezes and will continue to sink further and further in the tube the colder it grows.

31



143. Absolute Zero.—It has been stated that gases expand $\frac{1}{491}$ part of their volume for every degree of heat above 32° F. and contract a like amount for every degree below 32°. If the same rate of contraction continued for every degree of cold, at 491° below freezing, or at 459° below the zero of Fahrenheit, the volume of a gas would disappear and there could be no further contraction, some philosophers therefore think there must be an absolute zero. On the vibratory theory of heat there also should be an absolute zero where the molecules of all bodies are in a state of entire

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142. How is extreme cold measured? 143. What reasons are given for supposing there is an absolute zero ?

rest, but where that zero is can at present be only a matter of conjecture.

144. Extreme Heat, how measured.—If a Fahrenheit thermometer is heated, the mercury in it rises until it reaches 662°, and then begins to boil. A little more heat forms sufficient vapor of mercury to burst the tube. For this reason, a mercurial thermometer cannot be used to measure extreme heat. A platinum bar inclosed in a black lead tube shut at the bottom, is commonly employed for this purpose. Tube and bar are placed on the fire, or in the melted metal whose heat it is desired to measure, one end being left out, so that it can be seen. The consequence is that the platinum bar expands, and projects from the earthen tube. The tube itself expands but little. The further the bar projects, the greater is the heat. As it pushes out, it is made to move an index hand, and point to the number indicating the temperature, on a graduated arc. This arc is first graduated by repeated trials, observing how much the bar projects and moves the hand by the same heat which raises the mercury one degree in the Fahrenheit thermometer.

32

145. The Air Thermometer.—A column of air confined in a glass tube over colored water, was the first thermometer used. Heat expands the air and lengthens the column downward, pushing the water before it,

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144. How is extreme heat measured? 145. Describe the air thermometer.

while cold has the contrary effect. The temperature is thus indicated by the height at which the water stands.

146. Thermo-Electric Pile.—For the detection of slight variations of temperature an instrument called the *thermo-electric pile* is employed. In its simplest form it consists of a bar of bismuth and a bar of antimony soldered together at one end. The two bars are connected at the other end by a metallic wire which contains a galvanometer in its circuit. The slightest warming of the soldered junction generates a current of electricity. This current circulates through the galvanometer and produces a deflection of the needle. (305)

Liquefaction.

147. Solids become Liquids by Heat.—On being heated up to a certain point, solids are melted, or converted into liquids. Thus, at all temperatures below 32°, water is solid ice, but the moment it is warmed up to this point, by change of weather or other means, it begins to melt. The temperature at which this change occurs is called the melting point. 32° is therefore the melting point of ice. The melting point of sulphur is 226°; that of lead, 612°.

148. All Substances are fusible.—All substances are fusible, or in other words, may be melted; but the melting point of all is not definitely known. Thus, carbon has been fused by the heat of the galvanic battery, but it is impossible to state the melting point in

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146. What is the thermo-electric pile? 147. How do solids become liquids? 148. Are all substances fusible?

degrees. Under great pressure, increased heat is required to effect fusion. Thus the melting point of sulphur is raised from 226° to 285°, by a pressure of 11,880 lbs. to the square inch. There are exceptions to this law.

149. Disappearance of Heat in melting.—Melting or fusing is effected by heat, and a remarkable circumstance attending it, is the disappearance of the heat which has effected the change. Thus, if a thermometer be applied to ice or snow which has just begun to melt, it will be found to stand at 32°. Let the ice be then introduced into a tumbler, and placed on a stove, and the temperature again tested at the moment when the conversion into water is completed: The thermometer will be found again to stand at 32°. The water produced is no hotter than the original ice, yet heat has been pouring into it, through the bottom of the vessel, during the whole process of melting. If a piece of glass of the same size had been subjected to the same heat, it would have grown constantly hotter. It follows that in the case of the ice there has been a disappearance of heat. This disappearance always occurs whenever a solid is converted into a liquid.

33

150. Explanation.—According to the material theory the disappearing heat exists in the liquid as *com-*

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149. What remarkable circumstance attends the melting of bodies?
150. How is this explained by the dynamical theory?

bined or *latent heat*, just as an acid exists latent in every salt. According to the dynamical theory the heat which disappears in melting (as also in boiling) is consumed in overcoming cohesion. It has been converted into potential force which now resides in the separated atoms just as potential energy resides in a lifted weight; when the lifting ceases, the weight falls and the force is developed. So when the heating ceases "the atoms clash together with a dynamic energy equal to that which separated them, and the precise quantity of heat then consumed now reäppears."

151. FREEZING MIXTURES.—When solids take a liquid form by other means, as, for example, when salt dissolves in water, the temperature is generally much reduced. Nitre, for example, reduces the temperature of water in which it is dissolved from 15 to 18 degrees, and is therefore much used in the East, where it is abundant, for cooling wines. Mixed nitre and salammoniac have a still greater effect. Sulphate of soda drenched with strong muriatic acid, will reduce the temperature from 50° F. to zero.

152. When two solids, on being mixed, become both liquid, still greater cold is often produced. This is the case with a mixture of snow with common salt, or with chloride of calcium. By the former mixture, used as shown in paragraph 133, ice-cream is frozen.* By the

151. Mention some freezing mixture. How do they produce cold?
152. Mention other freezing mixtures. Why do they produce greater cold?

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* Fahrenheit regarded the temperature thus produced as absolute cold, and therefore assumed it as the zero of his scale.

latter mixture, a cold sufficient to freeze mercury may readily be produced. For this purpose, three parts of the chloride of calcium are to be mixed with two of dry snow.

153. The Melting of Snow cools the Air.—Whenever ice is converted into water, whether rapidly by fire or slowly by change of weather, the disappearance of heat, above mentioned, occurs. Thus, when the snow melts in spring, heat is drawn off from the air and made latent, or combined in the water which results from the melting. This makes the weather cooler than it would otherwise be, and retards in a measure the advance of spring.

154. Freezing.—Liquids become solids by the removal of their combined heat. Thus, if molten lead is allowed to stand awhile, the heat which it contains passes away into other objects, warming them; and the metal itself, having lost its heat, becomes solid. So in winter, the combined heat which is contained in water, is conveyed away by the colder air, and the water, having lost its heat, is converted into ice.

155. Freezing Point.—The temperature at which a substance passes from the liquid into the solid state is called the freezing point. Thus 32° is the freezing point of water. The freezing point of any substance is, as might be supposed, the same as the melting point. Water, for example, becomes ice in process of cooling,

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153. How does the melting of snow affect the weather? 154. How do liquids become solids? 155. What is the freezing point of a liquid?

at the same temperature that ice becomes water in process of heating.

156. ALL LIQUIDS HAVE THEIR FREEZING POINT.—There is good reason to believe that all liquids, without exception, have their freezing point, but the reduction of temperature requisite has not in the case of all been attained. Alcohol and ether, for example, have never been frozen.

157. IN FREEZING, LATENT HEAT BECOMES SENSIBLE HEAT.—If water, in sufficient quantity, is taken into an apartment where the temperature is several degrees below the freezing point, and then allowed to become ice, it will be found that the freezing process has actually warmed the apartment several degrees. The latent heat has been drawn off by the colder air of the room, raising its own temperature, and leaving the water in the condition of ice.

158. CELLARS WARMED BY ICE.—In accordance with the principles above stated, tubs of water are sometimes set to freeze in cellars, thereby to prevent excessive cold. And even in the coldest climates a sufficient supply of water might thus be made to secure an apartment against extreme cold.

159. EFFECT ON CLIMATE.—The milder climate of the vicinity of lakes which are accustomed to freeze in winter, and the moderation of the weather during a snow storm, are accounted for on the same principle.

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156. Can all liquids be frozen? Give examples. 157. In freezing, what becomes of the latent heat? 158. How can cellars be warmed by ice? 159. What effect has the freezing of water on climate?

As the melting of snow retards in a certain degree the advance of spring by the heat it abstracts from the atmosphere, so the formation of ice tends to make the advance of winter less rapid, by the heat which it evolves.

Vaporization.

160. Formation of Vapors. — Unlike melting or liquefaction, vaporization occurs gradually, and through a wide range of temperature. Thus water at all temperatures, and even ice, yield vapor. But there is a limit for each substance below which its evaporation does not occur.

161. Vapors Transparent.—All vapors are perfectly transparent, like the atmosphere. If water be boiled in a flask, it will be found that the steam within the flask is as transparent as air. The steam thrown from a locomotive would be invisible if it remained steam. We should hear its roar, but see nothing.

162. Density of Vapors.—Vapors are of all degrees of density. The vapor of water may be as thin as air, or, again, almost as dense as water itself.

163. Elasticity of Vapors.—All vapors are elastic, like air. Steam, like air, if compressed in a cylinder, with a close fitting piston, by a heavy weight, would expand again, and force the piston out, as soon as the

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160. What is said of the formation of vapors? 161. What is the appearance of vapors? 162. Is the density of vapors uniform? 163. Illustrate the elasticity of vapors.

weight were removed. The force with which a vapor expands, or strives to expand, supposing the weight not removed, is called its *elastic force* or *tension.*

164. DENSITY DEPENDS ON TEMPERATURE.—The vapor produced at ordinary temperatures by evaporation from the sea and the moist earth, is less dense, or in other words, contains less water in the same volume, than that formed during the heat of summer. Ordinary steam, or aqueous vapor, produced at 212°, has still greater density. Steam produced at 250° has double the density of ordinary steam, and by increasing the temperature to 294°, the density is again doubled. Steam of higher temperature than 212° can only be produced in closed vessels, or those with an imperfect vent. The law is the same in case of other vapors—the higher the temperature the greater the density, provided a surplus of the material from which the vapor is produced is present. But if this is not the case, heat has simply the effect of expanding the vapor as it would an equal quantity of air. In the case of a partial supply of water, the vapor grows more dense, but does not reach the highest density which it would have at the same temperature with a full supply.

165. DISAPPEARANCE OF HEAT IN VAPORS.—The same disappearance of heat which occurs when a solid is converted into a liquid, occurs also when a liquid is converted into a vapor or gas. Thus, if we wish to

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164. How does temperature effect density? 165. What remarkable circumstance attends the formation of vapors?

cool a room in summer, we sprinkle the floor. As the water evaporates, much of the heat of the room disappears. It has entered into combination with water to produce vapor, and has no longer the power of affecting the senses and the thermometer. In the same manner our bodies are cooled in summer by the constant evaporation of moisture from the surface. All vapors may, indeed, be regarded as combinations of heat with the liquids from which they are formed. In this case, also, the heat which becomes latent in thus combining, is called latent heat. (150).

166. Freezing by Evaporation.—The more rapidly a substance evaporates, the more heat does it require for the evaporation. This it obtains from objects in contact with it. Ether may be made to evaporate so rapidly as to freeze water, even in summer. This is best accomplished by covering the bottom of a test tube with a cotton rag, or several layers of porous paper, as represented in the figure, dipping it into ether, and then waving it to and fro in the air, or spinning it between the palms of the hands. By repeating this process several times, a few drops of water, previously placed in the tube, may be frozen. A mixture of liquefied carbonic acid and nitrous oxide gases, previously liquefied, produce on evaporation a temperature of 220 degrees below zero.

34

167. The Cryophorus or Frost-bearer.—This in-

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166. How can ether be made to freeze water? Explain its action. 167. Describe the cryophorus.

strument which was invented by Dr. Wollaston, consists of a tube with a bulb on one extremity, and an enlargement or bulb at the other end containing water. The air is expelled from the instrument by boiling the water in both bulbs at the same time and allowing the steam to escape at the opening at *e*, which is then hermetically sealed in a blow-pipe flame.

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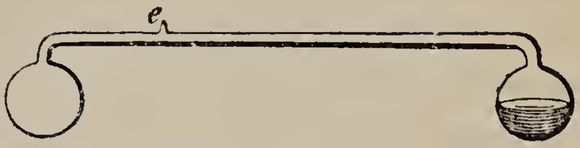

When the empty bulb is placed in a mixture of snow, or pounded ice, and common salt the condensation of the vapor with which the whole instrument is filled causes such rapid evaporation that the remaining water is frozen.

168. Protection from Heat by Evaporation.—By previously moistening the fingers, they may be dipped unharmed, for an instant, into molten lead, or passed through a stream of white-hot iron as it flows from the furnace. A cloak of comparatively cool vapor is formed from the moisture upon the fingers, and keeps them from contact with the molten metal.

169. Relations of Air and Vapor.—The earth is surrounded by air to the height of fifty miles. It is also surrounded by vapor occupying the same space which the air occupies. But they are independent of each other. Each contracts for itself, and expands for itself, according to the temperature. When more vapor is produced by evaporation from the sea, or other

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168. How does evaporation protect from heat? 169. Does vapor displace air?

sources, it rises into the air without displacing it or pushing it aside, only rendering the vapor which it before contained more dense, mingling with it and occupying a portion of space which was previously entirely filled by the air alone.

170. QUANTITY OF VAPOR IN THE ATMOSPHERE.—The air is always *full* of vapor; that is, where there is a cubic inch of air, there is a cubic inch of vapor with it, occupying the same space.

171. QUANTITY OF WATER THE AIR MAY CONTAIN AS VAPOR.—As the density of vapor is dependent on temperature and the supply of material to be vaporized, it is obvious that the quantity of water present in the air in the form of vapor, varies according to temperature and locality. In summer, and over the sea, it is commonly greatest. At a medium summer temperature of 75 degrees, the vapor in the air is sometimes so dense that every cubic yard of air contains a cubic inch of water, in this form. But it can never, at this temperature, contain more. It is then said to be "saturated," and also that its capacity for water is filled.

172. CAPACITY OF THE AIR FOR WATER INCREASED BY HEAT.—As the weather grows warmer, the capacity of the air for moisture is increased, so that at 100° it can contain twice as much as at 75°, or two cubic inches. On the other hand, as the weather grows cooler, its capacity is diminished, so that at 50° it can

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170. What quantity of vapor exists in the air? 171. Upon what does the quantity of water in the air depend? 172. What effect has heat upon the quantity of vapor present in the air?

hold scarcely more than half a cubic inch, and is saturated by this comparatively small quantity. In general, the capacity of the air for moisture is increased by the elevation of its temperature.

173. Effect of Wind.—Wind causes evaporation to proceed more rapidly, not because the air in motion has any greater capacity for moisture, but because new portions of air are brought successively into contact with the wet surface. As fast as one portion has imbibed a certain amount of moisture, another portion of drier and more thirsty air takes its place.

174. Deposition of Moisture.—It follows that air that is saturated, or, in other words, has its full portion of moisture in the form of vapor, must deposit a portion of it in the form of water in cooling. Thus a cubic yard of saturated air at 75°, on being cooled down to 50°, would yield half a cubic inch of water, or half of the whole quantity which it originally contained. If we suppose the experiment to be performed in a glass vessel where the effect of cooling could be observed, we should first see a mist or dew within the box, consisting of the particles of water which the colder air can no longer retain. This mist would gradually deposit and collect in the form of water, and if measured, would be found to make more than half a cubic inch. Something less than half a cubic inch would remain as invisible vapor in the cooled air. If

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173. How does wind effect the quantity of vapor in the air? 174. Explain the deposition of moisture.

the air were cooled further, part of this would be condensed to water.

175. Unsaturated Air.—Air that does not contain its complement of water will not yield any by slight cooling. It would be like slightly compressing a half-filled sponge. But as the cooling proceeds, the vapor becomes so dense that further cooling will cause a deposition of moisture. A cubic yard of air at 75°, containing only half a cubic inch of water in the form of vapor, would yield none on being cooled down to 50°. At this point the formation would commence. If it contained originally less than half a cubic inch, it would have to be cooled still lower before any moisture made its appearance. The less the moisture, the more cold it would require to wring it out.

176. Quantity of Vapor in the Atmosphere.—As has been already stated, the capacity of air for vapor is in proportion to its warmth. The air of summer therefore generally contains more moisture than that of winter. But this is not necessarily the case, for the capacity for moisture is not always filled. Hot air over a desert, for example, contains less moisture than cold air over the sea. And in the same locality, and during the same season, the quantity of moisture in the air will differ from day to day, and from hour to hour. This will depend a good deal on the wind, whether it blows from the land or from the sea. Sometimes it

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175. What is said of unsaturated air and its moisture? 176. Is the quantity of vapor in the atmosphere always proportionate to its warmth?

contains a cubic inch of water in the form of vapor in every square yard, but generally less.

177. MIST AND FOG.—These are aqueous vapors, rendered visible by the cooling of the air, as before explained. When the moisture of the air is deprived of the latent heat which converted it into invisible vapor it becomes visible as mist or fog, which consist of exceedingly minute vesicles or hollow globes of water containing air, which float about in the atmosphere just as soap-bubbles blown up by boys at play. Steam which issues from a boiler or the spout of a tea-kettle is at first invisible, but as it meets the air a portion is suddenly cooled and becomes visible as vesicular water or fog, but as soon as it mingles with a sufficient amount of air it again becomes an elastic vapor and entirely disappears. When the air is saturated, the least cooling will produce a fog, as in the case supposed in paragraph 174. When it is not saturated, more cooling will be required, as in the case supposed in the subsequent paragraph. The beautiful veil of mist, which forms in summer-nights over low places, is owing to the cooling of the air below its point of saturation, which takes place after sunset.

178. MIXED CURRENTS OF AIR.—The phenomena of mist, fog, clouds, and consequently of rain, are more commonly owing to the mixture of cold and warm winds or currents of air. When this admixture takes place, the warm air becomes colder, and tends to de-

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177. What is the cause of mists and fogs? 178. Explain the production of fogs by mixed currents of air.

posit its moisture, and the cold air warmer; and it might be at first supposed that those two influences would counteract each other. For example, if a cubic yard of air at 100° mixes with a cubic yard at 50°, they both become 75°, and it might be thought, that the warming of the colder cubic yard would increase its capacity for moisture, as much as the cooling of the warmer cubic yard would diminish its capacity, and that consequently no mist would be produced. But, as before stated, it has been ascertained by experiment that hot air at 100° will contain about two cubic inches, and air at 50°, about half a cubic inch of water. The two would therefore contain about two and a half cubic inches. But air at 75° can hold only one cubic inch, and consequently the two cubic yards would hold but two cubic inches. The surplus half inch would consequently take the form of visible moisture, called cloud, fog, or mist, according to circumstances. It is not to be understood, from what is above stated, that half a cubic inch of water is always yielded by every two cubic yards of air at 50° and 100° which come together; if they are not totally saturated, the quantity will be less.

179. Fogs on the Sea-Coast.—The sea is cooler than the land in summer, and warmer in winter. As a consequence, the air above the sea is cooler in summer and warmer in winter, than that above the land. The admixture of these bodies of air, which takes

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179. Why are fogs produced on the sea-coast?

place along the coast, produces fogs on the principle above stated.

180. Fogs on Rivers.—When land and water have the same temperature, as may be the case with small lakes and rivers, the difference of radiation during a single night often produces fogs. The land cools more rapidly than the water. As a consequence, the air above the land is cooler than that above the water. As the two bodies of air mingle, fog is produced, and is seen following the devious course of the river, or brooding over the lake in the morning.

181. Newfoundland Fogs.—The fogs on the banks of Newfoundland are owing to the mixture of cold winds from the north, with the warm air of the Gulf Stream, which passes along that part of the ocean.

182. Cloud-capped Mountains.—The temperature of the air at high elevations is always lower than at the general level of the earth. As the warm breeze comes up from the warmer valleys, the two currents mingling produce clouds. A clear atmosphere throughout a whole day is rare, on high mountains.

183. Dew Point.—It has been already seen that air has to be cooled more or less before it yields moisture, according to the amount which it contains. If it contains about one cubic inch to the cubic yard, or, in other words, is saturated, the least cooling will cause the appearance of visible moisture. If it contains half

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180. Why do fogs form on rivers? 181. What causes the Newfoundland fogs? 182. Why are clouds produced on high mountains? 183. What is the dew point?

as much, it must be cooled down to 50° F. If it contains less than half as much, still more refrigeration is required. The temperature at which the deposition begins in any case is called the *dew point.*


36

184. HOW TO FIND THE DEW POINT.—It is commonly found by adding ice, little by little, to a glass of water containing a thermometer. As the water grows cool, the glass cools also, and as a consequence, the exterior air immediately in contact with it. After a time, moisture begins to deposit. The temperature at which this occurs is noted, and is the dew point.

185. DEW.—The earth cools, as has before been stated, every clear night, by radiation. The air in immediate contact with it, becomes thereby so much cooler, that it cannot retain all its water in the form of invisible vapor, and the deposition of the surplus in the form of dew is the consequence.

186. Grass and foliage receive most dew because they are good radiators, and exposing to the air a great extent of surface they lose their own heat rapidly and cool down the air sufficiently to cause a deposition of its moisture. The soil and stones receive less dew or none at all; because though they are good radiators, they have but a very small extent of surface in proportion to the stores of heat they contain: they are also

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184. How can the dew point be found? 185. Explain the formation of dew. 186. Why do grass and foliage receive the most dew?

constantly receiving heat from the ground below, so rapidly that they do not become sufficiently cool to produce a rapid deposition of dew. Dew does not form on a cloudy night, because the clouds radiate heat to the earth and thus prevent the requisite cooling.

187. CAPACITY FOR VAPOR: EXPANSION NOT THE CAUSE.—It must not be supposed that the increased capacity of the air for vapor, which results from heating, is owing to its expansion. Air does indeed expand about one-twentieth between 50° and 100°, but its capacity for moisture is quadrupled by the same rise of temperature.

188. ABSORPTION NOT THE CAUSE.—It is not uncommonly supposed that the air acts to absorb vapor as a sponge does to draw up water. The term "*saturated*," used for convenience in scientific works, is calculated to give this impression. But vapors are found to rise, even more rapidly, into a vacuum, or space from which all the air has been removed.

189. INCREASED DENSITY OF VAPOR THE CAUSE.—The air receives any vapor that may be formed, whether more or less dense. At higher temperatures, denser vapor is produced. It follows that the air will contain more water, in proportion to the elevation of its temperature.

190. REMOVAL OF AIR DOES NOT INCREASE THE QUANTITY.—It might be supposed that more water

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187. How is it known that the increased capacity of air for moisture is not due to expansion? 188. What proves that absorption is not the cause? 189. What then is the cause? 190. Does the removal of air influence the formation of vapor?

would rise into a vacuum in the form of vapor than into a space filled with air, on the ground that the removal of the air would make more room for something else. It is found, however, that the presence or absence of air makes no difference in the quantity,* though it takes a longer time to fill a given space with moisture when it is filled with air.

191. SEVERAL VAPORS MAY OCCUPY THE SAME SPACE.—It follows from the last paragraph that vapors do not displace the air; they penetrate it instead. It is a remarkable fact, that a number of vapors may occupy the same space without interfering with one another; and each in the same quantity as if the rest were absent.

192. As much water will rise in vapor into a jar of air as if it were a vacuum. And in addition to this, as much alcohol and ether successively, as if the jar were entirely empty.

193. If the elastic force or tension of air is increased, it expands. Vapors possess elastic force as well as air. A mixture of air and vapor has the combined tension of both. The tension of aqueous vapor at 80°, being $\frac{1}{30}$ that of the air, it produces, on rising into the air, an expansion of $\frac{1}{30}$†. As the weight of the air is not

191. Do vapors and gases exclude each other? 192. Give examples. 193. Why is moist air lighter than dry air?

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* This statement relates to vapors rising into a confined space. In unconfined space, expansion of the mixture occurs, which is equivalent to displacement in the same proportion. (§ 193.)

† Steam at 212° having tension equal to that of the air, would double the volume. Gases and vapors, with the density they possess when collected in the usual manner, by displacement of mercury or water, would have the same effect, and thus, like steam, displace their own volume of air.

increased in the same ratio, ordinary moist air is lighter than dry.

Atmosphere.—Boiling.

194. Weight of the Atmosphere.—As an introduction to the subject of boiling, it will be necessary to consider the pressure of the atmosphere. The earth is surrounded by an atmosphere, estimated to be fifty miles high. It is very light compared with the earth itself, or with water. But it has weight, as may be proved by weighing a bottle full of air, and then pumping out the air and weighing it again. The empty bottle will be found to weigh less than the bottle full of air.

195. Another Proof of the Weight of the Air.—That the air has weight, is again proved by tying a piece of bladder over one end of a glass cylinder, placing the other end air-tight on the plate of an air pump, and then exhausting the air. The pressure of the column of air that stands on the bladder is sufficient to break it, and the air settles in, as effectually as if it were a column of iron. The atmosphere exerts such pressure, amounting to about fifteen pounds to every square inch, on all parts of the earth's surface.

196. A simple Means of Proof.—Wind a stick

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194. How can it be proved that the atmosphere has weight? 195. Give another proof that air has weight.

with cotton and press it to the bottom of a test-tube, containing enough water to moisten it thoroughly. It will be found difficult to withdraw the piston. The difficulty arises from the fact that the column of air which rests upon it, must be lifted at the same time. Having raised it a little way and released it, the piston flies with force to the bottom, owing to the weight of the same column of air. A common syringe closed at the bottom is very convenient for performing this experiment.

37

197. Elastic Force of the Atmosphere.—Every cubic inch of air at the surface of the earth, may be likened to a hollow cube of india-rubber, which has been forcibly compressed into the space of a cubic inch.* If we suppose a cube of rubber, while thus compressed, to be confined in a strong metallic box, it would evidently exert an elastic force in all directions, equal to the force which compressed it. So the lower portions of air, which are kept compressed by the air above, exert elastic force. And it is better to regard the pressure of fifteen pounds on every square inch of the surface of the earth, as a consequence of the elastic force of the lower portions of air, rather

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196. Describe a simple means of proving that air has weight. 197. Whence does the air derive its elastic force?

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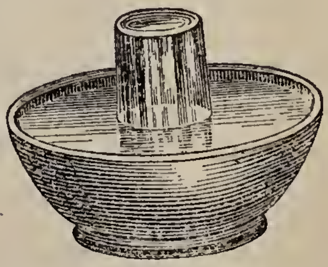
* India rubber may be made to change its form by presssure but its cubical dimensions are no more compressible than water which is usually regarded as almost entirely inelastic.

than the direct effect of the weight of the whole air. The weight of the whole atmosphere produces the elastic force of the lower portions by compressing them, and the elastic force of the lower portions exerts the pressure.

198. WHY THE PRESSURE OF THE AIR DOES NOT CRUSH US.—If a thin glass vessel were turned upside down, and air-tight, upon a table, it would collapse but for the fact that it is filled with air, which, according to the last paragraph, has elastic force equal to that of the air without. So our bodies would collapse, but for the fact that our lungs, and all of the cavities of the body, are filled with air, possessing the same elastic force as the external air; a force which it had acquired by compression, before it was taken into our bodies.

199. QUANTITY OF WATER THE PRESSURE OF THE AIR WILL SUSTAIN. — If a tumbler is filled under water, and then lifted to the surface, as represented in figure 38, it is well known that the water will not run out. The pressure of the atmosphere on the surface of the water outside, keeps the water forced up on the inside.

38



Fill a tumbler with water and cover it with paper, and placing the hand upon it turn it bottom upward,

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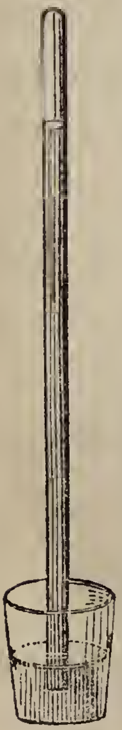
198. Why are we not crushed by the pressure of the atmosphere?
199. What sustains the water in the inverted tumbler represented in the figure?

then if the hand is withdrawn the water will remain in the tumbler, being held there by the upward pressure of the atmosphere as shown in the annexed figure.

39

200. The effect would be the same if the tumbler were twice as tall, or if we suppose it lengthened into a tube thirty-three feet long. If a still longer tube were used, in the first experiment the level of the water inside, would never be more than thirty-three feet above the level outside. The remainder of the tube would be empty, as represented in figure 40. In other words, the pressure of the atmosphere will sustain a column of water thirty-three feet high. Water rises in a pump from this cause.

40



201. QUANTITY OF MERCURY THE PRESSURE OF THE AIR CAN SUSTAIN.—In performing the experiment of the last paragraph with mercury, it will be found that the level within the tube will be *thirty inches* above the external level. In other words, the pressure of the atmosphere will sustain a column of mercury thirty inches high. This is because a column of mercury thirty inches high is just as heavy as a column of water thirty-three feet high.

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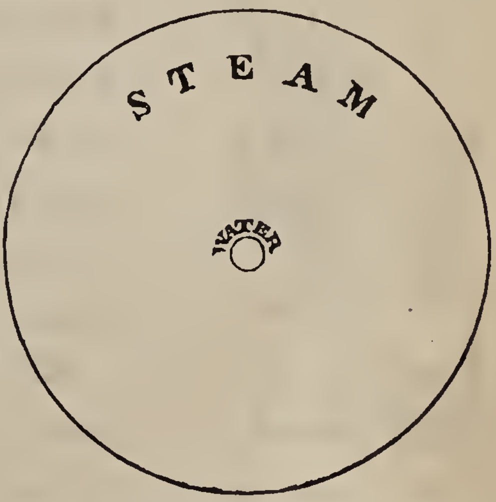
200. What quantity of water will the air sustain? 201. How many inches of mercury will the air sustain?

202. If a long tube is used, there is, of course, an empty space above. This is called the Toricellian vacuum, from the fact that a vccuum was first produced in this manner by an Italian philosopher, named Toricelli. It is not an absolute vacuum, a small portion of mercury being always present in the space in the form of transparent vapor.

203. Boiling.—Thus far we have considered solely the formation of vapors from the surfaces of liquids. But where any liquid is heated up to a certain point, vapor forms in bubbles below its surface. This rapid formation of vapor below the surface of a liquid causing it to burst out with a gurgling noise is called *boiling*.

204. Water begins to boil when it is heated up to 212°; alcohol, at 173°; and ether, at 96°. As the proper temperature is first reached at the bottom of the vessel, near the fire, the formation of bubbles begins there; and as the surplus heat comes in below, they continue to be formed at this point. Every liquid has its own boiling point.

41



205. Expansion in Boiling.—A cubic inch of water boiled in an open vessel, produces 1696 cubic inches of steam. A drop one-tenth

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202. Explain the Toricellian vacuum. 203. What is meant by the term boiling? 204. What is the boiling point of water? Of ether? Of alcohol? 205. How much steam does a cubic inch of water, alcohol, and ether respectively produce?

of an inch in diameter, would make enough to fill a sphere of the diameter of one and a fifth inches. A cubic inch of alcohol produces about 500 cubic inches of alcohol vapor; one of ether about 250. The ether vapor is most dense, that of alcohol next, and the steam least so.

206. Disappearance of Heat in Boiling.—If a thermometer is held in boiling water, it indicates a temperature of 212° F. Continue the fire, and although heat constantly passes up into the water through the bottom of the vessel, it grows no hotter. The steam which is produced has also precisely the same temperature. Neither water nor steam is hotter, although both have been constantly taking in heat. But the heat has not been without effect, any more than in the conversion of a solid into a liquid. It has combined with the liquid to *form the steam.* In this case, also, the heat which disappears is called latent heat. § 150.

42

207. Relation of pressure to boiling.—In order that a bubble of steam may form, it is necessary that a small portion of water, shall expand into a comparatively large portion of steam to form it. But the atmosphere is constantly pressing on the surface of the water, and acting through

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206. What is said of the disappearance of heat in boiling? 207. How does pressure oppose boiling?

the water, in all parts of the vessel, to prevent any separation of particles or expansion. The case is similar to that of the elastic cube before supposed, (197), which was forcibly compressed into a smaller space than it usually occupied.

208. HEAT OVERCOMES PRESSURE.—But if we could by some means increase the elasticity of the elastic cube, it would expand and lift the iron. So, if we can in any way increase the tendency of the particles of water to separate, it will finally be strong enough to overcome the pressure of the atmosphere above and effect separation. Heat has this effect. As the water becomes hotter, the tendency of its particles to fly apart becomes greater and greater, until, at last, it is sufficient to overcome the pressure which has before crowded them together, and a bubble of steam is formed. Others immediately follow, and boiling thus commences. This takes place at 212° Fahrenheit, which is therefore called the *boiling point* of water.

209. EFFECT OF HEIGHT ON BOILING.—At great elevations, the atmosphere is, in fact, lighter and there is less of it above us; the consequence is that water boils on mountains at a lower temperature than in the valleys below. It is found, by careful observation, that an elevation of five hundred and fifty feet above the level of the sea, makes a difference of one degree in the boiling point.

210. MEASUREMENT OF ALTITUDES.—This fact once

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208. Explain how heat overcomes pressure. 209. What effect has height on boiling? 210. How can the height of mountains be determined?

established, a tea-kettle and a thermometer are the only requisites for taking the height of a mountain. The summit being reached, the tea-kettle is boiled, and the heat of the water tested by the thermometer. If the mercury stands at 211°, it is known that the height is 550 feet; if at 210°, the height is 1100 feet; and at whatever point it stands, it is only necessary to multiply 550 by the number of degrees of depression of the mercury below 212°, to ascertain the elevation. On the top of Mont Blanc, water was observed by Sausure to boil at 184°. This gives us the means of calculating very closely the height of that mountain.

211. EFFECT OF DEPTH ON BOILING.—In mines the atmosphere is heavier, and there is, beside, more of it above us, than at the surface of the earth. Water must, in consequence, be more highly heated before it will boil. 550 feet makes, as before, a difference of one degree. We are thus provided with a simple means of determining the depth of mines. Owing to various causes, the atmosphere at the same elevation is a little heavier some days than others, so that the height of a mountain or the depth of a mine, as thus measured, would not be always precisely correct.

212. ARTIFICIAL CHANGE OF BOILING POINT.—It is obvious, from what has already been stated, that all it is necessary to do to change the boiling point, is to change the pressure of the atmosphere, on the surface of the water to be boiled. To produce this change of

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211. What effect has depth on boiling? 212. How can the boiling point of liquids be changed?

pressure, it is not necessary to ascend mountains, or to descend into mines; it may be done by removing the atmosphere by artificial means. This would be done by attaching a tube, air-tight, to the mouth of a test-tube or flask and drawing off the air by means of an air pump. Cold water may thus be caused to boil. So by pumping more air into the flask, the pressure would be increased, and the boiling point elevated; and by this means boiling water would be prevented from further boiling. The same effect will be produced by attempting to boil water in a flask firmly closed by a cork. The steam first formed so increases the pressure that boiling can only be continued by rapidly increasing the temperature much above the ordinary boiling point. This subject is further considered in paragraph 216.

43

213. Culinary Paradox.—Boil some water in a flask or test-tube, and then cork it tightly while steam is still issuing from its mouth. Though removed from the fire, the water will continue to boil. This will be best observed by inverting the flask or tube, as the bubbles of steam form more rapidly from the cork surface than from the glass. A few drops of cold water sprinkled on the tube will occasion a more violent ebullition; while on the other hand, boiling water, or the application of flame, will cause the boiling to cease.

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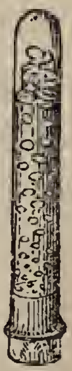

214. Explanation.—The principle is the same as in

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213. Describe the culinary paradox. 214. Explain the principle of the culinary paradox.

the experiment of paragraph 212. As the steam condenses, by the cooling influence of the air, a partial vacuum is produced, with diminished pressure, which enables the water to boil with less heat. Cold water, by condensing the steam and removing the pressure more perfectly, increases the ebullition, while boiling water or flame renews the steam, and consequent pressure, and therefore checks boiling.

215. Water Hammer.—The test-tube prepared as above, is a simple form of the "water hammer." If very thoroughly cooled, and then shaken with the kind of motion which would be required to make a bullet rise half way in the tube and fall again, the water will strike like lead on the bottom. It is because there is no air and but little vapor present to break its fall.

216. Sugar Boiling.—When syrup is boiled down under the ordinary pressure of the atmosphere, it is apt to be brown or injured in flavor. By boiling it in a pan with an air-tight lid, and pumping off the air, and the vapor as fast as formed, boiling may be easily effected at a temperature as low as 150°. This method is put in practice by sugar boilers, and the disadvantages above mentioned are thus avoided and a larger amount and better quality of sugar are obtained.

Many vegetable juices and infusions used for medicines which would be injured by a high temperature, are boiled down, like sugar syrup, under diminished pressure.

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215. Describe the water hammer. 216. How may syrup be boiled below 212° F.?

217. This method cannot be employed in cooking. The water might indeed be made to boil at 180°, but water boiling at this temperature would not have sufficient heat to cook our food like water boiling at 212°.

218. SINGING OF THE TEA-KETTLE. — The singing sound which precedes boiling, is owing to the collapse of the first bubbles of steam, as they rise into the colder water above. The very first bubbles that form are not steam, but air which the heat expels. Steam bubbles are then formed, which rise a little way, and, being reconverted into water, contract, and finally collapse. If the heat is continued and the water made hotter, the next are able to rise further. Finally, when the water becomes as hot as the bubbles, they make their way through, and boiling is thus commenced.

219. STEAM BOILERS.—The boiler is the vessel in which steam is formed. From the boiler it passes to other parts of the apparatus to move the machinery. Steam boilers are of various forms, but are always made of great strength to resist the internal pressure to which they are subjected.

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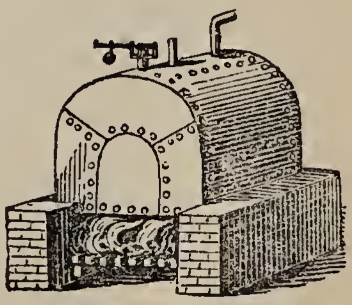

220. The figure represents an ordinary steam boiler, with the pipe which conveys the steam to the engine. A safety-valve is also represented, which will be more fully explained in another paragraph.

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217. Can food be cooked by the same method? 218. Explain the singing of the tea-kettle. 219. What is a steam-boiler? 220. Explain the figure.

221. Elastic Force of Steam.—Under ordinary circumstances, the elastic force of steam is obviously equal to the elastic force or pressure of the atmosphere. A man who rises from a chair with a fifty-six pound weight on his shoulder, must exert an extra muscular force, equivalent to fifty-six pounds, in rising; and he must continue to exert it while he stands. So every bubble of steam must have an elastic force equal to that of the air which it lifts, or it cannot be formed under the pressure of the atmosphere, or continue to exist when once formed.

222. Elastic Force, how increased.—As long as the vessel, in which steam is made, is open, the pressure is as stated in the last paragraph. But if the boiler is closed steam-tight, and the heat continued, more steam forms, and, crowding into the same space above the water increases the pressure. In other words, the space becomes filled with denser steam, of greater elastic force; and the force is finally sufficient to burst the boiler, unless it can find some vent.

223. Increased Temperature accompanies Increased Pressure.—Steam of high elastic force can only be made in a close vessel. But in proportion to the increase of elastic force, is the increase of pressure on the surface of the water. Therefore, the boiling point becomes higher and higher, or, in other words, the water has to grow constantly hotter, in order that

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221. How great is the elastic force of steam? 222. How is the elastic force of steam increased? 223. What accompanies increased pressure of steam?

steam may form; and as steam always has the temperature of the water with which it is in contact, the steam grows constantly hotter also.

224. The exact Relation of Temperature to Pressure.—It is desirable to know the increase of pressure for each elevation of temperature. A steam boiler supplied with a barometer gauge and a thermometer affords the means of ascertaining this relation. Or it may be done by a very small boiler, made for the purpose. The barometer gauge is nothing more than a bent tube fitted into a boiler, open to the air at the top, and containing quicksilver in the lower part of the bend. We will suppose all the air to have been expelled from the boiler, the stop-cock through which it made its escape closed, and the whole interior to be filled with steam. As more steam is produced, pressure is increased, and the temperature of both water and steam rise, as before explained.

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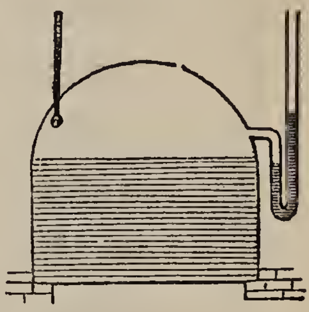

225. Where the temperature has reached 250°, it is found that the pressure of the steam, acting on the surface of the quicksilver, is sufficient to force and hold the latter thirty inches higher in one arm of the tube than in the other. But the steam with which the boiler was filled when the stop-cock was closed, exerted a pressure of fifteen pounds per square inch, just suffi-

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224. How can the exact relations of temperature to pressure be determined? 225. What pressure has steam at 250? at 275? at 294? How is this shown?

cient to balance the pressure of the external air, and prevent its forcing the quicksilver before it and crowding into the boiler through the tube. As before stated, when the thermometer reaches 250°, it is found that the denser steam will not only balance the atmosphere, but has force enough to lift the mercury thirty inches, which is equivalent to another atmosphere. Steam at 250°, and in contact with water, is therefore said to exert a pressure of two atmospheres, or thirty pounds to the square inch. At 275° it has a pressure of three atmospheres; and at 294° of four.

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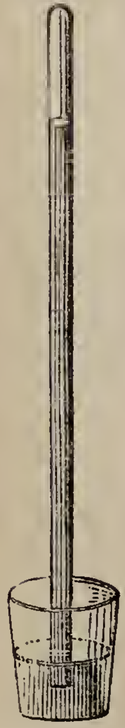

226. All Vapor has Elastic Force.—The apparatus just described shows the pressure of steam at and above 212 degrees. But vapor of water has elastic force at all temperatures. This is best shown by passing a little water up into a Toricellian vacuum, and observing the effect. The water is introduced by blowing it through a glass tube, one end of which is brought under the mouth of the inverted tube. The drop rises and floats on the mercury, and as vapor forms at all temperatures, a portion of it is immediately converted into vapor. At the same time the level of the mercury is depressed. It is crowded down in opposition to the pressure of the air outside, by the elastic force of the vapor formed. For the sake of simplicity, the space above the mercury was supposed to be a vacuum, but the effect is the same if it is filled with air. For, as

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226. What is said of the elastic force of vapors at low temperatures?

has been already shown, vapor is produced as well in air as in a vacuum, and with the same elastic force, though it is not formed so rapidly in air as in a vacuum. If the top of the tube is warmed, denser vapor is formed, possessing greater elastic force, and the mercury sinks lower, until at 212° the elastic force within, is equivalent to the pressure of the atmosphere without, and the mercury is pressed down to the external level. If instead of a drop of water a drop of alcohol or ether is allowed to pass up into the barometer-tube the depression of the mercury is greater than when water is admitted. The figure shows at A, a barometer tube in which there is a perfect vacuum at the top, or as perfect a vacuum as can be formed with the mercurial barometer; at B is a similar tube in which vapor of water is formed at the top; at C the top of the tube contains vapor of alcohol, and at D is a similar tube showing the depression caused by the formation

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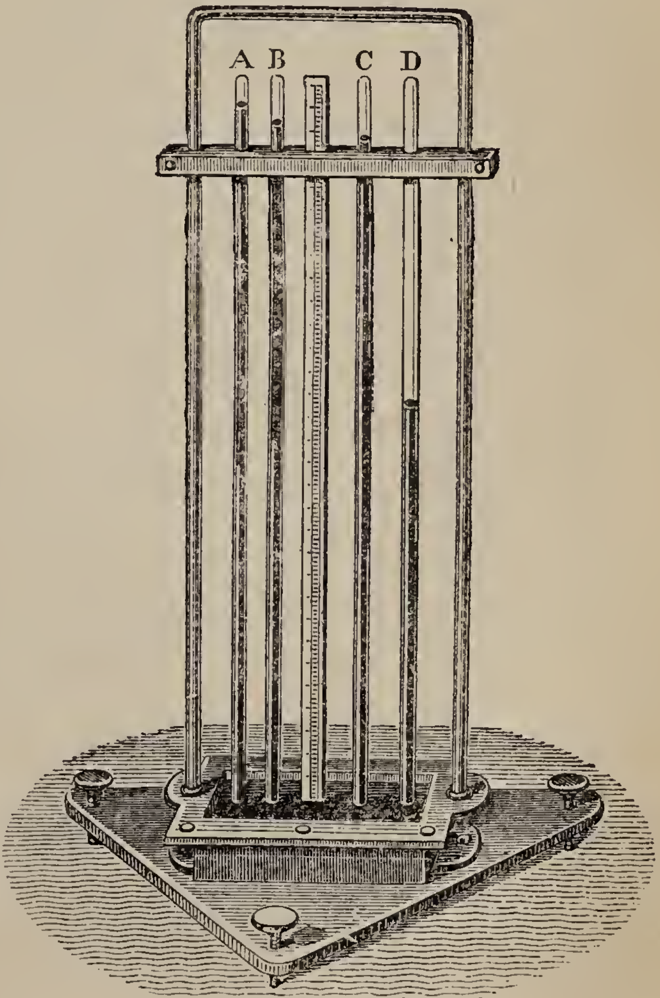

of vapor from a drop of ether passed up through the mercury. Here we see that vapor of alcohol has greater tension (or power of depressing the mercury) than vapor of water, and vapor of ether has still greater tension than vapor of alcohol.

227. BAROMETER-GAUGE.—The principle of the barometer-gauge has already been explained, (224.) A few words will be added here as to its use and construction. It is always desirable to know the pressure in a steam boiler, as an evidence of safety, and in order that the fires may be regulated accordingly, and no more fuel be consumed than is necessary. Sometimes the tube containing the quicksilver is of glass, and then the height of the mercury can be seen. In other cases it is made of iron, and the change of level of the quicksilver is indicated by a float.

228. OTHER STEAM GAUGES.—A thermometer may be made to answer, perfectly, the purpose of a steam-gauge, as is evident from what has been said in paragraph 225. The advantage of such a gauge is, that it takes but little room; its disadvantage, that it is liable to be broken.

229. There is still another kind of gauge, in which the force of the steam operates on a metallic spring, which moves an index more or less, according to the pressure. The spring-gauge is commonly used in locomotive boilers.

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227. Explain the construction and use of the barometer guage. 228. Explain the thermometer-guage. 229. Explain the principle of another guage.

230. ACTUAL PRESSURE IN DIFFERENT ENGINES.—The actual pressure of steam, used in different forms of the steam engine, varies very widely. There are low and high pressure engines. In the former, steam of ten to thirty pounds effective pressure is used; in the latter, the pressure often reaches, and sometimes exceeds, seventy-five pounds. To measure the pressure, the steam gauge described in paragraph 227 would have to be five or six feet long. It is on account of this inconvenient length, that other gauges are often substituted.

231. By effective pressure, is meant the surplus over and above that which is necessary to counterbalance the pressure of the atmosphere, or that of the uncondensed steam, on the opposite side of the piston.

232. SAFETY-VALVE. — The safety-valve is a contrivance by means of which the steam finds vent through a hole in the boiler, whenever its force becomes too great for safety. A piece of metal, shaped somewhat like a decanter stopper, fits into the hole above mentioned, and is loaded by a weight, which can be made greater or less at pleasure. As long as the steam has not too great pressure, the stopper continues in its place, and the boiler is as tight as if it had no such opening. When this pressure is exceeded, the valve is lifted, and steam escapes. The

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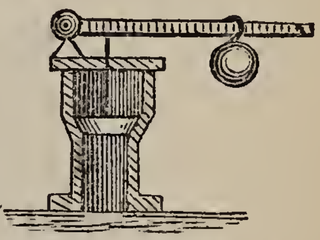

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230. Explain the difference between high and low pressure engines. 231. What is meant by effective pressure? 232. Explain and illustrate the principle of the safety valve.

stopper, being loaded, falls back again, as soon as the pressure is relieved.

233. The Steam Engine.—The power applied in the steam engine is the elastic force of steam. The figure represents a cylinder and close fitting piston, and tubes through which steam may be admitted at pleasure, either above or below. When the valve in the lower tube is opened, the steam under pressure in the boiler, expands and enters the cylinder, lifting the piston. If the steam is next admitted above, it drives the piston back again, and the latter may thus be kept in constant motion, and made to move wheels, shafts, or other machinery. In the earlier forms of the steam engine a man or a boy was employed to open and shut the cocks to admit or shut off the steam at the right moment. This service was long since dispensed with and the machinery is so constructed as to open and shut the valves at the right moment by its own motion. The arrangement by which this is effected will be understood by inspecting figure 51. At the top and bottom of the cylinders are openings called "ports" through which the steam enters and leaves the cylinders. On the side of the cylinder there is placed what is called a D-valve, which works in a box, and slides over a piece of metal which has three openings. This D-valve is shown at No. 3, and the metal face with its three openings over which the valve

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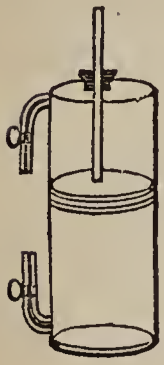

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233. Explain the principle of the steam engine.

slides is shown at No. 4. The upper and lower holes are seen to be connected by means of pipes with the top and bottom of the cylinder through which the steam passes to and fro. The middle hole is connected with a pipe through which the steam passes off into the air when it has done its work. In that part of the figure marked No. 1, the valve is shown in such a position that the steam from the boiler, which enters the box in the direction of the arrow, passes below the piston and forces it upwards. In No. 2 the steam from the boiler is passing to the top of the cylinder and is therefore pressing the piston downwards; in both positions that part of the cylinder which is shut off from

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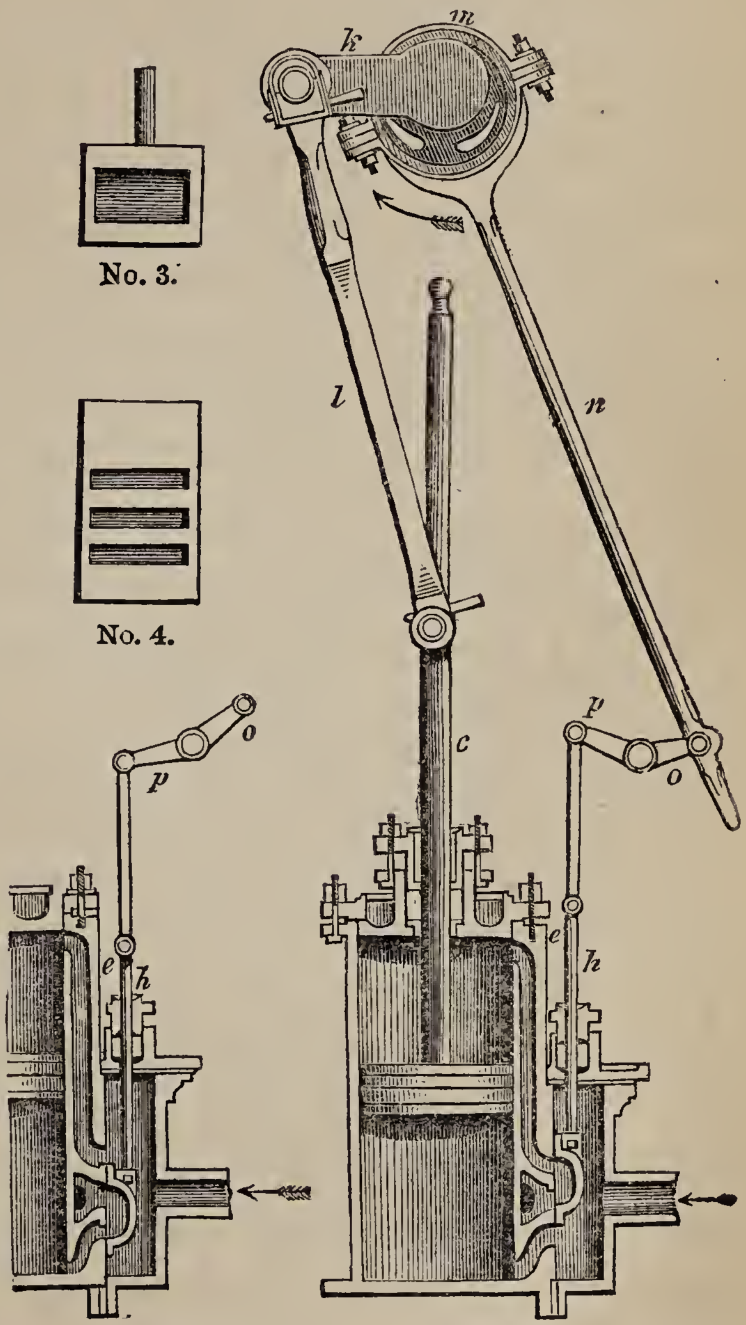

No. 3.

No. 4.

No. 2.

No. 1.

the steam-supply is losing its steam by the middle opening which is never closed by the D-valve. The piston-rod, *c*, is attached by the connecting-rod, *l*, to the crank, *k*, attached to a shaft which moves any machinery required. To the valve a rod, *h*, is fixed (Nos. 1 and 2,) and by means of another rod it is connected with a lever, *p o*, which is moved by a contrivance called an eccentric, *m*, attached to the shaft. The eccentric is a circular plate so attached to the shaft on one side of the center that it acts like a crank. If a pin is driven through a circular card at a little distance from the center and the card is turned around on the pin it will move like the eccentric of a steam-engine. Around the eccentric is a metallic ring connected with the rod, *n*, which is attached to the lever at *o*. When the eccentric turns around with the shaft, it either pulls or pushes the lever, *o p*. In No. 1, it has forced *o* down and *p* up; and as *p* is connected with the D-valve that has been raised to the top of the box the steam is allowed to escape from the top of the cylinder into the open air. In No. 2, *o* has been raised and *p* has been depressed, thus allowing the steam to proceed to the top of the cylinder while it escapes into the air from the bottom. By means of this ingenious arrangement the engine supplies itself with steam and so works continuously without the necessity of any human assistance.

The eccentric can be so arranged on the shaft and the D-valve so adjusted as to cut off the supply of steam before the piston is driven to the extremity of the cylinder. As steam expands with great force it fills the cylinder by its expansion and a great saving of steam and heat is thus effected. In this arrangement of the valves there is a short interval when the steam does not enter either end of the cylinder.

234. HIGH PRESSURE ENGINE.—The engine, here described, is called the high pressure engine. The steam which moves it, must evidently have elastic force greater than that of the atmosphere, or it cannot expand and drive out the waste steam, in opposition to the elastic force of the air. Steam of much higher pressure is used in such engines, than in those to be next described, and hence their name.

235. LOW PRESSURE ENGINE.—The same figure will answer to illustrate the low pressure engine. The difference is, that the steam which has been used is not driven out, but disposed of, on the spot, by converting it into water. The advantage of this will be readily perceived. Suppose the space above the piston to be full of steam. A jet of water is made to play into it and condense the steam, and thereby produce a vacuum. When, immediately afterward, steam is admitted below the piston, the latter has nothing on the other side to drive out, and consequently rises more easily. As less force is required, steam of lower pressure may be used, with a corresponding economy of the heat and fuel required in its production.

236. THE CONDENSER.—In steam engines, as now

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234. What is a high pressure engine? 235. Explain the principle of the low pressure engine. 236. What is the use and object of the condenser?

made, the water used to condense the steam does not come into the cylinder itself, but into a side vessel, called the condenser. The steam expands into this vessel, and is condensed, producing a vacuum in the cylinder itself, as effectually as if the water were there introduced. The object of this modification is to avoid cooling the cylinder and thereby diminish the effect of the steam subsequently entering from the boiler. This engine is called the low pressure engine, from the fact that steam of lower pressure may be employed to move it than with the engine previously described. It may, indeed, be made to run with vapor formed below 212°, instead of steam. But in practice, steam of from ten to thirty pounds effective pressure is employed.

237. ORIGINAL STEAM ENGINE.—In the original form of the steam engine, the pressure of the atmosphere, instead of steam, was applied on one side of the piston, and it therefore received the name of the atmospheric engine. Suppose the cylinder in the last figure to be open at the top, and the piston at its full height. On condensing the steam below it, the piston would evidently sink, in consequence of the pressure of the atmosphere. By thus employing steam pressure on one side, and atmospheric pressure on the other, a constant motion would be realized. But the effective power would evidently be less than in the low pressure engine, because part of it would have to be expended each time in lifting the piston, in opposition to the pressure of the atmosphere.

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237. Explain the original low pressure engine?

238. A test tube containing a few drops of water and provided with a wooded piston suffices to illustrate the source of power in the steam engine. On alternately heating and cooling the tube motion of the piston is effected.

239. THE MECHANICAL EQUIVALENT OF HEAT.—The mechanical equivalent of heat, or in other words the amount of force required to produce a given amount of heat, (and which can in its turn be produced by the same amount of heat), has been carefully determined by experiment. The result is the same whether the conversion of force into heat is effected by the falling of weights, the friction of metals, the agitation of liquids, or the hammering of solids. A pound weight falling through 772 feet will develop heat enough on collision with the earth to raise a pound of water one degree Fahrenheit in temperature.

Conversely, this same amount of heat applied mechanically (in the production of steam or otherwise) is competent to raise a pound weight 772 feet, or 772 pounds one foot. The amounts of force and heat thus indicated are therefore equivalent. The term *foot-pound* (equivalent to *foot-raised-pound*) has been introduced to express the force required to lift one pound to the height of a foot. "The quantity of heat required to raise the temperature of water one degree being taken as a standard, 772 foot-pounds constitute what is called the *mechanical equivalent of heat.*"

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238. How may the steam engine be simply illustrated? 239. How is the mechanical equivalent of heat determined? What is taken as the standard?

240. Conversion of Vapors into Liquids.—If a vapor, in any way, loses its latent heat, it at once becomes liquid. If, for example, steam be led into a cool pipe, the metal abstracts the latent heat, and the steam becomes water. At the same time, the heated pipe imparts warmth to the air around it.

241. Heating Houses by Steam.—Houses are thus heated, by steam pipes passing through the various apartments. The pipes abstract the heat, and give it out again to the air of the house. The steam thus converted into water, runs back into the boiler to be reheated, and to start again on its journey. As long as heat is supplied, the water continues its service as a carrier of heat. The great amount of latent heat which steam contains renders it an excellent medium for conveying heat to any apartment where it is wanted. In the most approved steam heaters steam of low pressure is used.

When buildings are heated by steam conveyed in pipes from a boiler used with high pressure the temperature often rises to 300° or 400°; and if the pipes are connected with wood-work the wood after a time becomes so thoroughly dried, that even the heat of the steam-pipes sets fire to the wood. Many accidents have occurred from this cause in buildings heated by steam. When steam at low pressure only is employed for heating buildings there is less danger of setting fire

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240. How are vapors converted into liquids? Example. 241. How are houses heated by steam? What accidents sometimes occur when buildings are heated by steam?

to the wood-work than when hot-air furnaces are employed.

242. Water heated by Steam.—When steam is led into water, the effect is the same as on leading it into a cold pipe. The water abstracts its latent heat, and becomes hot, while the steam itself becomes additional hot water. Water in different parts of a room, or even of a large manufacturing establishment, may thus be made to boil by one fire; steam being led into it, by long pipes, from a single boiler.

243. Proof that Boiling is effected by Latent Heat.—No amount of boiling water, if poured into cold water, will make it boil. But steam no hotter than the boiling water, if led into cold water, will have this effect. Now, as both the hot water and the steam were the same in respect to sensible heat, if the steam effects what the water does not, it is evident that it must do it by hidden, or latent heat. It is only latent heat which the steam loses, for it becomes itself converted into equally hot water.

244. Quantity of Latent Heat.—A pint of water will make enough steam to fill a globe nearly four feet in diameter. If this amount of steam could suddenly become a pint of water, and be prevented from flying off into steam again, it would become red hot. The latent heat of the steam would have raised the temperature from 212° to 1212°—a thousand degrees. Steam

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242. How is water heated by steam? 243. Prove that boiling is effected by latent heat. 244. How much latent heat does steam contain?

is therefore said to contain 1000 degrees of latent heat. According to Regnault the latent heat of steam varies at different temperatures. At 212° it is 966.6°. At 32° the latent heat of vapor of water is 1092.6°.

245. SUM OF SENSIBLE AND LATENT HEAT NEARLY CONSTANT.—Vapor formed by the heat of summer, occupies more space, and contains more heat, in a latent condition than is contained in steam. And it is found to be true that very nearly in proportion as vapor or steam *feels* cool, or indicates a lower temperature to the thermometer, it contains more latent heat to the same quantity of water. The sum of the sensible and latent heat at the ordinary pressure of the atmosphere is approximately the same—about 1178°.

246. ECONOMY IN EVAPORATION.—It follows that evaporation at low temperatures, such as is practiced sometimes in sugar-houses, has no advantage of economy. The vapor that passes off, carries with it less sensible heat, but enough more latent heat in proportion, to make up the difference.

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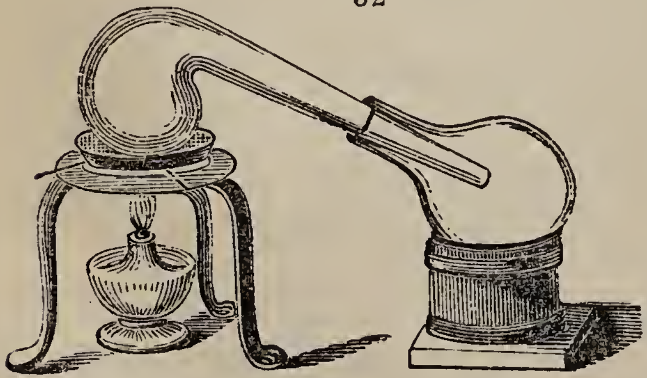

247. DISTILLATION.—Distillation consists in converting a liquid into vapor, and recondensing the vapor. The apparatus commonly em-

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245. What is the relation of sensible to latent heat? 246. Why is there no economy in evaporating at low temperatures? 247. Describe the process of distillation.

ployed in the laboratory for distillation, consists of a retort and a receiver, as represented in figure 52. The receiver is kept cool by the constant application of cold water. In Liebig's apparatus, figure 53, for the same purpose, the vapors are made to pass from the retort or flask through a long inclined tube, *a b*. The latter is inclosed in a second tube, A B, which is constantly supplied with cold water by the funnel, *f*, which extends higher than the end, *a*, of the larger tube, and escapes by the tube *d*. A more perfect condensation is thus effected. The simple apparatus shown in figure 54 also suffices for illustration. Water being boiled in the test-tube, the steam condenses in the cooler vial. If the latter is covered with wet paper, the condensation is more perfect.

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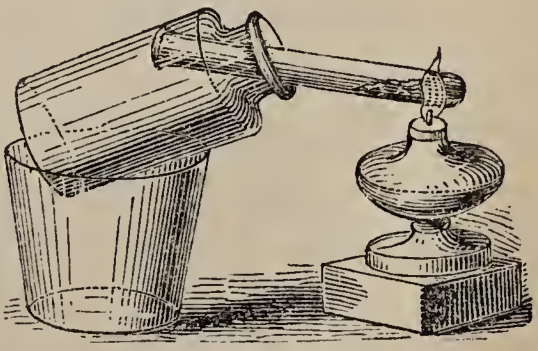

248. Object of Distillation.—The object of distillation is commonly to purify, or, in other words to

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248. What is the object of distillation? Give examples.

separate the liquid distilled, from other substances with which it may be mixed. Thus, sea water is distilled to separate the pure water from salt. The water becomes steam, and is condensed as pure water, while the salt remains behind. So alcohol is distilled, or converted into vapor, and recondensed, to separate it from water. and the various refuse matters which are mixed with it after fermentation. But the separation is not perfect, for, although alcohol is more volatile, and distills more rapidly, a portion of water always distills with it. Distilled liquors, therefore, uniformly contain a certain proportion of water.

CHAPTER IV.

MAGNETISM AND ELECTRICITY.

249. Native Magnets.—The native magnet, or lodestone, is a mineral which has the remarkable property of attracting metallic iron to itself, and of taking north and south direction, when suspended and free to move. Particles of iron brought near, rush toward it, and remain attached to its surface, without any visible cause. It exerts this attractive force just as well through wood, stone, or any other material, as through the air.

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249. What properties has the native magnet?

250. Artificial Magnet.—The same properties may be imparted to a piece of steel, by a process to be hereafter described. Such a piece of steel thereby becomes itself a magnet. Magnets are often made of a shape approaching that of a horse-shoe, the two poles being brought near each other. A piece of soft iron, called an armature, is placed across the end to prevent the loss of magnetic power, which is found otherwise to occur.

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251. Magnetic Needle.—If a steel bar be made into a magnet, and then balanced on a pivot, it will turn, until one end points north and the other south. That which moves toward the north is called the north pole, and the other end the south pole. A small bar thus balanced is called a magnetic needle, and is the essential part of the mariner's compass.

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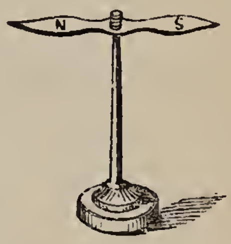

252. Attraction of Magnets for each other.—The law of attraction between magnets is, that unlike poles attract, and like poles repel. The north pole of one magnet, therefore, attracts, and is attracted by the south pole of another.

253. Why the Magnetic Needle points North.—The tendency of the north pole of the magnetic needle to turn north, and the other pole south, may be ac-

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250. Describe an artificial magnet. 251. What is the magnetic needle? 252. How do the poles of magnets act on each other? 253. Why does the magnetic needle point north?

counted for by the supposition of an enormous magnet running through the earth, with powerfully attracting poles in each hemisphere. This may be illustrated by suspending a small magnetic needle, *s n*, over a globe nine or ten inches in diameter in the axis of which a steel magnet, N S, is placed. When the axis of the magnet is horizontal the needle, *n s*, will arrange itself as shown in figure 57. This represents the condition of things at the equator. Figure 58 shows the relation of the earth and the needle as it approaches the north pole.

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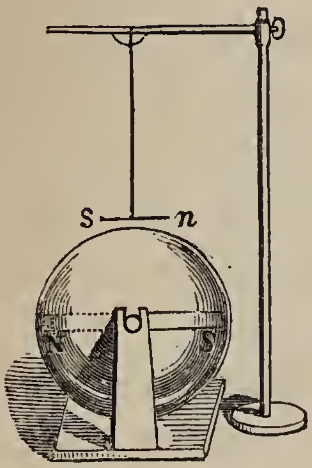

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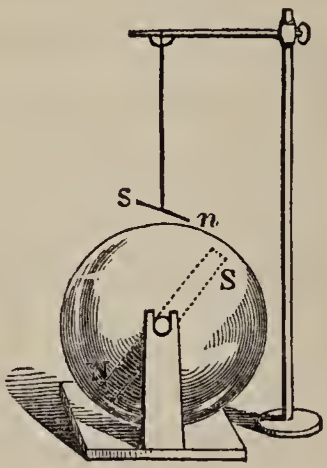

In order that the pole of the supposed magnet in the northern hemisphere of the earth may attract the pole of the magnetic needle which points to the north, we must suppose it endowed with that kind of polarity found in that pole of the needle which points to the south, that is, we must suppose it to be a south pole, and for a similar reason we must suppose the pole in the southern hemisphere to be a north pole. This inconsistency may be avoided, and the poles of the supposed terrestrial magnet named according to their geographical position, if we regard what is called the north pole of the needle, as endowed with austral or southern magnetism, and the south pole with northern or boreal magnetism. This view is, in fact, adopted in all writings on magnetism. The received theory is hereafter given.

254. Induced Magnetism.—When a piece of iron is brought near to a magnet, the iron receives magnetism, by induction, and becomes itself, temporarily, a magnet. If approached to the south pole, its adjacent end acquires north, and the remote one south, polarity, and mutual attraction results. By virtue of its acquired or induced magnetism it will attract another piece of iron, as is represented in the figure, and affect it in all respects similarly. From the second key, another smaller one may be suspended, and from this another, and so on. This arrangement of the keys affords an illustration of the probable inner constitution of a magnet. The atoms of which it is composed, themselves possess polarity and are arranged with their opposite poles adjacent. Induction is the communication of this polar arrangement.

59

If the keys or pieces of iron attached to the magnet, as shown in the figure, are tested by the approach of a magnetic needle the entire series acts only as an extension, or prolongation of the pole of the original magnet, the parts marked N and S in the figure both have the same action towards the needle used as a test. This is because the feeble north (N) polarity induced in the end of the key in contact with the south (S) pole of the magnet has its influence upon the testing needle

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254. Explain induction of magnetism in soft iron.

overbalanced by the greater intensity of south polarity in the magnet itself. In the same manner if a bar magnet of feeble intensity has its north pole placed in contact with the south pole of a very powerful magnet, the magnetism of the feeble magnet will be masked and it will appear, as in the case of the keys, to be merely an extension of the south pole of the powerful magnet, but when removed from the influence of the larger magnet it will again manifest its own polarity.

255. Diamagnetism.—If a needle of iron be hung by a thread, between the poles of a horse-shoe magnet, it immediately turns, so that one of its ends points to the north pole, and the other to the south. This is also a consequence of induced magnetism, as explained in the preceding paragraph. The metal nickel, oxygen gas, and many other substances, both solid, liquid and gaseous, are similarly attracted by the poles of a magnet, though in a much less degree. All bodies which are not attracted are repelled, and, if suspended between the poles, turn so as to bring their extremities as far away from the poles as is possible. The former class are called magnetic, and the latter *diamagnetic* bodies. To show the phenomena of attraction and repulsion with gases and liquids, the materials are inclosed in tubes or bulbs. In the case of most substances, excepting iron, these effects can only be attained by means of powerful magnets and delicate apparatus.

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255. What is said of diamagnetism

Electricity.

256. Frictional Electricity. — If a glass tube is rubbed with silk, it will afterward attract to itself filaments of the silk, as a magnet attracts iron. Or, if the knuckle be approached to the tube, a spark may be drawn from it. These phenomena are called electrical. Both glass and silk are said to be electrically excited. The same experiment may be made with a stick of sealing-wax, a roll of sulphur and a variety of other substances.

257. Two Kinds of Electricity.—Suspend a small piece of tissue paper by a fiber of silk, and bring near to it the glass tube previously excited as above directed, the paper will be first attracted to the tube and then as strongly repelled. While thus repelled by glass, bring towards it a stick of sealing wax excited in the same manner, and the paper will be immediately attracted by the wax and again repelled, but it will afterwards be again attracted by the glass tube. It is thus evident that by friction of the glass and of the wax two similar but opposite forces are developed. In order to distinguish these two opposite kinds of electricity, that which is obtained from glass has been termed *vitreous*, or *positive* electricity; while that derived from the wax is called *negative* or *resinous* electricity. The suspended paper is called an *electroscope*, or test for electricity.

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256. What is frictional electricity? 257. How is it shown that there are two kinds of electricity?

258. The coexistence of the two kinds of electricity in the same object may be illustrated by the elasticity of an ordinary spring as shown at S, figure 60. When the spring is not extended it may represent the body in its ordinary condition when no electricity is manifested. If one end of the spring is fastened to a pin, P, and a weight, W, is attached to the other end by a cord passing over a pulley, it will appear to be stretched by one force only. But this is not in reality the case. For if, instead of fastening one end to the pin, we attach to it another weight V, just equal to W, thus obviously introducing a second force, the strain upon the spring will not be changed. The case of electrical excitement is analogous; when one kind only appears to be developed by friction or any other means, a careful examination will always detect an equal amount of the opposite kind of electricity.

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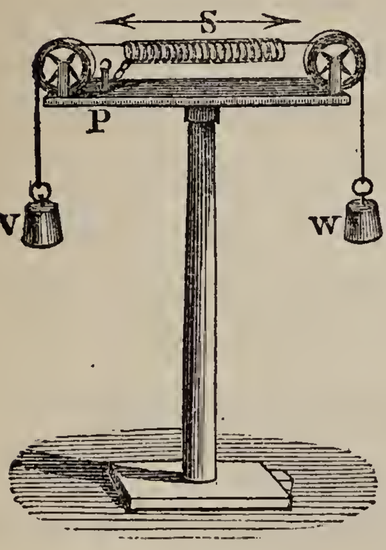

259. Theory.—According to the view commonly entertained of the class of phenomena described on the preceding page, all bodies contain two electrical fluids in a state of combination. When glass is rubbed with silk, the positive fluid accumulates in the glass and the negative in the silk. When sealing

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258. How can the action of two kinds of electricity be illustrated?
259. State the theory of electricity.

wax is rubbed with silk the positive electricity accumulates in the silk and the negative in the sealing-wax. The positive sustains the same relation to the negative, that the north polarity of a magnet does to the south; and, in consequence of the difference of the separated fluids, the two bodies containing them attract like opposite poles of a magnet. It is also true, that similarly electrified bodies repel like similar poles of magnets. Slips of gold leaf, attached to a conducting rod, fly apart when the rod is touched by an electrified body.

260. The human body may also be electrically excited, so as to yield a spark, by rapid sliding over a Brussels carpet. Gas may be lighted by the spark from the finger when the body is thus charged with electricity. The gas in certain manufactories is instantaneously lighted throughout the whole establishment by electricity developed by the friction of the machinery.

261. Conduction of Electricity.—Like heat or caloric, electricity may be conducted from one body to another. Thus, if a piece of metal be electrically excited, or, in other words, charged with a quantity of either the positive or negative fluid, another piece of metal will immediately become so on connecting it with the first by a metallic wire. The connection being formed, it will attract or repel filaments of silk or other material, precisely as the first one does. The fluid is supposed to flow from one piece of metal to the other, through the wire, and we therefore speak of a current

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260. Illustrate by examples. 261. Explain the conduction of electricity.

of electricity. But it is not necessary to suppose that any material substance is actually transmitted any more than in the case of light and heat before considered. § 288.

262. The Leyden Jar.—This instrument shown in figure 61 is designed to collect and preserve electricity for the purpose of experiments. It consists of a glass jar coated inside and outside with tinfoil for about three-fourths of its height. A brass knob at the top is supported upon a rod or wire passing through the cork and touching the coating of tinfoil on the inside of the jar. After the Leyden jar has been charged with electricity a strong spark is emitted whenever a conductor makes a connection between the knob and the outer coating.

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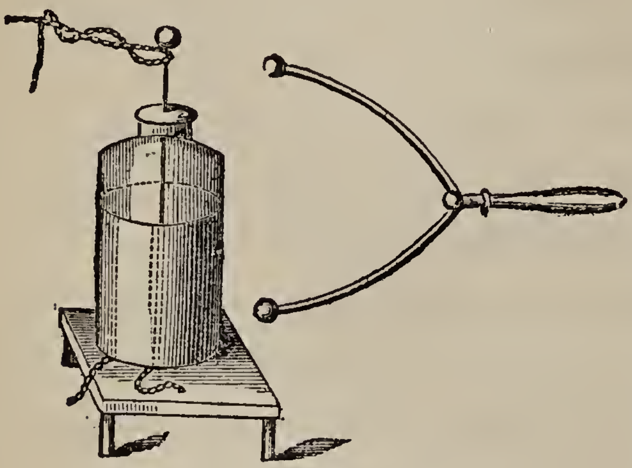

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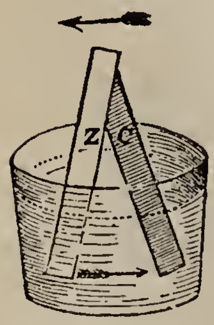

263. Voltaic Electricity.—This term is applied to electricity which is set in motion by chemical action and was adopted in honor of Volta, who discovered this kind of electricity. It is found that electricity is developed when two metals are placed in contact with each other, and with an acid at the same time, as is represented in the figure. The metals must be such that the acid will act

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262. Describe the Leyden jar. 263. What is Voltaic electricity?

on one of them. Zinc and copper being used, the former is dissolved, and the current flows continuously in the direction indicated by the arrows. This apparatus is the simplest form of the Voltaic battery.

264. ELECTRODES.—For convenience in certain experiments, it is customary to attach platinum wires, to the exterior portions of the metallic slips. These are called electrodes. The wire connected with the copper forms the positive electrode, and the one attached to the zinc, the negative, because the current of electricity passes from the copper over the wire to the zinc.

265. Platinum wire is chosen, because there is frequent occasion to immerse the electrodes in corrosive liquids, and this metal, for the most part, withstands their action. For many experiments, it is found best to flatten the ends of the wires forming the electrodes, so as to produce a larger surface. The same object may also be effected by terminating them with strips or plates of platinum.

266. ELECTRICAL CONDITION OF ATOMS.—All atoms of matter are regarded as originally charged with either positive or negative electricity. Hydrogen and the metals are electro-positive; oxygen, chlorine, and cyanogen, and other substances to be described hereafter, are negative. A molecule* of water is made up of a positive atom of hydrogen, and a negative atom of

264. What is an electrode? 265. Why is platinum used for electrodes? 266. What is the electrical condition of atoms?

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* The term *atom*, and *molecule*, are synonymous. But "molecule" is limited, in the present work, to the particle of a compound.

oxygen; hydrochloric acid, of positive hydrogen and negative chlorine; oxide of silver, of positive silver and negative oxygen. The figure, in which + represents positive and — negative, may represent a molecule of either of the compounds named.

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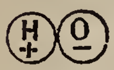

267. QUANTITY OF ELECTRICITY.—The quantity of electricity thus combined or neutralized, in almost all kinds of matter, is enormous. Faraday has stated that a drop of water, contains more than is discharged in the most violent flash of lightning.

268. DECOMPOSITION OF WATER.—If the electrodes are immersed in water, as represented in the figure, the water is decomposed, and separated into its elements, oxygen and hydrogen gases; one of which escapes at the positive and the other at the negative electrode.* The properties of these elements and the method of collecting and testing them, will be described when we come to speak of the chemical composition of water.

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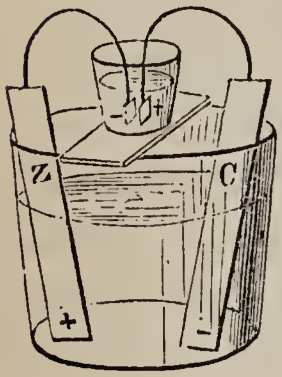

269. It is to be observed that *positive* hydrogen is liberated at the *negative* pole, as if the latter had a power analogous to that of the magnet for iron, to draw the hydrogen out of the water, in which it exists combined. On the other hand, negative oxygen is libera-

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267. What quantity of electricity is contained in water? 268. Describe the decomposition of water. 269. Why does hydrogen appear at the negative pole?

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* In making the experiment the compound circuit (290) is to be employed.

ted at the positive pole, as though the latter had the same attractive power for oxygen.

270. Theory of the Decomposition of Water.—It is a remarkable circumstance, in the decomposition just described, that it continues to occur even when the electrodes are quite widely separated from each other. Now, a molecule of water is extremely small, and cannot occupy the space between the electrodes, if they are separated to any considerable extent. The space must be occupied by many such particles, which, for the sake of definiteness, we will conceive of as arranged in straight lines, between the two electrodes. The circles in the figure, inscribed H and O, represent one of these lines of molecules. The difficulty now arises, to account for the fact, that when the hydrogen is liberated at the negative pole, the oxygen, combined with it a moment before, is not also liberated at the same point. The view to be taken of it is as follows: that as soon as the atom of oxygen loses its hydrogen, it combines with the hydrogen of the next molecule of water. The oxygen of this second one being thereby liberated, combines with the hydrogen of the next; and this decomposition and recomposition continues throughout the series. The end of the series being reached, the last oxygen atom escapes in the form of

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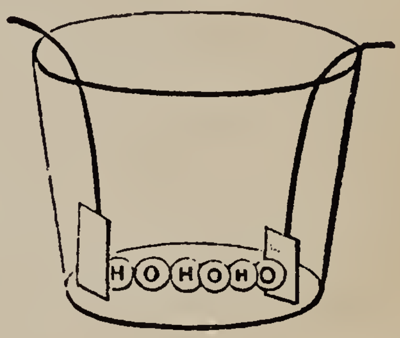

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270. Give the theory of the decomposition of water.

gas. The action being simultaneous throughout the series, this evolution occurs at the instant that the hydrogen is set at liberty at the negative electrode. It is, therefore, quite as proper to give the explanation of the difficulty first stated, by beginning with the liberation of oxygen at the positive electrode. We then suppose the hydrogen to combine with the oxygen of the next molecule of water in the series, and so on to the negative electrode, where hydrogen is evolved. The action is, in fact, as before stated, simultaneous.

271. Decomposition of a Salt.—The decomposition effected by the voltaic current may be more strikingly illustrated by introducing the electrodes into a dilute solution of sal-ammoniac, previously colored by litmus, or red cabbage. Chlorine is liberated at the positive pole, and bleaches the solution in its vicinity, while ammonia is evolved with hydrogen, at the negative pole, and changes the color of the solution from blue to red. That of the cabbage is changed by the same means, from red to green. By employing a glass box with two compartments, such as is represented in the figure, the two portions of the liquid may be kept distinct. It is essential, for reasons that will be understood from the preceding paragraph, that there be an unbroken chain of molecules of the *electrolyte*, or substance to be decomposed, between the electrodes. This is effected by

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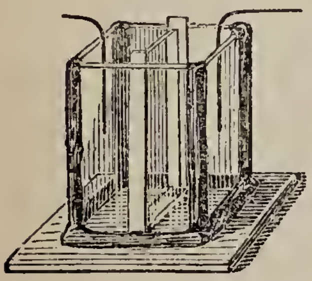

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271. Describe the decomposition of a salt.

making the partition quite loose, and keeping it in its place by strips of paper, placed along the edge. All the communication that is essential, then takes place through the pores of the paper, while the partition at the same time prevents the mixing of the contents of the separate cells. The same object may be accomplished by the employment of two tea-cups, holding the liquids, and connected by moistened lamp-wick; a larger pile, and a longer time, is in this case required to effect the decomposition. The glass box may be made according to the directions given in paragraph 33 for making a prism.

272. Deposition of Metals.—The metals are electro-positive. Oxygen, chlorine, etc., on the other hand, are negative. If, therefore, oxides, chlorides, or cyanides of the metals are subjected to the action of the electrodes, they are decomposed, while the metal goes to the negative, and the oxygen, chlorine, or cyanogen, to the positive pole. But the metals, when separated from their combinations, being solid bodies, cannot escape. They collect on the negative electrode, instead. If this be attached to a brass spoon or fork, or any other object it is desired to plate, the spoon becomes itself the electrode, and the metal is deposited upon it as long as the action of the battery continues. At the same time, the oxygen, or other negative element, goes to the positive electrode, generally corroding it, instead of passing off as gas.

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272. Explain the deposition of metals by galvanism.

273. Silvering Apparatus.—The requirements for electro-silvering or gilding, are first a battery of somewhat different form from that already described, though precisely the same in principle; second, an acid to excite it; and third, a solution containing gold or silver. These will be described in turn.

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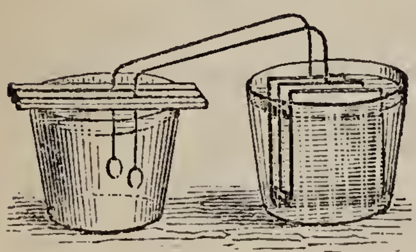

274. A convenient form of the apparatus is represented in the figure, and may be prepared from sheet zinc and copper in a few minutes. It consists of a bent strip of the former metal, with a strip of copper fastened between the two portions. The metals should be within an eighth of an inch of each other, but without contact. To secure this they are tied together with thread, bits of wood or cotton cloth being previously interposed. Copper wires being attached to the zinc and copper, as represented in the figure, the apparatus is placed in a common tumbler, and the battery is complete.

275. Before combining the battery as above described, it is best to wash the zinc with soap and water, and afterward with dilute sulphuric acid, and then to immerse it for half a minute or so in a solution of nitrate of mercury. By this process, the zinc acquires a thin film of quicksilver, which afterward protects it from the action of the acid used to excite the battery, excepting when the circuit is completed. When the battery is in

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273. What apparatus is required for electro-silvering? 274. Explain the figure. 275. How and why is the zinc coated with quicksilver.

operation, it also has the effect of making the action more equal and constant. It is then to be again washed, and newly immersed in the acid solution. This solution is prepared by dissolving quicksilver, of the bulk of two peas, in nitric acid, and pouring the clear liquid into a tumbler of water.

276. THE EXCITING ACID.—The exciting liquid is dilute sulphuric acid, consisting of one part oil of vitriol, to ten parts of water. The acid is mixed with the proper quantity of water, and set aside to cool.

277. THE SILVERING SOLUTION.—To make half a pint of the solution, a dime is placed in a test-tube and dissolved in nitric acid, the solution being diluted with water. Muriatic acid is then added, which precipitates the silver, in the form of a white curd. This is allowed to settle, and the green liquid, which contains the copper of the coin, is poured off. Water is again added, and the curd allowed to settle; this cleansing process is several times repeated. The test-tube is then half filled with water, and heated, and bits of cyanide of potassium added, until a transparent solution is obtained.

278. A solution for gilding is prepared by drying a solution of gold at a moderate heat, and dissolving it in cyanide of potassium, as above described. The process for gilding is in all respects the same as that for the deposition of silver.

279. THE PROCESS.—The battery and silvering solu-

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276. How is the exciting acid prepared? 277. How is the silvering solution prepared? 278. How is the solution for gilding prepared? 279. How is the silvering process conducted?

tion being prepared, the copper coin, or other object to be silvered, is cleansed with potash, rubbed with chalk or rotten-stone, and then attached to the wire proceeding from the zinc. A silver coin is fastened to the other wire, and immersed in the silvering solution; acid is then added to excite the battery, and the object to be silvered is lastly immersed. It should be hung face to face with the silver coin, and quite near to it, the two being kept in their places by blocks placed across the tumbler, as represented in figure 69. The coin will receive a perceptible coating within a few minutes, and will be more thickly covered, according to the time of immersion. The deposition is hastened by keeping the solution moderately warm. This is especially advantageous in the commencement of the process. The newly plated surface is without lustre, and requires burnishing after removal from the solution.

280. OBJECT OF THE SILVER COIN.—The piece of silver is attached to the positive wire, to maintain the strength of the solution. It is eaten away and dissolved as fast as silver is deposited on the objects connected with the negative wire. The reason of this is, that the cyanogen of the solution, when it goes to the positive pole, as before explained, combines with silver, forming new cyanide of silver, which dissolves and mixes with the rest. Thus, the strength of the solution is always maintained. The coin is attached to the negative wire, by flattening the latter, laying it on the

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280. What is the object of the silver coin?

back of the coin, and covering the whole with sealing wax; the coin and wire should be previously slightly warmed, and the wax used at a moderate heat, so that it shall not run between the wire and the coin, and prevent their perfect contact.

281. COPYING OF MEDALS.—If it is desired to copy the face of a medal or a coin, the same apparatus suffices. The reverse and edges of the coin are very slightly oiled, to prevent the adhesion of the copy about to be made. It is then placed in the solution. The metal deposits upon it, copying perfectly every elevation and depression. When the crust is sufficiently thick, which will be after the lapse of twelve hours, the coin, with its shell of metal, is removed, and the whole process repeated with the mold. The deposit which now forms in the shell, is an exact copy of the face of the original coin. Molds are also made by stamping the coin into soft metal, and using the impression thus produced instead of the copper shell. Copper plates, for engravings, may be copied so perfectly by the first method, as to be fully equal to the original.

282. COPYING WOOD CUTS.—A mold of the wood cut is first made by pressing it into wax; but as the wax is not a good conductor, it will not itself receive a negative character from the negative wire of the battery, and will not take positive metal from the solution. This difficulty is obviated by covering the wax mold with a fine powder of plumbago or black lead, which has good conducting power.

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281. How are medals copied? 282. How are wood cuts copied?

283. This process is very extensively practiced. Where a large number of cuts of the same kind are wanted, as for example, to print labels for dry goods, only one engraving on wood is made, and numerous copies are taken by the above process, which is much less costly.

284. Heating Effects of the Current.—If the electrodes are connected while the battery is in action, the wire becomes heated more or less strongly, according to the size of the plates. If the plates are very large, the wire melts, even though it be of platinum, the most infusible of metals. Gold may even be converted into vapor by the same means. Carbon, supposed a few years since to be entirely infusible, may be also superficially fused, and even volatilized between the electrodes. It condenses again at a little distance, in the form of microscopic crystals. Imperfect diamonds have been thus artificially produced. With such a battery as has been described the elevation of temperature would be scarcely perceptible.

285. The Electric Light.—If the current be allowed to pass between two points of prepared charcoal, an exceedingly intense light is produced, accompanied by great heat. Charcoal is employed because it is comparatively infusible, because the solid particles torn off from one of the points have the power of becoming intensely luminous at the high temperature produced by

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283. In what cases is the process practiced? 284. Describe the heating effect of the current. 285. How is the electric light produced?

reason of the low conducting power. A metallic wire, under the same circumstances, would melt, or if too large to undergo fusion, would allow the current to flow readily through it, without that detention which is essential to the production of the above effects, in their highest degree.

286. If the charcoal points be withdrawn from each other, a splendid electric flame is produced between them. This flame is not the result of combustion, for the charcoal is extremely dense, and wastes away but slowly. It is purely electric. Metals melt in it, and are dissipated in vapor. A large battery is requisite for the production of either the light or flame. In experimenting with the compound battery, a slight spark will be observed, on separating the electrodes.

287. Source of Voltaic Electricity.—Having considered the effects of the Voltaic current in previous paragraphs, the student is now better prepared to understand its origin. Our explanation relates especially to the simple form of battery already described. For other cases it is essentially the same. The origin of the current is to be found in the chemical action, induced by that electrical condition of the atoms of the metals and the acid which results from their contact. This will be the more readily comprehended if we consider first the case of a single metal and acid, and see why they will not suffice to produce a current. Suppose a curved bar of pure zinc Z to be immersed at its two

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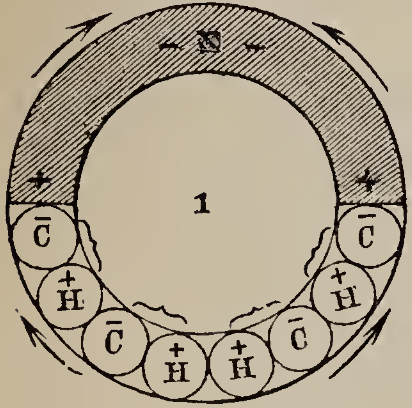
287. Why will not an acid and one metal suffice?

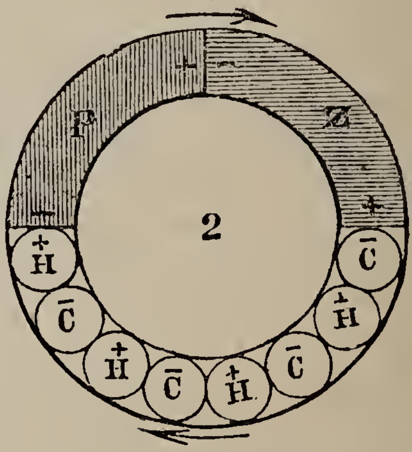
ends in hydrochloric acid. The metal becomes by mere contact positively electrified at the points which are in contact with the acid and negatively electrified in the portion which is more remote. The liquid also becomes electrically polarized, and in obedience to the polarizing influence, its molecules turn their negative or chloric atoms toward the zinc. But in this form of the experiment no communication existing between the negative part of the zinc and the positively electrified atoms of hydrogen, no change ensues beyond the production of this state of electric tension.

68



288. Let us next suppose the half of the zinc on the left to be removed and a piece of platinum P to be substituted and brought into contact with the acid, but not as yet with the remaining portion of the zinc. The platinum is at once polarized by induction from the polarized liquid; the portion in contact with the acid becomes negatively, and the more remote portion positively, electrified. But in this case, as in the former, the circuit still remaining uncompleted no change ensues beyond the state of electrical tension before described.

69



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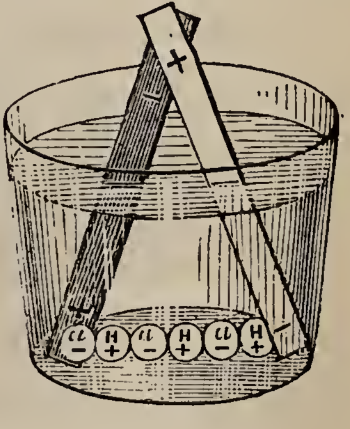
288. How do two metals and an acid act?

Let us finally suppose that the outer extremities of the zinc and platinum are brought into contact and the circuit completed. Communication being thus established the opposite electrical conditions of these portions of the metals mutually neutralize each other. A similar act of equilibrium takes place at the same instant throughout the whole circuit. The zinc, which is positive where it is in contact with the acid, combines with the negative atom of chlorine which is adjacent; the hydrogen thus liberated seizes upon the chlorine of the molecule lying next to it in the series; the hydrogen of this second molecule combines with the chlorine of the next and a similar action occurs throughout the chain. The last atom of hydrogen being incapable of combination with the platinum transfers its positive electricity to that metal and itself escapes as a gas.

With each escaping atom of hydrogen a new wave is added to the current. Fig. 70 illustrates the same subject in essentially the same manner. It is not to be supposed that any material substance is actually transmitted in the passage of the so-called current. What really occurs is a progressive alternation of the polar condition of the atoms which cannot in the present state of science be more accurately defined.

70



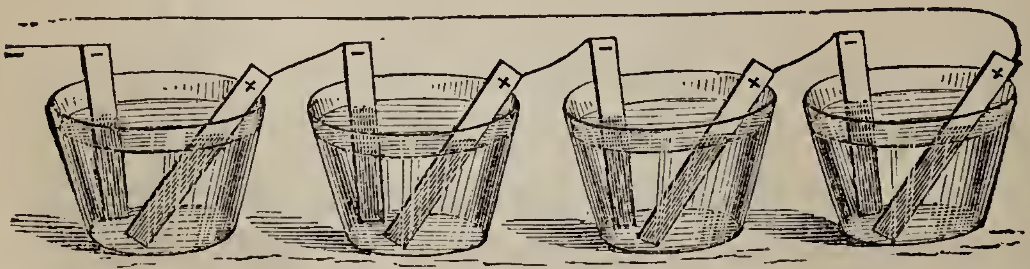
289. A Salt employed as Excitant.—It is not essen-

Is material substance transmitted in the current? 289. Explain how a battery can be excited by a salt.

tial, that an acid should be used as the exciting liquid in the Voltaic circuit. A metallic salt is sometimes employed. This may be best illustrated, by supposing chloride of copper to be employed instead of hydrochloric acid, which is chloride of hydrogen. The chlorine goes to the zinc, as in the previous case, and the copper of the salt, to the strip of copper, placed in the solution. Being a solid, it remains there, and encrusts the copper, instead of being evolved, as in the case of hydrogen.

290. THE COMPOUND VOLTAIC CIRCUIT.—For the sake of simplicity the foregoing decompositions have been described as the effect of the current generated by a single pair of plates. Several couples employed in connection are in general required, their size and number being varied according to the special object in view. The connection may be made as shown in figure 71.

71



There will in this case be no increase in the quantity of the current over that which may be obtained from a single pair of the same size. But its *intensity* or capacity of overcoming resistance, offered in a greater or less degree by all conductors and in all decompositions, is greatly enhanced. Such an arrangement constitutes

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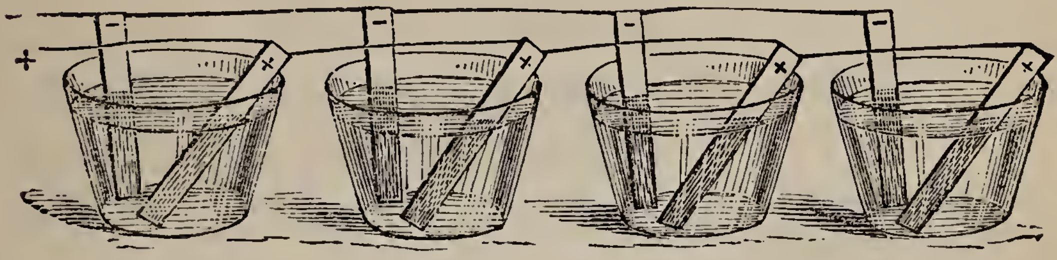
290. What is said of the compound circuit?

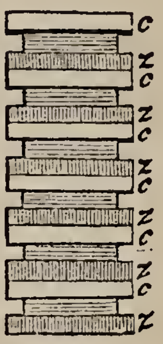
a *compound Voltaic circuit.* Or, secondly, the plates may be united as in Figure 72. This arrangement has the same effect as the enlargement of the dimensions of a single pair. The *quantity* of the current is thus increased.

72



291. The Voltaic Pile.—The first form of Voltaic battery ever produced is represented in the figure, and is called the Voltaic pile, from the name of its inventor. It consists of a succession of discs of zinc, copper and cloth, moistened with acid, alternating with each other, as represented in the figure. Each series forms a simple battery, and the whole pile is a compound battery, essentially the same as that before described. Wires to serve as electrodes are to be attached to the extreme copper and zinc.

73



292. The enlarged form of the Voltaic pile represented in the next figure will be found a most efficient apparatus for effecting decomposition. It is composed of sixteen plates of each metal, each having a surface of

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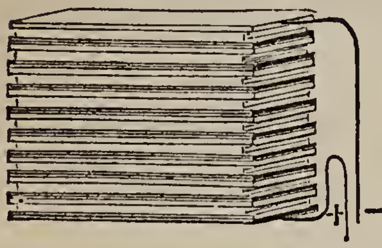
291. Describe the Voltaic pile. 292. What is said of the enlarged Voltaic pile?

twelve inches square. The zinc should be amalgamated, as before explained. Flannel, or any similar material may be employed to separate the plates. With this piece of apparatus, the spark is readily obtained, and slight shocks may be taken by bringing the two hands into contact at the same moment with the top and bottom of the pile. On terminating the electrodes with fine iron wire, and frequently uniting and separating them, scintillations of the burning metal may also be readily produced. By increasing the number of the plates still more striking effects are obtained. With a pile consisting of six or eight plates a foot square, platinum wire connecting the electrodes may be readily fused. Such a battery is also more effectual in the electro-magnetic experiments which follow.

74.



293. Different Kinds of Batteries.—There are different kinds of Voltaic batteries, but the principle in all is the same. Two of the forms in most common use are described in the Appendix. Smee's battery is especially recommended to the student, for its cheapness, simplicity, and efficiency. It is very similar, as will be seen, to the simple one which has been already described.

294. Magnetic Properties of the Current.—If

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293. What is said of the different kinds of batteries? 294. Describe the magnetic properties of the Voltaic current.

the wire connecting the zinc and copper of the Voltaic battery be wound in a spiral, as represented in the figure, the coil, or helix, as it is termed, becomes possessed of magnetic properties. Like a magnet, it attracts iron, and other magnets, and according to the same laws.

75

295. The suspended Bar.—A rod of iron brought near one of the extremities of the coil, is not only attracted, but actually lifted up into the centre of the coil, where it remains suspended without contact, or visible support, as long as the battery continues in action. Science has thus realized the fable of Mahomet's coffin, which was said to have been miraculously suspended in the air. The helix, for this and similar experiments, is wound closer than is represented in the figure, and is composed of several layers of wire. A powerful battery is also essential to success in this experiment.

76

296. Polarity of the Coil.—That such a coil has polarity, may be proved, precisely as with a magnet. One end of it attracts the north pole of a magnet, and is therefore a south pole. The other end attracts the south pole of a magnetic needle, and is therefore, itself, a north pole. But the direction in which the

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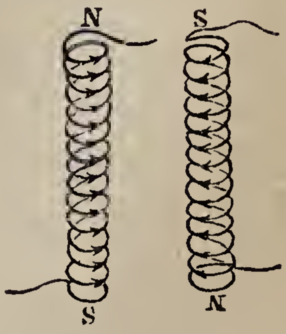

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295. How may a rod of iron be suspended in the air? 296. What is the action of a single wire on magnetic coil?

current moves around in the helix, determines which shall be north, and which south. As the current is represented to move in the first of the two coils in the figure, the upper end of the coil is north, and the lower end south. If it is made to move in the other direction, as in the second figure, the poles are reversed.

297. Consequent Motion of a Suspended Coil.—To obtain motion of the coil itself, as a consequence of its magnetism, it is necessary to suspend it; and in order to suspend it with perfect freedom of motion, it is necessary to suspend the battery with it. Such a suspended coil and battery is represented in the figure. In preparing it, the wire is wound forty or fifty times around a test-tube, (which is afterward removed,) and copper and zinc plates then attached to the ends. The plates are tied together with several layers of paper between them, then dipped in acid, and the apparatus carefully suspended by an untwisted silk fibre. The acid absorbed by the paper, suffices to maintain for some time the action of the battery. On approaching a magnet to either pole of the suspended coil, it is attracted or repelled precisely as if it were a magnet. Instead of suspending the apparatus by a thread, it may be floated on acidulated water, by means of a cork, and submitted to the same experiment. In this construction, the wires proceeding from the end of the coil, pass

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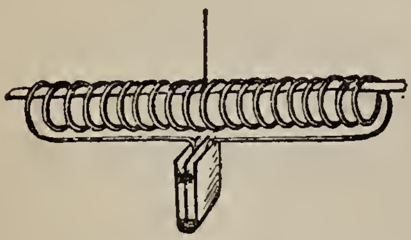

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297. How may we obtain motion of the coil itself?

through the cork, before connecting with the metallic plates. The first described method of suspension is regarded as the best.

298. The Coil a Magnetic Needle.—On floating a coil with extreme delicacy upon water, and protecting it from all currents of air and water, it assumes north and south direction, and becomes, in fact, a magnetic needle. This can only be accomplished by means of a light glass cup, blown for the especial purpose, and prolonged into a cone below, to give it steadiness in the water. This cup is filled with dilute acid, in which the plates are immersed, and is then floated in a larger vessel.

299. Mutual Action of Coils. — Two helices, or coils, such as are described in the last paragraph, floating near each other, repel or attract, precisely as if they were magnets, according as like or unlike poles are brought together. They finally attach themselves to each other in the position represented in the figure, lying parallel and with opposite poles in contact. In this position, it will be observed, that at the point of contact, the currents are moving in the same direction. The attraction of the unlike poles, may be regarded, then, as a consequence of the attraction of like currents. For it is found to be universally true, that currents moving in the same general direc-

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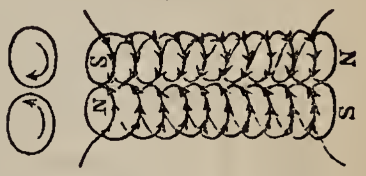

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298. How may the coil be converted into a magnetic needle? 299. Describe the mutual action of magnetic coils.

tion, attract each other, while those moving in opposite directions, repel.

300. Mutual Action of Coil and Magnet.—If a floating magnet be substituted for one of the coils, in the above experiment, the result is not in the least affected. They act towards each other precisely as if both were magnets, or both coils.

80

301. Action of a single Wire on a Coil.—A single wire, carrying a current, acts on a floating coil in the same manner. Stretched above it, as indicated in the figure, the north pole of the coil will move to the right. The motion is such as to bring adjacent currents, in the wire, and in the coil, to coincide in direction.

302. Polarity of the Coil imparted to Iron.—A bar of soft iron placed in the coil, becomes itself magnetic, and receives the name of electro-magnet. It should be wound with several layers of continuous wire, the latter being covered with cotton, to prevent any lateral passage of the current. The horse-shoe shape, in which the poles are brought around near to each other, is the more common. The power of such magnets continues only while the current is passing. Electro-magnets have been constructed capable of lifting a ton, or even more. They are sometimes employed

81

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300. What is the mutual action of a coil and magnet? 301. What is the action of single wire on a magnetic coil? 302. What effect has the magnetic coil upon metals?

in dressing iron ores, to separate, by their attraction, the workable ore from the refuse earth with which it is mixed. A steel bar introduced into the helix while the current is passing, becomes permanently magnetic. Permanent magnets are now commonly made in this manner.

303. PERMANENT MAGNETISM OF STEEL.—It appears, from the last paragraph, that a bar of soft iron is a magnet, as long as an electrical current circulates around it. But the steel, if once magnetic, remains so permanently. This is accounted for, by supposing that the current, in the wire, excites a current in the surface of the steel itself, which continues to flow, without interruption, after the wire is removed.

82

304. ACTION OF A SINGLE WIRE ON A MAGNET.—A wire, carrying a current in the direction shown in the figure, acts on a magnet, precisely as on a floating coil (301). The magnetic needle may therefore be employed to detect the passage of a Voltaic current. An instrument constructed on this plan is called a *galvanometer*.

305. ELECTRICAL THEORY OF MAGNETISM.—According to this theory, all magnetism, including that of the lode-stone, the magnetic needle, and that of the earth itself, is a consequence of the circulation of electrical currents. In the earth, such currents are known to be excited, and kept in motion, by the sun, heating

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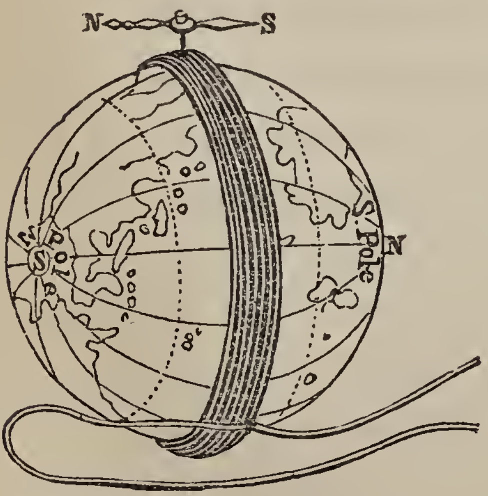
303. What effect has the magnetic coil upon steel? 304. What is the action of a single wire on a magnet? 305. Explain the electrical theory of magnetism?

in turn successive portions of its surface. They flow from east to west, making of the earth, as it were, an immense coil, or helix. In magnets they are also in constant circulation, the direction being dependent on the position in which the magnet is held. In the case of a magnet whose north pole is directed north, the direction is from west to east across the upper surface, and of course, in the contrary direction on the under side. The earth acts on a magnet, or a floating coil, as one helix acts on another. The north and south direction of the magnetic needle is a consequence of this action.

306. The Theory Illustrated.—In illustration of this theory, let a globe be coiled with a wire, carrying a current, as indicated in the figure. Let the current flow from east to west through the coil. A small magnetic needle placed at different points on the surface of the globe, however the position of the latter may be changed, will always point to its north pole. It is understood, in this experiment, that the current is strong enough to overcome the influence of the earth itself on the magnet. A freely movable coil through which a current was passing, would, in this case also, act precisely like a magnet.

83



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306. Explain the figure.

307. MAGNETIC TELEGRAPH. — The explanation of the mechanism of the magnetic telegraph belongs to Natural Philosophy. The principle of its operation may be here given. It has already been stated, that a piece of soft iron becomes a magnet, when a current of electricity circulates in a coil surrounding it. Now, suppose the two ends of such a coil, situated in a distant city, to be made long enough to reach a battery in the place where the reader resides, and to be stretched along over posts, and connected with the poles of the battery. The current occupies no perceptible time in its passage. Therefore, as soon as the battery is set in operation, it circulates through the whole extent of the wire, and, of course, through the coil in the distant city. The piece of iron which it incloses is made a magnet, and will immediately lift its armature. If the current is stopped, the piece of iron ceases to be a magnet, and drops its armature. But the operator at the battery can send or stop the current at will, by simply disconnecting one of the wires, and thereby lift or let fall the armature a hundred or a thousand miles off, as often as he pleases. He can have an understanding, also, with the person in the distant city, who sees the motion of the armature, as to what it shall mean. One lift may indicate the letter A ; two, lifts, the letter B ; and so on. Words may be similarly spelled out, and it thus becomes possible to communicate ideas by electricity. If these lifts of the armature can be made to

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307. Explain the principle of the magnetic telegraph ?

record themselves on a slip of papèr, the further advantage of writing at the distant station is gained. And this is precisely what is realized in Morse's telegraph, and more particularly described in all recent works on Natural Philosophy.

308. THE EARTH USED AS A CONDUCTOR.—It would seem requisite to extend both ends of the wire forming the coil through all the intervening distance, and then to connect them with the opposite poles of the battery; but it is found, in practice, that one is sufficient, and that all the middle portion of the second wire may be dispensed with. The remaining ends, one connected with the helix, and the other with the battery, being made to terminate in large plates, and buried in the ground, the earth between them is found to take the place of the second wire, and complete the circuit.

309. APPLICATIONS OF THE TELEGRAPH.—There are many applications of the telegraph besides the one of transmitting intelligence to distant places. In the city of Boston, an alarm of fire is instantaneously communicated throughout the city, and the bells are rung by telegraphic apparatus.

In Marseilles, France, a single clock is made by similar means to indicate the time on dials, placed in the street lamps of the city. Electro-magnetic apparatus has also been employed with the most remarkable success in increasing the dispatch and accuracy of astronomical observations; making it possible to accomplish

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308. What is said of the earth as a conductor? 309. Mention some remarkable applications of the telegraph.

during a single night in the study of the heavens, what formerly cost a month of labor.

310. Physiological Effect of Voltaic Electricity.—The nerves of animals are extremely susceptible to the influence of Voltaic electricity. The apparatus represented in the figure, which consists of strips of zinc and copper, three inches in length, separated by a cork, is sufficient to produce convulsive twitching in the legs of a frog or toad. A larger apparatus produces more decided effects. The legs are to be employed, with a portion of the back bone attached, which is grasped by the sharpened extremities of the Galvanic tweezers. As often as the circuit is completed, by bringing the other extremities into contact, by the pressure of the fingers, the legs are observed to twitch, as if they were still possessed of life. The leg of a grasshopper, held in its thickest part, may also be employed in the experiment. In both these cases, the moisture of the flesh or skin is the exciting fluid of the Voltaic couple.

84

311. Correlation of Forces.—The intimate relation that exists between Mechanical Force, Heat, Light, Electricity, Magnetism and Chemical Affinity, has already been abundantly illustrated. We have found, for example, that chemical action in the cell of a Voltaic battery produces a current of electricity, and that this may be converted, in turn, into Heat, Light, Magnetism or

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310. Describe the physiological effects of Voltaic electricity. 311. What is said of the correlation of forces?

Mechanical Force. Or, beginning at the other end of the series, we have seen how Mechanical Force may be changed into Heat, and this in turn into Electricity, Magnetism and Light. This conversion is always effected in proportions which are definite and constant.

312. CONSERVATION OF FORCE.—Further, the quantity of any force thus produced is reconvertible into the original force, without loss, excepting such as is due to imperfections of method. And even this portion, which seems to be wasted, takes the form of some other of the correlated forces. The heat which is expended in raising a weight to a given height will be reproduced when the same weight is allowed to fall to the earth. The force of affinity which effects the solution of zinc in the battery may be reproduced, with only such loss as is above indicated, by decomposing a solution of zinc and thus isolating a portion of metal and acid by means of the current which the original act of combination has excited.

Force in nature is indestructible. It may appear at one time as heat pouring upon the earth from the sun, again as electricity generated by his rays; it may commence its course as affinity residing in some atom, then take the form of a Voltaic current traveling a wire and again appear as magnetism lifting an armature, but it is never destroyed or in any degree diminished. The forces of nature like the atoms of matter are indestructible except by the Power which called them into being.

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312. What is said of the convertibility of forces? Conservation of force?

PART II.

LAWS OF COMBINATION.

CHAPTER I.

313. Number of Elements.—The number of elements, or simple substances, at present known is sixty-~~two~~ nine. Only thirty-five of these are of sufficient importance to be considered in this work. The rest are of rare occurrence, and are found in comparatively small quantity.

314. Subdivision of the Elements.—The elements may be divided into metals and metalloids, or non-metallic substances. They are thus divided in the table given on page 154. Hydrogen and oxygen belong to the class of non-metallic substances, but are placed by themselves, for reasons which will appear in the sequel.

315. Atomic Constitution.—All of the elementary substances, whether they be solids, liquids, or gases, are regarded as made up of minute atoms, as explained in Chapter I. All of the atoms of the same substance are alike in every respect.

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313. What is the number of the elements? 314. How are the elements subdivided? 315. Of what are the elementary substances made up?

316. Combination by Atoms.—When combination takes place between portions of any two elementary substances, it may be regarded as consisting in the attraction and juxtaposition of their individual molecules. Thus, when zinc tarnishes in the air, each of the atoms which form the surface of the zinc, takes to itself an atom of oxygen from the air, and the whole surface becomes covered with molecules of oxide of zinc. In the same manner, sulphuric acid is made up of compound molecules, each one of which consists of an atom of sulphur, and three of oxygen.

317. Atomic Weights.—Although the atoms of all substances are too small to be separately seen, chemists believe not only that they have evidence of their existence, but that they know their relative weight. The relative weight of the atoms of a few of the elementary substances, as compared with the hydrogen atom, which is the lightest of all, is given in the following table, as nearly as it can be given in whole numbers.

318. It is to be borne in mind that the table does not undertake to tell the absolute weight of the hydrogen atom, or of any other atom. This is not known. It only informs us that whatever may be the weight of the hydrogen atom, that of oxygen weighs eight times, that of sulphur sixteen times, and that of carbon six times as much: and so on of the other elements.

319. Chemical Symbols.—To facilitate the statement

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316. How does combination take place? 317. What is known of the weight of atoms? 318. How is the table which follows to be understood? 319. What are symbols?

and explanation of chemical charges certain abbreviations of the names of elements are employed, called symbols. The abbreviation or symbol representing any substance consists of the first letter or letters of the name by which the substance is known to men of science. This is not always the common name, thus O stands for oxygen, S for sulphur, and C for carbon, &c., while K stands for potassium, called *Kalium* by chemists, and N stands for sodium or *natrium*, and Ag for silver or *argentum*.

320. Explanation of the Symbols.—The symbols may best be regarded by the student as standing for single particles of the several substances. Thus, N, Cl, P, K, S, Ca, indicate respectively single atoms of Nitrogen, Chlorine, Phosphorus, Potassium, Sodium, and Calcium, and the numbers in the next column of the table indicate the relative weight of the atoms. In the case of compounds, the symbols also show their composition. Thus, NO_5 stands for a single molecule of Nitric acid, and, besides, indicates, as represented in the figure, that every such molecule is a compound molecule consisting of one atom of nitrogen, and five atoms of oxygen.

85

321. Again, KO stands for a single molecule of Potassa, and indicates that it is a compound consisting of one atom of potassium and one of oxygen. Such a compound of two elements is called a *binary* compound.

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320. What do the symbols stand for? Give examples. 321. What does KO indicate?

[illegible] acid

TABLE OF SOME OF THE MORE IMPORTANT ELEMENTS AND THEIR COMPOUNDS

METALLOIDS.

[illegible]

Name.	*Symbol.*	*Atomic weight.*
HYDROGEN,	H	1
OXYGEN,	O	8

METALLOIDS.

Name.	*Symbol.*	*Weight.*
Nitrogen,	N	14
Chlorine,	Cl	35
Phosphorus,	P	32
Sulphur,	S	16
Carbon	C	6

METALS.

Name.	*Symbol.*	*Weight.*
Potassium, (*Kalium.*)	K	39
Sodium, (*Natrium.*)	Na	23
Calcium,	Ca	20
Magnesium,	Mg	12
Barium,	Ba	68

METALLOIDS WITH OXYGEN FORM ACIDS.

Nitric Acid,	NO_5
Chloric Acid,	ClO_5
Phosphoric Acid,	PO_5
Sulphuric Acid,	SO_3
Carbonic Acid,	CO_2

METALS WITH OXYGEN FORM OXIDES OR BASES.

Potassa,	KO
Soda,	NaO
Baryta,	BaO
Calcia,	CaO
Magnesia,	MgO

ACIDS WITH BASES FORM SALTS.

Nitrate of Potassa,	KO,NO_5	Sulphate of Potassa,	KO,SO_3
Nitrate of Soda,	NaO,NO_5	Sulphate of Soda,	NaO,SO_3
Nitrate of Baryta,	BaO,NO_5	Sulphate of Baryta,	BaO,SO_3
Nitrate of Calcia.	CaO,NO_5	Sulphate of Calcia.	CaO,SO_3
Nitrate of Magnesia,	MgO,NO_5	Sulphate of Magnesia	MgO,SO_3

Each of the other acids forms its class of salts. There are other classes of acids, to be hereafter mentioned, which contain no oxygen.

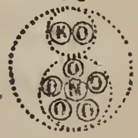
What do metalloids form with oxygen? Give some examples.

What do metals form with oxygen? Give some examples.

What do acids form with bases? Name all of the salts which may be formed from the acids and bases above mentioned.

322. In the same manner KO,NO_5 stands for a single molecule of Nitrate of Potassa, and indicates that every such molecule is a compound, made up of two other compound molecules, one of nitric acid, and another of potassa. Such a compound, of two binary compounds, is called a *ternary* compound. The symbols may, indeed, be regarded as standing for larger quantities, in the same relative proportion; but it is an assistance in understanding chemical phenomena, to regard them as has been suggested.

86



323. Atomic Weights of Compounds.—The relative weight of the atoms of simple substances is given in the table. With the help of these and the symbols, the relative weight of the molecules of compounds is easily calculated. Thus, the symbol of nitric acid, being NO_5, we know that 54 must be the weight of the molecule of nitric acid. For the symbol informs us that it is made up of a single atom of nitrogen (14) and five atoms of oxygen, (40). The weight of a molecule of potassa is 47, its symbol (KO) informing us, that it is made up of one atom of potassium, (39), and one atom of oxygen, (8).

324. Calculations of Weights from Symbols.—From the symbols of compounds, the relative weight of their components may be calculated. NO_5, being the symbol of nitric acid, we know, as above shown, that the weight of its least particle is 54, and that this

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322. What does KO, NO_5 indicate? 323. How are atomic weights of compounds determined? 324. How are absolute weights calculated from symbols?

weight is made up of nitrogen, 14, and oxygen, 40. As a larger quantity is composed of precisely such particles, the relative weight of the constituents must be the same. Fifty-four pounds of nitric acid, therefore, contain 14 pounds of nitrogen, and 40 pounds of oxygen. In the same manner, from the symbol KO, with the help of the table of atomic weights, we ascertain that 47 pounds of potassa contain 39 pounds of potassium, and 8 pounds of oxygen. CaO,SO_3, is the symbol of Sulphate of Lime or Gypsum. Adding the atomic weight of its constituents, we have 68 as the sum. Sixty-eight pounds of sulphate of lime, therefore, contain 20 pounds of calcium, 16 pounds of sulphur, and 32 pounds of oxygen.

325. Definite Proportions.—The composition of the same substance is always the same. When hydrogen and oxygen unite, in the proportion of one of the former to eight of the latter, they form water, (HO). If an excess of either element is employed, it remains uncombined. When they unite in a different proportion, as they do in another process, they form not water nor a modification of water, but an entirely new and distinct substance, viz., peroxide of hydrogen, (HO_2), whose composition is also uniformly the same. So nitrogen combines with oxygen, in each one of the proportions indicated by the symbols, NO, NO_2, NO_3, NO_4, NO_5, in each case forming a new substance.

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325. Illustrate the law of definite proportions.

326. Multiple Proportions.—As combination always takes place by whole atoms, and never by fractions, it is evident that whenever it occurs in more than one proportion, the others must be multiples of the first proportion or atomic weight. Thus the proportions, by weight, in which oxygen unites with nitrogen, are 8, 16, 24, 32, 40. In other than such exact proportions, combination never takes place.

327. Chemical Equivalents.—It has already been shown that the atomic weights express the proportions in which substances combine with each other. It also expresses, as would be naturally inferred, the proportions in which they replace each other, whenever such replacement occurs. Thus, chlorine sometimes expels and replaces oxygen in chemical compounds. Whenever this takes place, 35 parts of the former, by weight, are required to replace 8 parts of oxygen. These numbers, therefore, express chemical equivalents of the two substances, and in general, a table of atomic weights, is also a table of chemical equivalents. So, when sulphuric acid expels nitric acid from any of its salts, it replaces it in the proportion of 40, to 54. The atom of sulphuric acid is the equivalent of that of nitric acid in another sense. It has precisely an equivalent effect in neutralizing the base with which this acid may be combined.

328. The composition of a mixture, is sometimes ex-

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326. What is the law of multiple proportions? Give examples. 327. What is a chemical equivalent? Give an example. 328. How is composition expressed by equivalents?

pressed by equivalents. Gunpowder, for example, may be described as containing one equivalent of sulphur, one of nitre, and three of carbon. This signifies that it is composed of 16 parts of sulphur, 101 of nitre, and 18 of carbon, as may be ascertained, by calculation, from the table of atomic weights.

329. Names of Oxides.—It will be observed from the table, that the oxide of potassium is called potassa; the oxide of sodium, soda, and so on, each oxide having a special name, derived from the name of the metal. The oxides of most of the other metals, not mentioned in the table, have no special names, but are called oxide of iron, oxide of lead, oxide of zinc, &c.

330. Names of Salts.—Compounds formed by the union of oxides and acids are called salts. In naming the salts of the oxides the term oxide is generally omitted for the sake of brevity. Thus, we say, nitrate of iron, sulphate of iron, phosphate of iron, instead of nitrate of oxide of iron, sulphate of oxide of iron, etc.

331. Formation of Oxides.—Most of the oxides of the table are immediately formed as soon as their respective metals and oxygen come together. Thus, out of silvery potassium and transparent oxygen, white potassa is instantaneously produced. But, it is more commonly necessary to heat a metal with oxygen, to form its oxide. The oxides are also called bases. They are further considered in Part III.

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329. How are the oxides named? Give examples. 330. What are salts, and how are they named? Give examples. 331. How are oxides formed? Give an example.

332. As oxygen forms oxides with metals, so chlorine, bromine, iodine, fluorine and sulphur form, respectively, chlorides, bromides, iodides, fluorides, and sulphides. The latter are also called sulphurets.

333. Formation of Acids.—Simple contact of a metalloid, and oxygen, is not generally sufficient to produce an acid. Heat is one among the additional means employed. Thus, carbon or charcoal, heated with oxygen, or in air which contains it, is immediately converted into carbonic acid. Different acids are sometimes formed, by the combination of different proportions of oxygen, with the same substance. The names by which these are distinguished, are given, for reference, in the Appendix.

334. Formation of Salts.—Most salts may be formed by simply bringing the proper acid and oxide together. Thus, as soon as liquid sulphuric acid and white magnesia come together, they unite and form sulphate of magnesia or Epsom salt. But the stimulus of heat is often required, particularly when the acid, as well as the oxide, is a solid substance. The affinity between acids and bases, is in accordance with the general law, that chemical attraction between substances is strongest in proportion as they are most unlike, or opposed to each other, in their properties.

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332. What compounds do chlorine, iodine, sulphur, etc., form? 333. How are acids formed? Give an example. 334. How are salts formed? Give an example.

335. PROPERTIES OF ACIDS AND BASES.—The properties of these two classes of compounds are opposite, and when brought together, they neutralize each other. Thus, when acid and soda are brought together, the acid taste of the former and the alkaline taste of the latter both disappear. Acids change certain vegetable blues to red. Bases restore the color. The experiment may be made with an infusion of litmus* in water. A leaf of purple cabbage answers the same purpose. Acids color it red, while potash and the alkalies change the red to green.

336. EFFECT OF HEAT TO PRODUCE COMBINATION.—It is seen from the foregoing, that heat is often essential to chemical combination. This is almost always the case where both substances are solid. Beside heightening their chemical affinity, heat has the effect of destroying the cohesion, and of bringing the particles into closer and more general contact, and, within the range of affinity, by the melting or fusion which it accomplishes. Sulphur and iron, for example, require the aid of heat to bring about their union. The sulphur melts, and then combines with the iron.

337. Further heating, has often just the contrary

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335. What are the properties of acids and bases? 336. What is the effect of heat on chemical combination? 337. Mention another effect of heat.

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* Litmus is a blue vegetable pigment much used by chemists for the purpose mentioned in the text.

effect. It causes substances already combined, to separate from each other again. This is especially the case when one of them is a gas. Thus, if oxide of silver or gold is heated, the oxygen passes off in the gaseous form and leaves the metal behind.

338. Heat owes its decomposing effect, in this and similar cases, to the tendency which it imparts to certain substances, to assume the gaseous form. And as all bodies would, probably, be gaseous, at a sufficiently high temperature, sufficient heat would probably decompose all chemical compounds.

339. Effect of Solution.—The solution of one or both of two substances to be combined, has, in a multitude of cases, the same effect, in promoting chemical combination, as that produced by heat. The reason is also the same. It destroys the cohesion of the particles, makes them movable, and brings them into more general and thorough contact. This is illustrated in the case of ordinary soda powders, the two constituents of which will not act on each other, unless one, at least, is dissolved.

340. Electrical Relations of Elements.—The metals are sometimes spoken of as electro-positive and the metalloids as electro-negative, for reasons given in the chapter on Electricity. Electricity also resolves salts into the bases and acids which compose them. The acid goes to the positive pole, and is, therefore, electro-

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338. Why does heat have this effect? 339. What is the effect of solution? 340. What are the electrical relations of the elements?

[illegible]
[illegible] acid, [illegible]
[illegible]

negative. The base goes to the negative pole, and is therefore, electro-positive.*

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* The laws of combination, and other subjects which belong to chemical philosophy, are further considered in the chapter on Salts, in the introduction to Organic Chemistry, and in the Appendix. Additional remarks on the atomic theory adopted in the text are also given in the Appendix.

Chemistry is probably from
chimia found in alchemy,
Chemical Physics relating to
Light Heat and Electricity
The science of Chemistry treats
of the composition of substances
& the relations of their elements
to each other and the laws
~~in~~ which they are mutually
affected.
[illegible] elements
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PART III.

INORGANIC CHEMISTRY.

CHAPTER I.

NON-METALLIC ELEMENTS.

341. CLASSIFICATION OF ELEMENTARY BODIES.—The simple division of elementary bodies is into *metals* and *non-metallic* elements. The non-metallic elements are:—

1. Oxygen,
2. Chlorine,
3. Iodine,
4. Bromine,
5. Fluorine,
6. Sulphur,
7. Nitrogen,
8. Phosphorus,
9. Arsenic,*
10. Carbon,
11. Silicon,
12. Boron,
13. Hydrogen.

Oxygen.

Symbol O; *Equivalent*, 8; *Specific-Gravity*, 1.1.

342. DESCRIPTION.—Oxygen is a transparent and colorless gas, a little heavier than the atmosphere. It is

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341. How are elementary bodies divided? 342. What is oxygen? Where does it exist?

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[*] Arsenic is commonly regarded as a metal, but for reasons that will be given hereafter it is placed among the non-metallic elements.

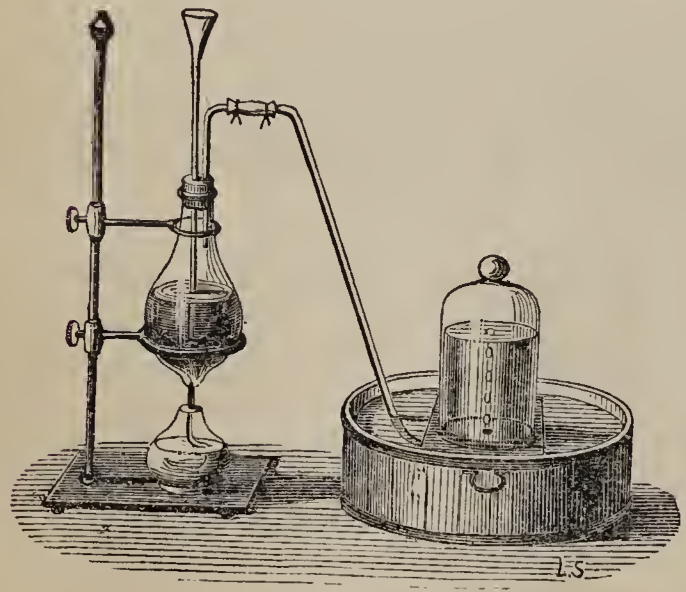
metalloids are [illegible] non-metallic [illegible]
metallic [illegible]

[illegible]

by far the most abundant substance in nature. About one-fourth the weight of the air, eight-ninths of the waters of the globe, and probably half of the solid earth is oxygen. Oxygen is essential to the support of all forms of animal and vegetable life, and of ordinary combustion.

343. Preparation of Oxygen.—Oxygen gas is expelled from many substances which contain it by the simple agency of heat. Chlorate of potassa and black oxide of manganese are such substances.

87



Mix equal quantities of chlorate of potassa and black oxide of manganese and put one or two ounces of the mixture into a flask of green glass, (the flasks in which sweet oil is imported from Florence are well suited to this purpose,) adapt a cork to the mouth of the flask and insert through the cork a tube of sufficient length to reach the pneumatic cistern* when the flask is placed over a lamp as shown in figure 87. A jar is to be filled with water and inverted in the cistern to receive

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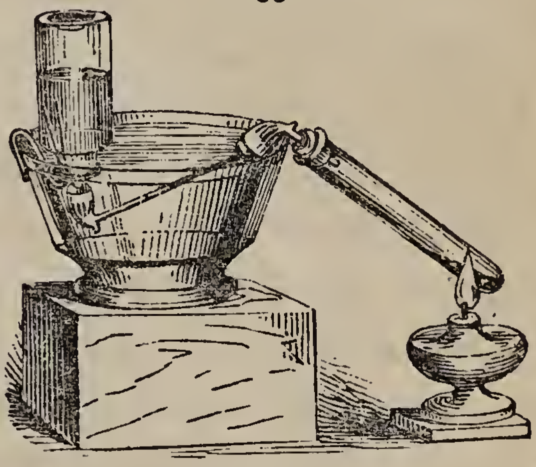
343. How is oxygen prepared? Give the complete process.

* A tub with a shelf across the center near the top forms a good pneumatic cistern.

the gas. After lighting the lamp the first portion of gas which comes over being mixed with the air previously contained in the flask is to be allowed to escape, afterwards an abundance of gas may be collected in the manner shown in the figure. Each ounce of the mixed powder in the flask will give off about a gallon of oxygen gas. All other gases that are not absorbed by water may be collected in the same manner.

88



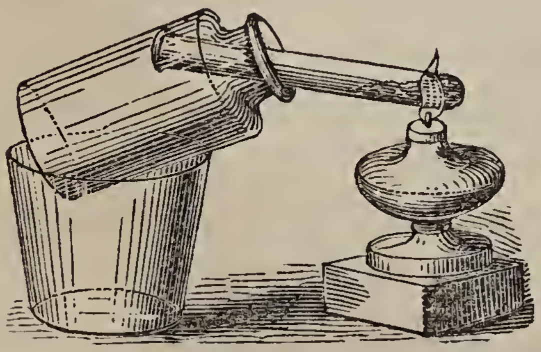
Where a small quantity of oxygen only is required it may be collected by the simple apparatus shown in figure 88. Half a teaspoonful of the dry mixed powder of chlorate of potassa and black oxide of manganese may be heated in a test tube connected air-tight with two clay pipes, as represented in the figure. The connections are made by winding the pipe-stems with strips of wet paper, folded in such a manner that the stopper thus formed tapers slightly toward the end. The first portions of gas, which contain an admixture of the air of the tube, are allowed to bubble through the water and escape. The rest is made to rise into a half-pint vial, which it gradually fills, by displacing the water. The vial has been previously filled with water, then covered with a bit of glass, and inverted in the water. If it is desired to hang it on the side of the bowl, a hook is then introduced, made of strong, doubled wire,

89

the two parts being kept about half an inch apart, and the vial is then hung, by its help, on the side of the bowl; or this may be dispensed with, and the vial held by the hand in its proper place, while the gas is collected. When the process is completed, vial and hook, if the latter has been used, are to be lowered into the bowl, the mouth being carefully kept below the surface; the hook is then removed, the mouth covered with a bit of glass, and the vial then inverted upon a plate containing a little water, and so kept until it is wanted for an experiment.

344. Explanation.—Black oxide of manganese may be employed alone as a source of oxygen but it does not yield this gas at the temperature employed in the above experiment. At a red heat part of the double portion of oxygen which the black oxide contains is expelled in a gaseous form. The mixture of this oxide facilitates the evolution of oxygen from the chlorate but the reasons are not well understood, for any other infusible powder answers the same purpose.

90



345. A Simpler Method.—The above methods of preparing oxygen are here given, because they illustrate the mode of collecting gases in large quantities, and make its accumulation visible to the

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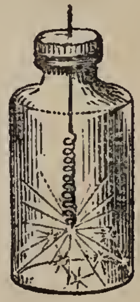
344. Explain the process of making oxygen. 345. Give a simpler method of preparing oxygen.

eye. The oxygen needed for the following experiments may be more conveniently prepared by placing the mouth of the test tube, containing the proper materials, in a wide-mouthed vial, and heating, as before. As the gas is evolved, it will expel the air, and soon fill the vial.

346. Iron Burned in Oxygen.—Make a coil of very fine iron wire, by winding the latter around a pencil; fasten one end into the middle of a cork, by slitting the latter, and attach a fine splinter to the other end. Light the splinter, and introduce it into a vial of oxygen. The wire itself will take fire, and burn with brilliant scintillations. In this and the following experiments, the cork is to be placed loosely over the mouth of the vial, to prevent its violent expulsion by the heated gas.

91



347. Explanation.—In this experiment the oxygen in the vial unites with the iron of the wire, and becomes solid, in the form of oxide of iron. The oxide fuses into a small globule on the end of the wire, and occasionally falls, and melts its way into the glass. This is apt to be the case, even when water is left in the bottom, so that a vial is likely to be destroyed by this experiment. The process is exactly the reverse of that which takes place when binoxide of manganese is heated, to produce oxygen. In the one case, oxygen

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346. How can iron be burned in oxygen? 347. What takes place in the above experiment?

was driven from the metal; in the other, it is drawn to it, though not in the same proportion.

348. TAPER REKINDLED IN OXYGEN.—Introduce a newly extinguished taper or shaving, with a little fire at the end, into a vial of oxygen. It will be immediately rekindled. This experiment may be many times repeated without a new supply of gas.

349. Combustion is more vivid in pure oxygen, than in air, because the latter is diluted with other gases which do not take part in the combustion.

350. COMBUSTION OF PHOSPHORUS.—Place a piece of phosphorus, of the size of a pea, on a piece of chalk, slightly hollowed out for the purpose and connected with a cork by a fine wire. Ignite the phosphorus and introduce it immediately into a bottle of oxygen. It will burn with the utmost brilliancy, producing a light which the eye can scarcely bear.

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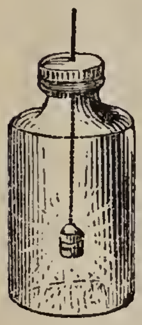

351. The white fumes which fill the bottle in this experiment, are composed of particles of phosphoric acid, which are produced by the union of the phosphorus and oxygen. They collect on the sides of the vial, and soon dissolve in water, which they absorb from the air. The water will be found to possess a sour taste, and to redden blue litmus paper, which is a characteristic of acids.

352. COMBUSTION OF CHARCOAL. — Attach a small

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348. Describe the taper experiment. 349. Explain the last experiment. 350. Describe the experiment with phosphorus. 351. What acid results from this experiment? 352. Describe the experiment with charcoal.

piece of charcoal to a fine wire, ignite one end of it thoroughly, and introduce it into a vial of oxygen, having a cork at the other end, as before. It burns with brilliant sparks. A piece of charcoal bark is best adapted to this purpose.

93

353. Carbonic acid is formed in the above experiment, from the union of carbon with oxygen. It is a gaseous acid, and cannot be seen. Neither can it be detected by its taste. But a piece of moistened litmus paper, held for some time in the bottle, will be reddened by it, and proof of the presence of an acid may be thus obtained. When wood burns it also yields carbonic acid.

354. Definition of Combustion.—All of the above experiments are cases of combustion, and combustion may be defined as combination of any two substances, attended by light and heat. Metals which will not burn in the air, because it is diluted oxygen, burn brilliantly, as has been seen, in pure oxygen.

355. Previous Heat required.—In order that most substances may burn, they must first be heated, to increase their affinity for oxygen. Take carbon, as an example. Before heating, its affinity for oxygen is not sufficient to bring about the requisite combustion. In this condition it may, therefore, lie for any length of time, in the air, or oxygen gas, without uniting with it. But heat stimulates the tendency to combination, and

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353. What is produced in this experiment? 354. Define combustion. 355. Why is heat required to start combustion?

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the bit of charcoal previously ignited, goes on burning until it is consumed. The first particles obtain the necessary stimulus of heat, from the previous ignition, the next from the burning of the first, and so on.

356. Uncombined Oxygen requisite.—Mere presence of oxygen is not sufficient for combustion. It must be free, or uncombined oxygen. After burning charcoal in oxygen gas, the vial contains just as much oxygen as before, but being already combined, it has no affinity, or appetite, for more carbon, and therefore will not produce a new combustion.

357. Each Particle in turn must be heated.—If the first particles that combine, do not communicate sufficient heat to the next, then the combustion stops. This may be illustrated by lighting a tightly wound roll of paper, and holding the flame upward. It is soon extinguished, because the heat that is produced by the combustion of one portion of the paper, is not communicated to the next, but passes off into the air. But if the taper be held with the flame downward, each particle in turn receives the stimulus of heat necessary to combination, and the whole is consumed.

358. Decay of Leaves and Wood.—The decay of leaves and wood is a sort of slow combustion, but not sufficiently vigorous to produce light and sensible heat. In this case, as in the ordinary combustion of wood or coal, the

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356. What kind of oxygen is required for combustion? 357. If each particle is not heated, what takes place? Why? 358. What causes the decay of wood?

particles which have combined with oxygen pass off into the air, in an invisible form.

359. Bleaching.—Bleaching may also be regarded as a kind of slow combustion. On exposing cloth to sun and air, its coloring matter is gradually burned up by the atmospheric oxygen.

360. Oxygen a Purveyor for Plants.—It has been seen that both in combustion and decay, the oxygen of the air combines with the particles of leaves, wood and coal, and passes off with them in an invisible form. It flies off with them into the air, and yields them again to living plants, to produce new leaves, flowers and fruits. Indeed, they are entirely dependent, for their support, on what they thus obtain from the death and decay of their predecessors, through the agency of this ever active purveyor, the oxygen of the air. But for the fact that the particles of vegetable and animal matter can thus be used again and again, the supply would soon be exhausted, and vegetation cease upon the face of the earth.

361. Relations to Life.—Oxygen is as essential to life, as it is to combustion. The diluted oxygen of the air, is better adapted to breathing, than pure ~~air~~, but ~~that~~ air which contains much less than its due proportion is no longer fitted to support life. Respiration consumes oxygen, so that the air of a close room is constantly being deprived of this essential constituent without obtaining any new supply. As a consequence, it soon

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359. How may bleaching be regarded? 360. Explain how oxygen is a purveyor for plants. 361. What relation to life does oxygen sustain?

becomes unfit to breathe. The case is similar to that of a taper burned in a bottle. The oxygen of the air in the bottle is gradually consumed, and the flame grows gradually more and more dim until it goes out. So life grows fainter and fainter, in a close unventilated room.

Fish obtain oxygen from the air, rich in oxygen, which is dissolved in the water. See Section 539.

362. Oxygen has been used, with great success, as a means of resuscitation, in cases of suffocation and drowning, when similar use of air was without effect. In such cases, it is forced into the lungs through a tube, from a jar or bladder.

363. OZONE.—By passing an electrical current, continually, through oxygen gas, for some time, it becomes mysteriously changed in its properties. In this changed condition it is called *ozone.* It is, as it were, intensified in its affinities by the current, so that like chlorine, it will attack silver, and exhibit many other of the properties of the latter gas. The electricity of the air has similar effects on the oxygen which it contains, and, in consequence of its varying electrical condition, the proportion of ozone is, also, from time to time, extremely varied. There is reason to believe that this substance has an important influence upon health, and that either its deficiency or excess is injurious. In cholera seasons, it has been observed to be present in comparatively small quantity, while, during

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362. What is said of oxygen as a means of resuscitation? 363. How is ozone produced?

the prevalence of a species of influenza called "grippe," it is said to be more abundant. These observations need confirmation, by further experiments, before the facts can be regarded as fully established. The presence of ozone, is indicated by the discoloration, through the influence of a current of air, of a test paper, prepared by moistening ordinary biblous paper with a solution of starch and iodide of potassium. This test paper becomes blue by the action of even a minute quantity of ozone.

Chlorine.

Symbol, Cl; *Equivalent*, 35.5; *Specific Gravity*, 2.47.

364. Description.—Chlorine is a yellowish green gas, of peculiar odor, about 2½ times as heavy as the air. More than one-half of common salt is chlorine. Salt mines and the ocean, therefore, contain it in immense quantities.

365. Preparation of Chlorine.—Chlorine is prepared from muriatic acid, which is composed of chlorine and hydrogen, by using some agent to retain the latter and liberate the former. Black oxide of manganese is such a substance.

The oxide of manganese is placed in a flask and covered with muriatic acid poured in through the funnel and safety-tube, F, figure 94, and a gentle heat is

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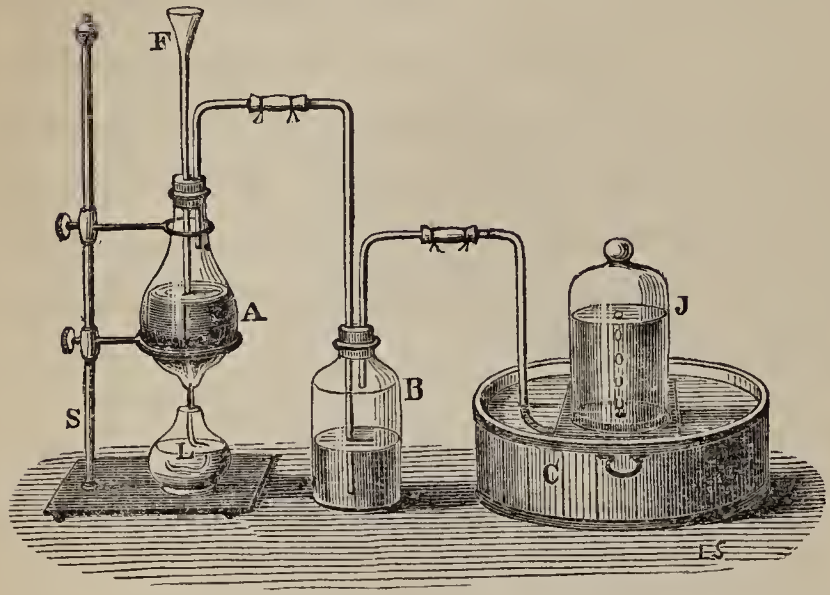
364. What is chlorine? Where is it found? 365. How is chlorine prepared? Describe the process.

applied by the lamp, L. As the gas comes off it is passed through a bottle, B, containing a little water to absorb any muriatic acid that passes over in vapor, and the gas is collected over the pneumatic cistern, C, in a jar, J, filled with hot water, to prevent absorption of the gas, which is largely absorbed by cold water. A strong solution of common salt, may be used instead of hot water in collecting chlorine, as it does not absorb this gas even at the common temperature.

94



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366. Collection by Displacement.—As chlorine is heavier than air it may be collected by displacement by the simple apparatus shown in figure 95. The oxide of manganese placed in a phial is well covered with muriatic acid and kept warm by a cup of hot water, as represented in the figure. Chlorine gas soon displaces the air in the second vial. It should be corked as soon as filled.

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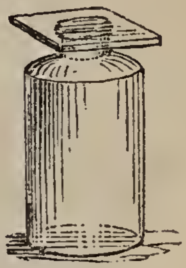
366. Give the process of collecting chlorine by displacement.

367. It will be remembered that black oxide of manganese, is a substance containing a large portion of oxygen, part of which is feebly held, and very willing to go. Its use in making chlorine depends on this fact. The loosely held oxygen, seizes upon the hydrogen of the muriatic acid, remaining with it as water, and at the same time setting its chlorine at liberty.

368. A Simpler Method.—Acids expel chlorine from many bases which have previously been made to absorb it. Lime is one of these bases. Pour into a wide-mouthed, half-pint vial, a table-spoonful of dilute sulphuric acid, and add rather more than the same bulk of chloride of lime or bleaching powder. It is best to add it in small portions, covering the vial with a cork or bit of glass after each addition. The vial will soon be filled with faintly green chlorine gas. More of the materials will be required, if the chloride of lime is deteriorated by exposure to the air, as is often the case. The gas thus produced, may be used for most of the experiments which follow, without transferring it to another vessel.

96



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369. Chlorine Heavier than Air.—This is already imperfectly proved, in the first method of collecting chlorine, but the following proof is more satisfactory. The gas produced in the last experiment, may be slowly

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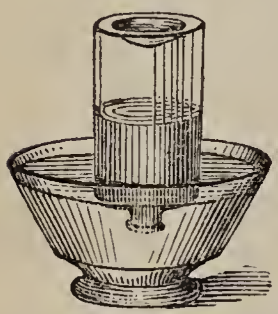
367. Explain the process. 368. Describe another method of preparing chlorine. 369. What proof that chlorine is heavier than air.

poured from the vessel containing it, into another wide-mouthed vial. The second vial, if the smaller of the two, may be thus filled without receiving any acid from the first. This experiment should be conducted in the open air or under a large flue as even a small quantity of chlorine produces considerable inconvenience and irritation to the lungs of the operator. In small quantities the gas cannot be seen to flow, but will actually pass from one vessel into the other. Its presence may be proved by the methods given in the following experiments.

Chor 2nd

98



370. Chlorine dissolves in Water.—Having filled a vial with chlorine, by the first of the methods above described, cork it, and open it under water, contained in a bowl. As the gas dissolves in the water, the latter will rise to take its place. When it has risen a little way, cork and shake the vial, and open it again below the surface. The water will then rise and dissolve still more of this gas. The solution is to be set aside for a subsequent experiment. Gas produced by the last method above described, may also be used in this experiment, if previously transferred to another vial.

371. Action of Chlorine on Metals.—Chlorine gas combines with many metals, converting them into chlorides. Their action may be illustrated by sprink-

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370. What proof that chlorine dissolves in water? 371. Describe the action of chlorine on metals.

ling finely pulverized antimony into a bottle of chlorine. Each particle of metal ignites as it falls through the gas, and a miniature shower of fire is thus produced. The white smoke which is produced in this experiment, is composed of minute particles of chloride of antimony. Potassium, tin and arsenic also take fire spontaneously in this gas, and iron and copper in fine powder when moderately heated take fire in the same manner. Vapor of mercury admitted into a jar containing chlorine takes fire and burns with a brilliant flame.

372. NASCENT CHLORINE.—Nascent chlorine, in its action on the metals, is the most powerful agent known. Even the noble metals yield to its power, and waste away in the liquid which contains it. The term *nascent* signifies being born, or in the act of formation, or escape from a previous combination.

373. All gases are most energetic, in their action at the first moment of their separation from compounds which contain them, and while they may be regarded as still retaining the solid form themselves. The subsequent expansion into the gaseous form, diminishes their energy.

374. Nascent chlorine is best obtained by mixing hydrochloric acid with half its bulk of strong nitric acid. Such a mixture is called *aqua regia.* The latter acid compels the former to yield a constant supply

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372. What is the action of nascent chlorine? 373. What is the general fact in relation to nascent bodies? 374. How is nascent chlorine best obtained?

of its own chlorine in the nascent condition. It does this, by means of its oxygen, which seizes upon the hydrogen of the hydrochloric acid, forming water, and setting its chlorine at liberty. The remnant of the nitric acid escapes, as in the case of its action on metals hereafter described.

375. CHLORINE DECOMPOSES WATER.—If chlorine water be exposed to the sun for some days, it loses its green color. The chlorine combines with the hydrogen of the water, forming hydrochloric acid, and sets its oxygen at liberty. If the experiment be made in a bottle, inverted in water, so that the oxygen may collect, bubbles of this gas will be found above the liquid. This experiment proves the powerful affinity of chlorine for hydrogen.

99

376. BLEACHING BY CHLORINE.—Introduce bits of printed muslin into the solution of chlorine before obtained. Most colors will soon disappear. If the solution is weak, the bleaching effect will be better shown with infusion of litmus or red cabbage. Color may also be removed from cloth or paper by hanging the article to be bleached, previously moistened with water, in a vial of gaseous chlorine.

377. Chlorine water may be prepared in larger quantity by leading the gas directly into water. The second of the two methods before described, will be found the most advantageous.

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375. Does chlorine decompose water? 376. How is calico bleached by chlorine? 377. How is chlorine water best prepared?

378. OXYGEN THE REAL BLEACHING AGENT.—The real bleaching agent in this method of bleaching, is the same as that mentioned in paragraph 359. It is oxygen, always present during the process, as an element of the water which moistens the material. The chlorine simply acts to bring nascent oxygen into activity. It does this by depriving it of the hydrogen with which it is combined. The oxygen having thus lost its companion, looks about, as it were for something else with which to combine. The coloring matter of the cloth being the first thing at hand, is destroyed by the extreme energy of its affinity.

379. ACTION OF NASCENT OXYGEN.—The superior force of an element in its nascent condition is strikingly shown in the above experiment. A piece of printed muslin hung in a bottle of oxygen gas would not lose its color. But the nascent oxygen which chlorine liberates, begins to destroy the coloring matter on the first instant of its liberation.

100

380. CHLORINE AND TURPENTINE. — Immerse a rag wet with camphene or spirits of turpentine in a vial of chlorine gas. It is immediately inflamed, with the production of dense black smoke. Spirits of turpentine is composed of hydrogen and carbon. The hydrogen combines so energetically with chlorine, as to produce flame in the above

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378. Explain how chlorine bleaches. 379. Show the advantage of nascent oxygen. 380. Describe the inflaming of turpentine by chlorine.

experiment, while the carbon is separated in the form of black particles, which constitute the smoke.

381. USE AS A DISINFECTANT.—As chlorine destroys color, when used as a bleaching agent, so it destroys noxious vapors in the air. Its minute atoms fly forth like birds of prey, seizing on the impurities of the atmosphere and devouring them. Chloride of lime is commonly substituted for chlorine for this use. A little of this salt is placed in a saucer and moistened, when it gradually yields chlorine through the action of the carbonic acid of the air. Stronger acids evolve it abundantly.

382. CHLORINE A DESTRUCTIVE AGENT.—Chlorine, as has been seen, is one of the most destructive of all substances. It not only destroys colors and odors, but any kind of vegetable or animal matter long submitted to its action, wastes away and is destroyed. It does this partly by its own direct action, and partly by letting loose the atoms of nascent oxygen, as before described.

383. IN WHAT SENSE DESTRUCTIVE.—It is always to be borne in mind that the term destruction is used in chemistry in an entirely figurative sense. Thus, neither oxygen nor chlorine, strictly speaking, destroy. They only combine with the particles of the substances they seem to destroy, forming new, and often invisible compounds. Many of these will be hereafter mentioned.

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381. Is chlorine a disinfectant? Why? 382. What is said of chlorine as a destructive agent? 383. In what sense is it destructive?

384. Relations to Animal Life.—Chlorine is a poisonous gas. No danger, however, is to be apprehended from the escape of small portions into the air during the preceding experiments. The diluted gas, however, is apt to produce irritation of the throat and consequent coughing.

385. Resemblance to Oxygen.—In many respects chlorine is similar to oxygen, as has already been shown. It combines with almost all of the elements, and with many compounds. This combination is often attended with light and heat, and is therefore combustion. The metal antimony, for example, as has already been shown, will burn in chlorine gas even without previous heating.

386. Compounds of Chlorine and Oxygen.—Chlorine combines with five atoms of oxygen to form chloric acid. This acid is of importance, principally, as a constituent of the chlorate of potassa, analogous in its leading properties to nitrate of potassa. Hypochlorous acid, a constituent of bleaching powders, is another compound of chlorine with oxygen. It is again mentioned in the section on chlorides.

Iodine.

Symbol, I; *Equivalent*, 126; *Specific Gravity of Vapor*, 8.7.

387. Description.—Iodine is commonly seen in the

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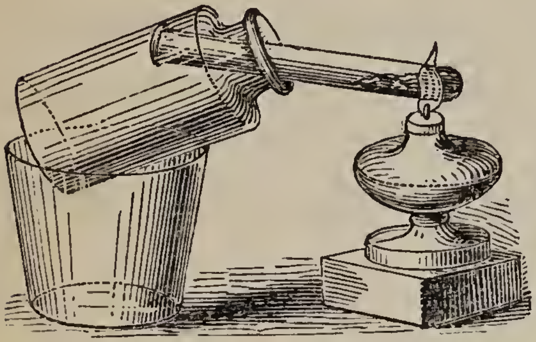
384. Give the relations of chlorine to animal life. 385. In what respects does chlorine resemble oxygen? 386. Mention some compounds of chlorine and oxygen. 387. What is iodine? Where is it found?

form of brilliant blue-black scales, somewhat similar to plumbago in appearance. In odor it resembles chlorine. It is found in the water of the ocean, in sea-weeds, sponges, &c., but always in combination with sodium or some other metal. Minute traces of it are found to exist in the atmosphere, and thence are transferred to the bodies of animals.

101



388. Preparation.—For the preparation of iodine, a lye made from the ashes of certain sea-weeds is heated with oil of vitriol and black oxide of manganese. The liberated oxygen of the latter expels vapors of iodine from the mixture. These being led into a receiver, crystallize in brilliant scales. A retort and receiver are commonly used in the process. The ashes of sea-weeds employed for the purpose are called *kelp*, and are prepared in great quantities on the coast of Scotland.

102

389. Violet Vapors of Iodine.—Introduce a few scales of iodine into a test-tube or vial. and heat it for a moment over the spirit lamp, The solid iodine is immediately converted into a beautiful violet vapor, which fills the vial. As the latter cools, the iodine becomes again solid, in the form of minute crystals. On warming these crystals the color re-appears.

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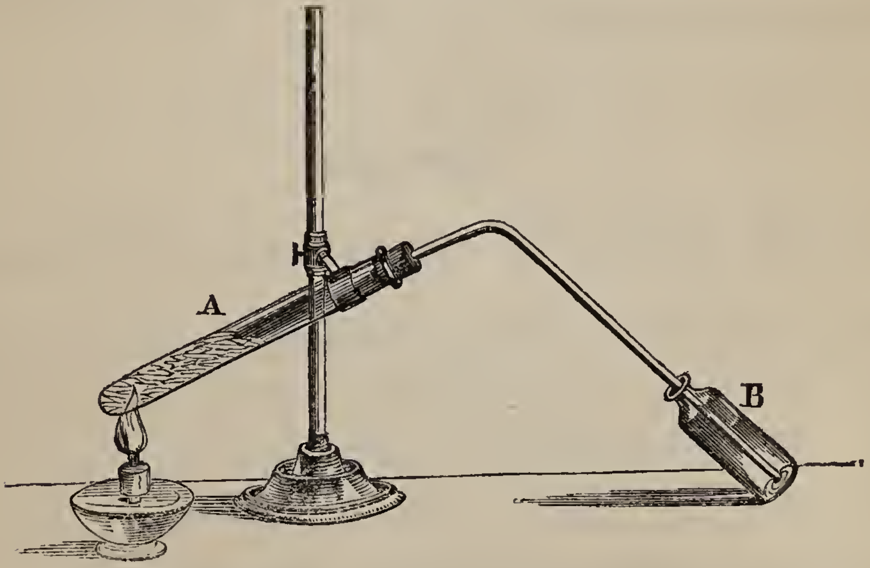
388. Explain the manufacture of iodine. 389. How are violent vapors of iodine produced ?

390. Coloring Effect on Starch.—Heat a little iodine in a pipe bowl, and as soon as vapors appear, blow them against a sheet of paper covered with figures made with thin starch paste. The iodine vapor immediately colors them blue. The paste may be made in a test-tube, over a spirit lamp.

103

391. Application of the Test for Iodine.—Burn a common sponge and having carefully collected the ashes place them in a test-tube, A, with an equal bulk of black oxide of manganese and add a little oil of vitroil; close the mouth of the tube with a cork through which is passed a tube leading into a phial, B, containing a solution of starch as shown in figure 104. On applying a gentle heat the vapor of iodine will pass over and produce a beautiful blue color by union with the starch.

104



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390. Describe the effect produced by iodine on starch paste. 391. Give an instance of the application of this test.

392. Engravings Copied by Iodine. — A transient copy of an engraving, or other printed matter, may be made, by exposing it to faint fumes of iodine, and then pressing it down upon paper moistened with vinegar, or dilute nitric acid. The vapors, adhere to the ink only, and are transferred by pressure; producing, with the starch contained in ordinary letter paper, a blue impression.

393. Poisoning by Iodine.—Iodine is much used as a medicine, but it is sometimes swallowed by accident in too great quantity, and it then acts as a corrosive poison. The antidote for iodine is starch which forms with it a harmless compound.

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Bromine.

Symbol, Br; *Equivalent*, 78; *Sp. Gr.* of Vapor, 5.34; *Sp. Gr.* of Liquid, 3.2.

394. Bromine is a dense reddish-brown fluid, exhaling at ordinary temperatures a deep orange-colored vapor. It is similar, in its chemical properties, to chlorine, but the latter is the stronger of the two and expels bromine from its compounds. Thus, if chlorine be passed into one end of a heated tube containing bromide of silver, the vapors of bromine will be seen to pass out at the other end, and escape, while the chlorine remains, and takes possession of the metal. Bromine, like chlorine, is found in sea-water and in the

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392. How are engravings copied by iodine? 393. What is the proper antidote for poisoning by iodine? 394. What is said of bromine?

water of mineral springs, combined with sodium or some other metal. Bromine has also been found in an ore of silver from Mexico, in which bromide of silver is found mixed with chloride of silver. The power of chlorine to expel it from its compounds is made use of in manufacturing bromine. This substance is used in photography, but is otherwise of little general interest. Although widely distributed, it exists in nature in comparatively small quantities. Bromine vapors have the effect of imparting to starch a beautiful orange color. Bromine is freely dissolved by both alcohol and ether, and like iodine it acts as a corrosive poison, for which starch is the best domestic antidote.

Fluorine.

Symbol, F; *Equivalent,* 19; *Specific Gravity,* 1.3. (?)

395. Fluorine is a yellow-brown gas, of strong odor, somewhat similar to that of chlorine. It is one of the elements of the beautiful mineral *fluor spar.* It is prepared from the fluoride of potassium, by means of the galvanic current. Its isolation has been attended with great difficulties, and the gas is therefore imperfectly known. Its principal compounds are hydrofluoric acid and fluor spar, to be hereafter described.*

395. What is said of fluorine?

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* Many compounds of chlorine, bromine, iodine and fluorine, with each other and with oxygen, are known to the chemist, but they are without interest to the general student.

Sulphur.

Symbol, S; *Equivalent*, 16; *Specific gravity*, 2.05.

396. Description.—Sulphur is a brittle yellow solid, twice as heavy as water, burning with a peculiar odor made familiar in the ignition of common friction matches. With the metals it forms sulphides or sulphurets. In Sicily and certain other volcanic regions, it occurs in beautiful, yellow crystals. Gypsum, and iron pyrites or fools' gold, represent the two principal classes of minerals that contain it. It also enters in small proportion into the composition of all animal and vegetable substance. It is the sulphur in eggs that blackens the silver spoon with which they are eaten. Sulphur is insoluble in water and consequently tasteless.

397. Preparation.—In preparing commercial sulphur, the impure material of volcanic regions is highly heated, and thus made to fly off as vapor, leaving its earthy impurities behind. The vapors are condensed as flowers of sulphur. The process by which a solid is thus vaporized, and re-converted into a solid, is called *sublimation*. Native sulphur may also be partially purified by simple fusion. Its earthy impurities having settled, it is poured off into molds and thus converted into roll brimstone.

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396. What is sulphur? Where does it occur? 397. Describe the manufacture of sulphur?

105

398. Sublimation of Sulphur.—The sublimation of sulphur may be shown by heating a small bit of the substance in a test-tube. Flowers of sulphur will deposit in the upper portion of the tube.

399. Combustion of Sulphur.—Melt some flowers of sulphur upon the end of a wire wound with cotton thread, and hang them after ignition in a vial of oxygen gas. The oxygen gas combines with the sulphur, forming a new compound gas, called sulphurous acid. A brilliant blue flame accompanies the combination. It thus appears that acids may be gaseous as well as liquid. The acidity may be proved, as usual, by blue litmus paper.

106

400. Bleaching by Sulphur.—Introduce a red rose or other flower into a vial filled with sulphurous acid. It will soon lose its color. Wash it with dilute sulphuric acid and the color reappears. This experiment may also be made in a bottle in which sulphur has been burned in common air.

401. Explanation.—Sulphurous acid forms a white compound with the red coloring matter of the rose. It may seem incomprehensible that a colorless gas and red coloring matter should unite to form white, and it

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398. How may the sublimation of sulphur be shown? 399. What is said of the combustion of sulphur? 400. Describe the process of bleaching by means of sulphur. 401. Why does sulphurous acid bleach?

would be so, were the case one of mere mixture. But it is an instance of chemical combination, in which, as is often the case, the properties of the constituents entirely disappear. When sulphuric acid is afterward used, the color re-appears, because the stronger acid has expelled the weaker, and has itself no inclination to form with the coloring matter a similar combination.

402. STRAW BLEACHING.—The bleaching of straw goods is always effected by sulphurous acid. They are first moistened, and then exposed to the fumes of burning sulphur. An inverted barrel is often made to serve the purpose of a bleaching chamber. Articles thus bleached by sulphurous acid, after a time, regain their color. This is not the case in chlorine bleaching, because the coloring matter is not merely changed, but destroyed. This agent is not applicable to straw, on account of a faint brown tinge which it imparts to the material.

403. COPYING MEDALLIONS.—Sulphur melts, readily, by application of heat. (239° F.) At a higher temperature it thickens again. (350° F.) Still further heating makes it again fluid (at 500°. F.) In this second period of fluidity, it has the remarkable property of assuming a waxy consistence on being poured into water. In this condition it is used for copying seals, coins, and medals. The copy acquires, in a few hours,

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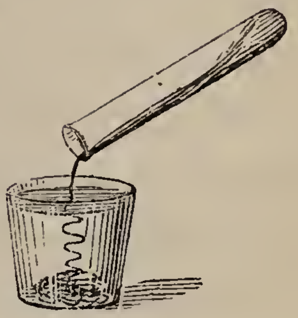
402. Describe the process of straw bleaching. 403. Explain the copying of medallions by sulphur.

the original hardness of sulphur. The plastic material may be obtained in the form of elastic strings, by pouring molten sulphur from a test-tube into cold water.

107



404. Sulphur Crystals.—Sulphur may be obtained in a crystalline form, by melting it in a pipe bowl, at a gentle heat, and then allowing it to cool. A crust soon forms on the top, which is broken, and a portion of the liquid sulphur below poured out. On breaking the pipe, it is found filled with crystals, shooting across the interior from the incrusted walls.

108

Sulphurous Acid. SO_2.

405. Description.—Sulphurous acid is a gas, having the smell of a burning match. It is composed of sulphur and oxygen, in the proportion of one atom of the former to two of the latter. The termination "ous" indicates, as in other cases, a smaller proportion of oxygen than is contained in some other acid composed of the same elements.

406. Preparation.—It has already been shown that this acid may be prepared by burning sulphur in oxygen. A better method is to heat in an earthen retort, or in a flask made of hard glass, two parts of flowers of sulphur intimately mixed with three parts of black

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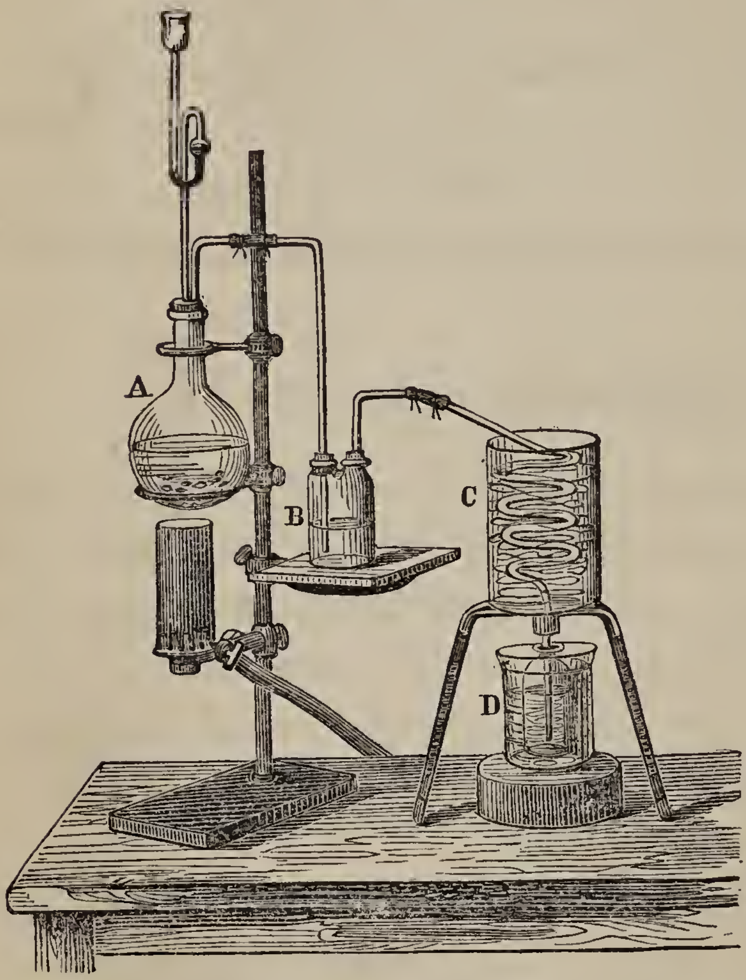
404. How may crystals of sulphur be obtained? 405. What is sulphurous acid? 406. How is sulphurous acid prepared?

oxide of manganese in fine powder. The gas having been passed through a bottle of water to remove a little vapor of sulphur and sulphuric acid which is carried over may be collected in another bottle of water, forming a strong solution of sulphurous acid, or the gas may be collected in a dry bottle for examination. Sulphurous acid may also be obtained in the liquid form free from water by means of the apparatus shown in the figure. The materials for preparing the gaseous acid are placed in the flask, A, heated by a lamp. The gas is purified by passing through concentrated sulphuric acid in the bottle, B, and then transmitted through the pewter worm, C, surrounded by a freezing mixture of ice and salt, and collected in the receiver, D, which is also kept in a freezing mixture. From the bottle, D, it may be transferred to tubes and hermetically sealed and kept for future use. At ordi-

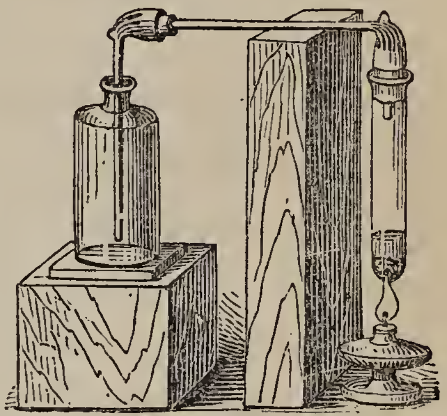
109



nary temperatures this acid would again assume the gaseous form, and at 60° F. it exerts a pressure of two and a half atmospheres.

407. A Simpler Method of preparing this gas for experiment is to heat oil of vitriol with bits of copper. The oil of vitriol is thus deprived of part of its oxygen, and converted into sulphurous acid. The process may be conducted in a test-tube. By leading the gas through a smaller tube into a vial partly filled with water, a solution of sulphurous acid may be obtained, possessed of the same bleaching and other properties as the gas itself. When the evolution of the gas commences, the heat of the lamp is no longer required.

110



408. Explanation.—Copper has a very strong affinity for oxygen, and takes it from the oil of vitriol, which possesses it in large proportion. The oil of vitriol, thus deprived of part of its oxygen, is converted into sulphurous acid gas.

409. Use in preserving Wines.—Sulphurous acid, in small quantities, is sometimes added to wine to prevent its souring. This change is owing to the absorption of oxygen from the air. Sulphurous acid is a substance possessed of an excessive appetite or affinity for

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407. By what other method may this gas be prepared? 408. Explain the process. 409. Why is sulphurous acid sometimes added to wine?

Prof. Silliman used to say
of sulphuric acid used
[illegible] manufa-

oxygen. A small portion of it in a wine cask will seize on what little oxygen finds admission, and so prevent the deterioration of the wine. It destroys itself in this act of protection, and is converted into sulphuric acid. Sulphurous acid in the form of sulphite of lime is also used to stop the fermentation of cider when it has acquired a pleasant flavor; for this purpose one ounce of the sulphite is added to every gallon of cider.

410. Use in Sugar Manufacturing.—The oxygen of the air so modifies the juice of the sugar-cane, that it cannot be made to yield its due proportion of sugar. Sulphurous acid, by appropriating the oxygen to itself, prevents this effect, and is said to double the product. It is generally used in the form of its lime compound, called sulphite of lime. The objection to its use consists in the slight sulphurous taste which it imparts to the sugar. But this is said to be removed by clarification, at a loss of ten per cent., leaving still a large gain from the employment of the process. The bleaching effects of sulphurous acid have already been illustrated.

411. Disinfecting Properties.—Sulphurous acid is a powerful disinfectant. The fumes of burning sulphur by preventing oxidation check the first development of animal and vegetable life. In the same manner it prevents putrefactive fermentation and decomposition, and immediately destroys all animal odors and emanations. For these purposes it is in many respects preferable to chlorine. The fumes of burning sulphur are employed

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410. How is sulphurous acid employed in manufacturing sugar? 411. For what other purpose is sulphurous acid employed?

degree of civilization.

that the number of [illegible]
greatly by a [illegible]
him indicate [illegible]

to cleanse apartments that have been occupied by patients with contagious diseases.

Chap 5th

Sulphuric Acid. $SO_3 = 40$.

Oil of Vitrol; $HO,SO_3 = 49$.

412. Description.—Sulphuric acid is a colorless, oily fluid, of intensely acid taste, known in commerce as *oil of vitriol.* It is composed of sulphur and oxygen, in the proportion of one atom of the former to three of the latter. It also contains water, with which it is chemically combined. As it is among the most important of all chemical products, the process of its manufacture will be given with some detail.

413. Preparation.—Sulphuric acid may be made directly from its elements, by igniting a mixture of air and vapor of sulphur with a red-hot iron. Sulphuric acid was formerly prepared by distilling sulphate of iron called copperas, or green vitriol, and hence the oily acid thus obtained was called *oil of vitriol.* In quantity, it is now generally made from sulphurous acid, by imparting to the latter additional oxygen. Take a bottle in which sulphur has been burned, and which therefore, contains sulphurous acid, and hold in it, for a short time, a rod or stick moistened with nitric acid. The gaseous sulphurous acid obtains oxygen from the nitric acid, which is rich in this element, and very liberal of it, and thereby becomes sulphuric acid. A little water,

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412. Describe sulphuric acid. 413. How many sulphuric acid be prepared?

previously placed in the bottom of the vial, absorbs the acid thus formed. To acidify the water to any considerable extent, it will be necessary to burn sulphur, and introduce the moistened rod repeatedly. That the acid is not the sulphurous or the nitric acid, employed in the process, may be proved by using it with zinc to make hydrogen gas.

111

414. Remark.—The red fumes which fill the vial in the last experiment, consist of the changed nitric acid, (nitric oxide,) which has just given up part of its oxygen, and is now resuming part of it from the air. It thereby becomes a third substance, of a red color, to be again mentioned in the section on nitric acid.

415. Manufacture of Oil of Vitriol.—The method of the production of oil of vitriol on a large scale, is essentially the same as that above given. Fumes of burning sulphur and vapor of nitric acid, with air and steam, are introduced into a leaden chamber, when the process proceeds, as before described.

416. Comparatively little nitric acid is needed in the process, for it is found that while it yields oxygen to the sulphurous fumes, the changed acid greedily seizes oxygen from the air of the chamber, and imparts it again, to keep up the process. The air is, therefore, the real

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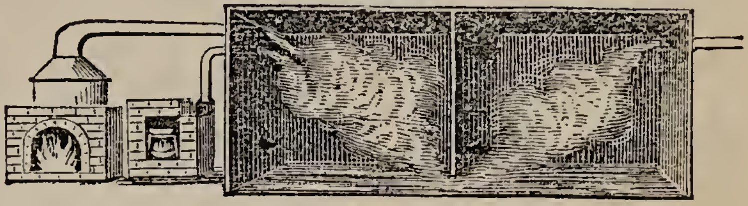
414. What causes the red fumes in the above experiment? 415. Explain how sulphuric acid is manufactured. 416. Why is but little nitric acid required?

oxidizer, while the changed nitric acid only acts to transfer it to the sulphurous fumes.

417. Description of Acid Chambers.—The figure represents one form of the leaden chambers employed in the above manufacture. Connected with them are a steam boiler and two furnaces, in one of which sulphur is burned, and converted into sulphurous acid. Over the sulphur is another vessel, containing the materials for making nitric acid, the formation of which commences as soon as the sulphur flame has imparted the requisite heat. The vapors thus produced, are mingled with air and steam in the leaden chamber. How they act together to produce sulphuric acid, has been already explained. The space is divided by a partition, in order that all the materials may be more thoroughly mixed, as they pass through the narrow opening below it. The acid, as it forms, dissolves in water which covers the bottom of the chamber, and is thus collected. Lead is used as a lining for the chambers, because the acid would destroy almost any other material that might be employed.

112.



418. The dilute acid obtained from the chambers, is concentrated first in leaden vessels, and afterward, when it has become strong enough to corrode the lead,

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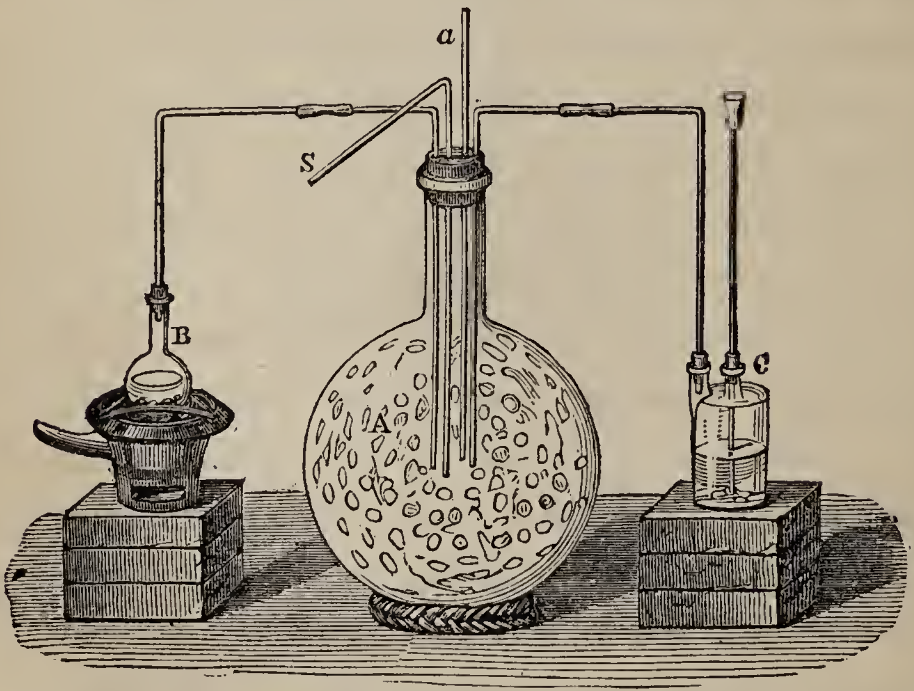
417. Describe the acid chambers. 418. How is the acid chamber constructed?

in retorts of platinum. The metal platinum being of about half the value of gold, the vessels in which the evaporation is carried on are extremely expensive. Some manufactories deliver tens of thousands of pounds of sulphuric acid per day.

This method of manufacturing sulphuric acid is called the English process, because it was first practiced in England.

419. Illustration.—This process of manufacturing sulphuric acid may be illustrated in the lecture-room by means of the apparatus shown in the figure. A large receiver, A, is filled with air and communicates with the atmosphere by the tube *a*. The flask, B, contains a mixture of sulphur and black oxide of manganese from which sulphurous acid is produced by the heat of a small furnace; binoxide of nitrogen is supplied by the jar, C,

113.



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419. How may the manufacture of sulphuric acid be illustrated?

by the action of nitric acid upon fragments of copper; copious red fumes of peroxide of nitrogen are formed by the union of the air in the balloon, A, with the binoxide of nitrogen. In a few minutes the inside of the balloon becomes coated with a white crystalline deposit formed by the union of sulphurous acid, peroxide of nitrogen and water. Steam is then supplied by the tube, S, when the crystalline deposit is immediately dissolved and decomposed with brisk effervesence; binoxide of nitrogen escapes, and sulphuric acid remains in solution. The binoxide of nitrogen again absorbs air and reappears in red fumes as peroxide of nitrogen, which again unites with sulphurous acid and water to form white crystals, which are, in their turn, dissolved and decomposed as before, forming a fresh portion of sulphuric acid. In this manner a small quantity of binoxide of nitrogen acts repeatedly as a carrier of oxygen from the air to the sulphurous acid, converting it into sulphuric acid. In the large chambers where sulphuric acid is manufactured on a large scale, all these changes go on simultaneously.

420. Comparative Strength of Sulphuric Acid.—Sulphuric acid is the strongest of all acids. This may be shown by bringing it to a direct trial of strength with other strong acids. If poured, for example, on nitrate of potassa, which is, as its name applies, a compound of nitric acid and potassa, it takes sole possession of the base, and expels the nitric acid in the form of vapor.

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420. How is the strength of sulphuric acid shown?

It expels muriatic acid from its compounds in the same manner. This is the method by which nitric and muriatic acids are always obtained. Whatever they can accomplish when free, may therefore be traced back to the power of sulphuric acid which gave them their liberty. The latter is the king among the acids, who accomplishes indirectly what he cannot effect in person. The solution of the noble metals by aqua regia is one among these indirect results.

421. Sulphuric acid is volatile at high temperatures. Phosphoric and other non-volatile acids, are, therefore, under certain circumstances, superior to it. This is illustrated in certain crucible operations, where compounds containing sulphuric acid are heated with such acids. The sulphuric acid is then easily dispossessed, and compelled to take refuge in flight.

422. ACTION OF SULPHURIC ACID ON METALS.—Sulphuric acid attacks all metals with the exception of platinum and gold. Even the dilute acid acts on all the metals hereafter named, as far as manganese.

The action of the dilute acid may be illustrated by placing a few bits of zinc in a tumbler, with a little water, and adding a small portion of oil of vitriol. The metal dissolves with the evolution of hydrogen gas. The reason of the evolution of this gas is given in the section on hydrogen.

The action of the strong acid may be illustrated, by

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421. Is it strongest at high temperatures? 422. What is the action of sulphuric acid on metals? Illustrate the action of the dilute acid. Illustrate the action of the strong acid?

heating a little copper, with oil of vitriol, in a test-tube. The metal dissolves with the evolution of sulphurous acid fumes. The reason of the appearance of sulphurous acid is given in Section 408.

423. Affinity for Water.—The affinity of sulphuric acid for water is so strong that it lays hold on every particle of the invisible aqueous vapor of the atmosphere. It finds it in what seems the driest air; and every particle which it catches it retains. It grows in bulk by what it thus drinks, as will be seen if a little oil of vitriol is left exposed to the air, for a few days, in an open vessel. It is sometimes necessary, in chemical operations, to free gases from all the aqueous vapor which is mixed with them. This is done completely by causing them to bubble through oil of vitriol, and again collecting them.

424. Heat by Dilution.—When sulphuric acid and water are mixed, condensation takes place, accompanied by elevation of temperature. Fifty cubic inches of sulphuric acid and fifty cubic inches of water, when mixed, do not fill a vessel of the capacity of one hundred cubic inches, but fall about three inches short. Condensation has therefore taken place to the amount of three inches. Heat is, as it were, pressed out in such cases, as explained in the early part of this work.

425. Wood Charred by Sulphuric Acid.—Wood

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423. What is said of the affinity of sulphuric acid for water? 424. What takes place when sulphuric acid is diluted? 425. Why does sulphuric acid char wood?

dipped in oil of vitriol is soon charred. Wood is composed of carbon, hydrogen and oxygen. The last two together form water. The affinity of sulphuric acid for water has been mentioned above. The acid and the wood being in contact, it would seem that the hydrogen and the oxygen of the latter agree to combine and satisfy this demand. The carbon being at the same time isolated, appears in its natural black color. Sulphuric acid exerts a similar action on other vegetable substances.

426. Important Uses of Sulphuric Acid.—Sulphuric acid is largely employed for dissolving indigo, for use in dyeing and calico printing; also, for converting common salt into sulphate of soda, as a preparatory step to the manufacture of carbonate of soda. It is also essential in the manufacture of super-phosphate of lime, an article now extensively used in agriculture. Nitric and muriatic acids are produced through its agency from nitre and common salt.

Nitrogen.

Symbol, N; *Equivalent*, 14; *Density*, .97

427. Description.—Nitrogen is a transparent gas, without taste or odor. It forms about four-fifths of the air we breathe. It occurs also in combination with other elements in a solid form. It is an essential ingre-

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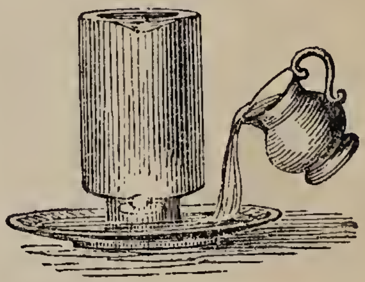
426. What are the uses of sulphuric acid? 427. What is nitrogen? Where is it found?

dient in all animal tissues, one-fifth of the weight of the dried flesh of animals being nitrogen. It is also found in many vegetable substances, and it enters into the composition of nitre and other salts. The gas emitted from the volcanoes of Europe is said to be principally nitrogen; but carbonic acid (to be hereafter described) is discharged in great abundance from the active volcanoes of America.

428. PREPARATION OF NITROGEN.—Nitrogen is prepared from ordinary air by removing its oxygen. For this purpose a small portion of phosphorus is floated on a slice of cork upon water, and kindled, and a vial or a jar is inverted over it. As it burns it abstracts the oxygen; the water rises to take its place, and what is left of the air is nitrogen. The cork should be a little hollowed out, and chalk scraped into the cavity. Water must be poured into the saucer as the first portion rises into the bottle. The bottle is then cooled, either by water or long standing, and corked while yet inverted. It is then shaken, to wash the gas. A piece of phosphorus, of the size of a large pea, is sufficient for the preparation of half a pint of gas.

114



429. EXPLANATION.—The burning phosphorus selects all of the oxygen atoms in the air, and, by combining with them, converts them into solid particles of a certain oxide of phosphorus called phosphoric acid. These

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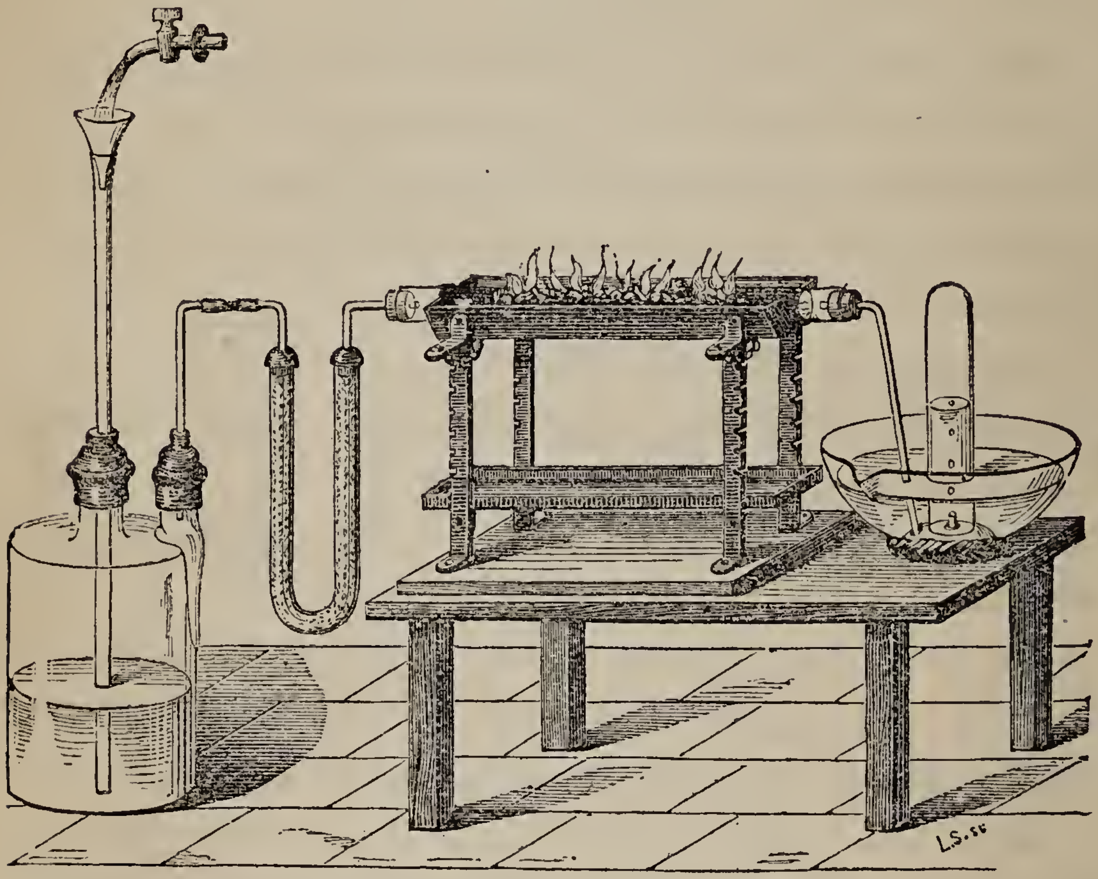
428. How is nitrogen prepared? 429. Explain the process.

particles at first appear as a white smoke, and are afterward dissolved in the water.

430. Nitrogen may be procured in large quantities by passing a current of air, deprived of carbonic acid, over copper turnings heated to dull redness, when the copper will absorb the oxygen, and the nitrogen set free may be collected over mercury, or over water deprived of air by boiling. To perform this experiment introduce copper turnings into a tube of porcelain, or hard glass, placed over a chafing dish. One extremity of this tube is connected with an apparatus designed to furnish a current of air, the other is connected with a

115



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430. How may nitrogen gas be procured in larger quantity?

curved tube communicating with a jar arranged to receive the gas. The U-shaped tube seen in figure 115 is filled with pumice-stone saturated with caustic-potash to deprive the air of the carbonic acid which it contains. If we wish to obtain the gas entirely free from moisture the air should be passed through a second U-shaped tube filled with pumice-stone saturated with concentrated sulphuric acid. When the apparatus is thus arranged water flows from the stop-cock through the funnel into the jar and drives the air it contains through the apparatus and pure nitrogen is obtained in abundance. This method should be employed in preference to all others where large quantities of nitrogen are required. By measuring the amount of air driven through the apparatus and the nitrogen collected, the proportion of nitrogen in the air is easily estimated.

431. NITROGEN EXTINGUISHES FLAME.—If a burning taper be lowered into the bottle of nitrogen, as above prepared, it will be immediately extinguished. Flame is the brightness which accompanies active chemical combination, but here is nothing to combine. Nitrogen is a sloth among the elements, possessing no degree of chemical activity.

432. PRINCIPAL OFFICE OF NITROGEN.—The principal office of the nitrogen of the air is to dilute its oxygen. The latter, if pure, would soon consume our bodies as it hastens the combustion of a taper or other combustible.

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431. Does nitrogen extinguish flame? Why? 432. What is the principal office of nitrogen?

433. THE ATMOSPHERE.—The air we breathe, and which, to the depth of fifty miles or more, forms the transparent envelope of the globe we inhabit, is a mixture of nitrogen and oxygen gases with aqueous vapor. It also contains small and varying proportions of carbonic acid and ammonia. The growth of plants, the respiration of animals, the combustion of burning bodies, and other chemical operations upon the face of the earth's surface are continually effecting changes in the gases which compose the atmosphere, yet these changes are so beautifully adjusted that the composition of the atmosphere remains unchanged from age to age.

434. PROOF THAT AIR IS A MIXTURE.—That air is a mixture, and not a chemical compound, is sufficiently evident from the fact that it possesses no new and peculiar properties different from those of its constituents. It is further proved to be a mixture, from the fact that heat, which is the usual attendant on chemical combination, is never occasioned when air is artificially produced by the admixture of its constituents. Water absorbs the oxygen and nitrogen of the air in the same relative proportions that it would absorb each of those gases in a free state. The air expelled from rain water or melted snow by boiling contains one-third oxygen, while common air contains only one-fourth oxygen. This fact also shows that air is not a chemical compound but that the gases composing it are merely mingled mechanically.

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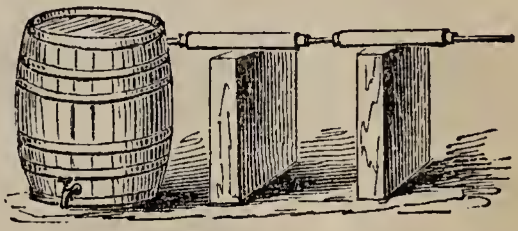
433. What is the composition of the air? 434. How is it proved to be a mixture?

435. Use of Carbonic Acid and Ammonia in the Air.—Carbonic acid and ammonia, although present in the air in extremely small quantity, subserve the most important purposes in administering to the growth of plants. They constitute the gaseous food of all forms of vegetable life, as will be more fully explained in succeeding chapters of this work.

436. Analysis of the Air.—The method by which the relative amount of oxygen and nitrogen in the air is determined has been already given. On burning phosphorus under a glass jar, as there described, the water is found to rise and fill a little more than one-fifth of the vessel, thereby indicating that one-fifth of the air which it contained was oxygen gas. The remaining four-fifths is nearly all nitrogen. In accurate experiments, a graduated tube is employed, instead of a jar or tumbler. It is not essential that the phosphorus should be ignited. Without ignition, it will gradually combine with all the oxygen, and remove it from the air contained in the tube.

116



In order to determine the amount of aqueous vapor and carbonic acid in the atmosphere, a gallon, or other measured quantity of air, is drawn through tubes containing materials to absorb these substances. This

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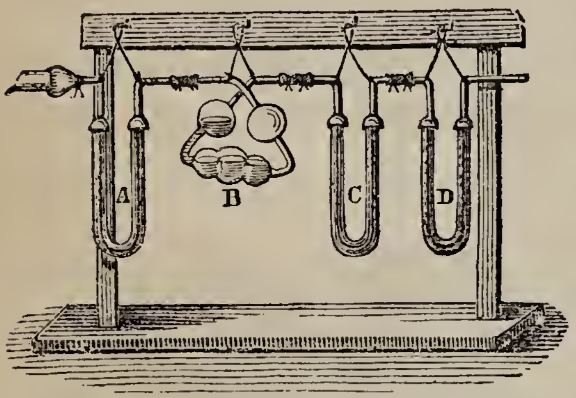
435. What purpose is served by its carbonic acid and ammonia? 436. How is the proportion of nitrogen determined? How is the amount of carbonic acid water and ammonia determined?

quantity is known by the increased weight of the tubes after the experiment is completed.

437. The Apparatus described. — The apparatus used in the experiment is represented in the last figure. It consists of a bottle or small cask, filled with water and provided with a cock below. The cock is turned, and as the water flows out, air flows in through the tube to take its place. The quantity of air that has passed through the tubes is known by the quantity of water that has flowed out from the cask. The materials employed in the tubes are pumice stone drenched with oil of vitriol, in the first, to absorb the water; and caustic potassa, in the second, to retain the carbonic acid. Instead of straight tubes it is found more convenient to employ the series of U-shaped tubes and bulbs shown in figure 117. A and D are filled with pumice saturated with oil of vitriol, B is partly filled with a concentrated solution of caustic potash, and C is filled with fragments of fused potash. The acid in D absorbs all the moisture from the air to be analyzed and the acid in A prevents the access of moisture from the cask of water or aspirator towards which the air is drawn. The increased weight of B and C shows the amount of carbonic acid in the air drawn through the the apparatus. The method for determining the amount

117



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437. Describe the apparatus used in this analysis.

of ammonia in the atmosphere is essentially the same, muriatic acid being used as the absorbent.

438. PROPORTIONAL COMPOSITION OF THE AIR.—The proportions of the four constituents of the air above mentioned, as obtained by the method just described, are about 21 per cent. of oxygen, 79 of nitrogen, $\frac{1}{2500}$th of carbonic acid, and $\frac{1}{10000000}$th of ammonia. The proportion of aqueous vapor is extremely variable. That of carbonic acid and ammonia is also variable to a considerable extent.

Nitric Acid. $NO_5 = 54$.

Aqua Fortis; $HO,NO_5 = 63$.

439. DESCRIPTION.—Nitric acid is a thin, colorless and intensely acid fluid. It corrodes metals instantaneously, with the evolution of deep red vapor. It is composed of nitrogen and oxygen, in the proportion of one atom of the former to five of the latter. It contains, in addition, water, with which it is chemically combined. It is possible to make it anhydrous, or free from water, but such an acid is never used.

440. PREPARATION.—Nitric acid exists in a dormant state in ordinary saltpeter. Its affinities being entirely satisfied by the potassa with which it is combined in that substance, it lies there perfectly inactive. Sulphuric acid being stronger, has the power of taking its base, and expelling the acid in the form of vapor.

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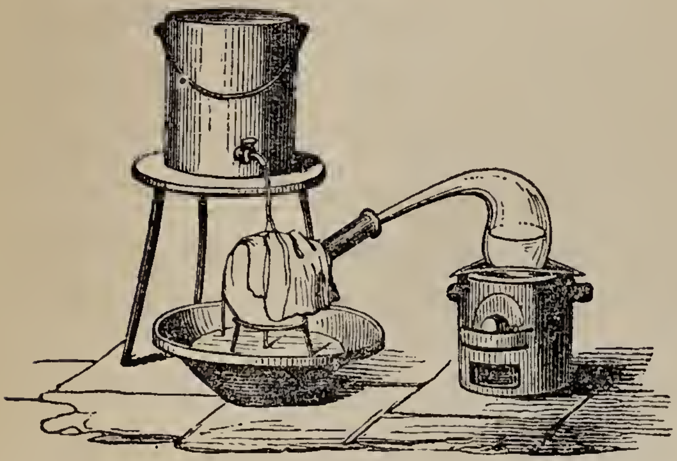
438. What are the proportions of the different constituents of the atmosphere? 439. What is nitric acid? 440. How is nitric acid prepared?

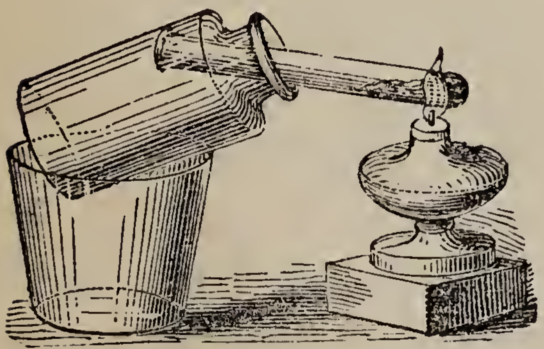
Saltpeter (nitrate of potash) with an equal weight of sulphuric acid is heated in a retort, connected with a a receiver, kept cool by a stream of water dropping upon a cloth spread over it as as shown in figure 118.

118



For the purposes of experiment nitric acid may be prepared by placing the saltpeter and oil of vitriol in a test tube heated over a lamp as in figure 119, while the acid fumes may be collected in a vial or flask. It is necessary to keep the vial covered with porous paper or cloth, and to moisten it frequently in order to maintain its coolness.

119



441. Oxidation of Metals.—If a little nitric acid is poured upon a copper coin, placed in a capsule or saucer, the coin will immediately begin to dissolve. It is not, strictly speaking, the metal which dissolves. One portion of the acid first converts the metal into oxide, by giving it part of its own oxygen. It thereby destroys itself, while another portion of undecomposed acid dissolves the oxide which is formed. One portion,

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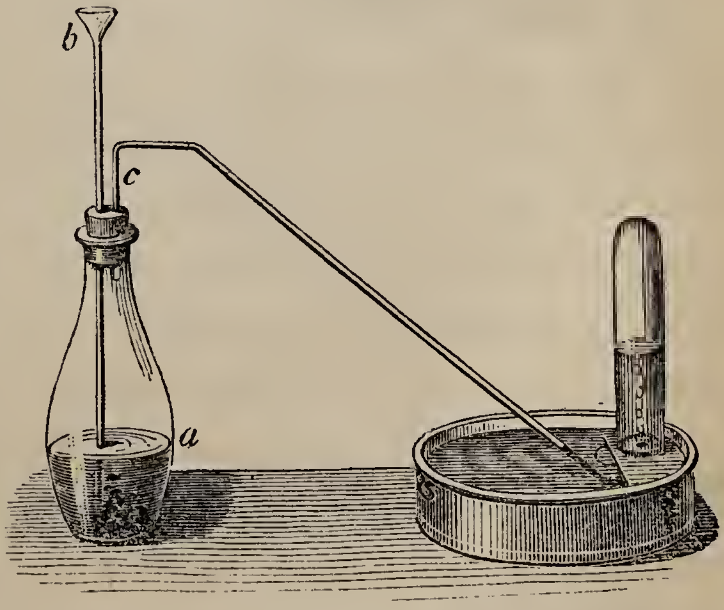
441. What effect has nitric acid on metals?

in reality, sacrifices itself to satisfy the appetite of the other. Most other metals are similarly acted on by nitric acid.

442. Oxidation without Solution. — Nitric acid oxidizes tin and antimony but does not dissolve them. The experiment will be best made with tin-foil. After the action of the acid, it will be found converted into a white powder. Gold and platinum are neither dissolved nor oxidized by nitric acid.

NO_2 **443.** Nitric Oxide.*—The vapors which are given off in the experiment with copper described in Section 441 are nitric oxide, changed by the air into which they rise. The nitric oxide is, so to speak, the fragment of nitric acid, which is left after three atoms of its oxygen are abstracted. Rising into the air, it combines with oxygen enough partly to supply the place of that it has just lost, and is thus converted into red NO_4 fumes of peroxide of nitrogen containing four atoms of oxygen. This compound is also called hyponitric acid.

120



444. Preparation. — Binoxide of Nitrogen or Nitric Oxide may

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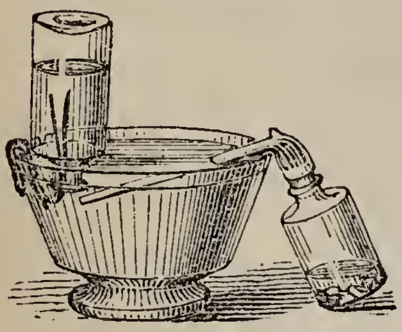
442. How does nitric acid act on tin? 443. What is nitric oxide?

[*] It will be observed that the term oxide is sometimes applied to compounds of the non-metallic substances with oxygen. (See Chapter III, Inorganic Chemistry.)

be obtained by pouring nitric acid through the funnel, *b*, upon fragments of copper contained in the flask, *a*, as shown in figure 120. The gas escapes through the tube, *c*, and may be collected over water. This gas has a strong disagreeable odor, and it extinguishes burning bodies, as a lighted taper or phosphorus, when plunged into it. This gas retains its own oxygen with great tenacity and greedily absorbs more from the atmosphere. When a jar partly filled with this gas is raised from the water bath and atmospheric air is admitted, dense red fumes appear, which are peroxide of nitrogen, containing four atoms of oxygen to one atom of nitrogen. These red fumes are quickly absorbed by water. This experiment may be performed with entire satisfaction by means of the simple apparatus shown in figure 121. The peroxide of nitrogen may be reduced to the liquid form at a low temperature. It is readily decomposed by oxidizable metals, and, as it readily parts with oxygen, it is a powerful oxidizing agent.

121



445. Protoxide of Nitrogen or Laughing Gas.—This gas is obtained by heating nitrate of ammonia in a flask over a lamp. The salt first melts and is then decomposed and converted into water and protoxide of nitrogen, which contains one atom of nitrogen united to one atom of oxygen. This is a colorless gas, sweetish to the taste, and it imparts its flavor to water in

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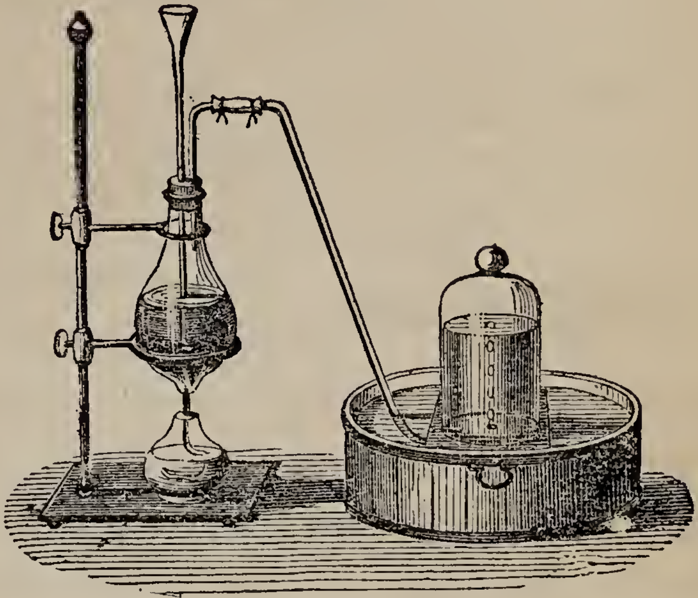
444. How is binoxide of nitrogen prepared? 445. How is protoxide of nitrogen prepared? Describe the properties of this gas.

which it is sparingly soluble. A candle recently extinguished is relighted with nearly the same facility as in oxygen. Other bodies burn in this gas with greater facility than in common air, showing that its elements are united by a feeble affinity.

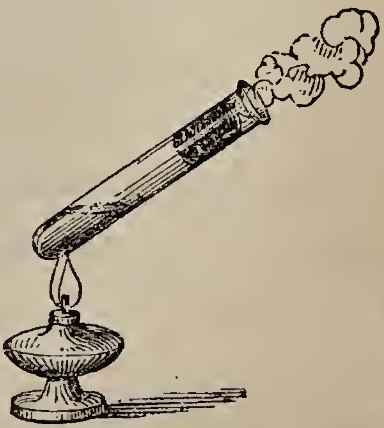
122



When this gas is inhaled from a large bladder or gas bag it produces exhilirating effects from which it has received the name, laughing gas. Impurity of material or excess of heat cause the production of other deleterious gases mingled with the protoxide of nitrogen, from the inhalation of which serious accidents have sometimes occurred. In view of these facts the preparation and inhalation of laughing gas is not to be recommended to the student.

446. Combustion by Nitric Acid.—As nitric acid contains much oxygen, combustion by its means would seem to be a very probable result. To prove that it has this effect, boil strong

123



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446. How may combustion be effected by nitric acid?

nitric acid in a test-tube, the mouth of which is filled with hair. As the vapors pass through they will cause it to smoke, and, if the acid is sufficiently strong, produce ignition.

447. Combustion of Phosphorus. — Phosphorus is readily ignited by throwing it upon nitric acid. If the acid is not very strong, it must be previously heated. Particles of phosphorus scarcely larger than mustard seed should be used in this experiment.

124

448. Destruction of Organic Tissues. — Strong nitric acid destroys all organic tissues and forms a powerful cautery much used in medicine. It also gives a yellow color to the nails and skin even when diluted, and it has the same effect upon wool; the orange patterns upon woolen table covers are produced by the same means. Other uses of nitric acid are mentioned in the chapter on Organic Chemistry.

Nov 8 to May 6th 1870
[illegible] L.A.H.

Phosphorus.

Symbol, P.; *Equivalent*, 31; *Specific Gravity*, 1.83.

449. Description.—Phosphorus is a substance remarkable for its power of emitting light in the dark. It is a

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447. Describe the experiment with phosphorus? 448. What is the effect of nitric acid upon organic substances? 449. What is phosphorus? Where does it occur?

wax-like and nearly colorless solid, readily ignited by heat or friction.* It is insoluble in water (and hence nearly tasteless,) but it is soluble in ether and in oils.

Phosphorus is never found uncombined, but it occurs in the form of phosphate of lime in the mineral called *apatite*, in primitive and volcanic rocks, from the gradual decomposition of which it finds its way into the soil. It is taken up by many plants and accumulates in their seeds. In this form it becomes the food of animals, and forms an important element in the composition of bones. It is also an essential ingredient in the substance of the brain and nerves.

450. PREPARATION.—Phosphorus is prepared from bones. These are composed, principally, of gelatine and phosphate of lime. The individual constituents are gelatine, lime, oxygen and phosphorus. To obtain the phosphorus, all the rest are to be first removed. Fire removes the gelatine, oil of vitriol the lime, and charcoal the oxygen.

The bones having been previously burned, the ground ash is mixed with dilute sulphuric acid and water, and, after several hours, filtered. Sulphuric acid unites with a considerable part of the lime, forming an insoluble sulphate, and the phosphoric acid remains combined with only a small portion of the lime

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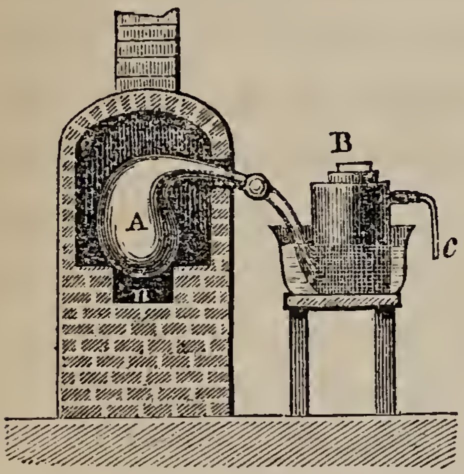
450. How is it prepared? Give the complete process

This is a very dangerous substance to handle producing very obstinate and severe burns when it takes fire upon the hands, hence it should always be cut under water and every particle not used should be immediately returned to a bottle of water protected from light.

in a form called superphosphate of lime. The solution containing this superphosphate is then mixed with charcoal, and after being carefully dried, it is heated in an earthen or iron retort, A, connected with a copper receiver, B, containing water, and furnished with an escape tube, C. Several such retorts are placed side by side in a furnace, *n*, where they can be conveniently heated. The carbon takes the oxygen from a large portion of the phosphoric acid, and passes out of the retort with it, as gaseous carbonic oxide. The phosphorus which is thus set free, being vaporized by the heat, is also expelled, but is converted into solid phosphorus by the cold water into which it passes. The gas produced by the process bubbles through the water and escapes, while the phosphorus is hardened by it and remains. The mass thus obtained is melted under water and run into moulds.

125.



In preparing phosphorus in the large way, a number of retorts are placed in the same furnace.

451. PHOSPHORESCENCE.—This term is applied to the luminous appearance of sea-water when agitated, and to other faint light unaccompanied by perceptible heat. It is observed when an ordinary friction match is rubbed upon the hand in the dark. The light in the lat-

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451. What is phosphorescence?

ter case is owing to a slow combustion of phosphorus, which takes place without kindling. The product of the combustion, is a white powder, called phosphorous acid, which soon becomes liquid, by absorbing moisture from the air.

The phosphorescence of sea-water has been supposed to be owing to the liberation of phosphorus by the decay of jelly-fish or blubber so abundant in the ocean. Many sea-fish emit light in the dark soon after death if placed in saline solutions, but the effect ceases when putrefaction commences. Many bodies containing no phosphorus emit light in the dark when there is no apparent oxidation. The cause of phosphorescence is but imperfectly understood, though it is believed to be generally due to the slow oxidation of the phosphorescent matter.

452. A HARMLESS FIRE.—By agitating phosphorus with ether, a small portion of the former substance is dissolved. This solution, if rubbed upon the face and hands, makes them luminous, in the dark. This is another case of phosphorescence. A piece of phosphorus of the size of a pea is amply sufficient for the experiment.

453. COMBUSTION UNDER WATER.—Phosphorus may be burned under water by the help of substances rich in oxygen. Place a few scales of chlorate of potassa, and a bit of phosporous of the size of a pea, at the bot-

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452. How may a harmless fire be produced? 453. How may phosphorus be burned under water?

Bisulphide of carbon with phos-
phorus mixed [illegible]
[illegible]

tom of a wine glass previously filled with water. Partially fill the bowl of a pipe with oil of vitrol, and drop it in small portions on the mixture, bringing the pipe stem, each time, close to the bottom of the glass. As soon as the stronger acid is applied, chloric acid, containing much oxygen, is liberated and decomposed, and the phosphorus inflamed. A similar combustion of phosphorus, by means of nitric acid has already been described. In both cases the result is the production of phosphoric acid.

126.

454. Friction Matches.—Great quantities of phosphorus are annually consumed in the manufacture of friction matches. For this purpose the phosphorus is first intimately mixed with a hot solution of glue, or gum, to which saltpetre is added, and the paste thus formed is frequently colored with vermilion or Prussian blue. The match splints are first dipped in melted sulphur, when cold they are dipped in the phosphorus paste, and after being thoroughly dried in an oven heated by steam they are packed in boxes convenient for use.

455. Red Phosphorus.—When phosphorus is sublimed in a perfect vacuum, or surrounded with an atmosphere of carbonic acid or hydrogen, it becomes changed in color and properties. It then assumes the form of red scales, acquires a density of 1.94, and instead of fusing at 111° F., as in the ordinary con-

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454. What is said of friction matches? 455. What is said of red phosphorus.

dition, it may be heated to 392° without becoming luminous, and it requires a temperature of 500° to melt it, but at this temperature it is reconverted into the ordinary form. While the ordinary form of phosphorous is a rank poison, and highly inflammable, the red phosphorus, if perfectly pure, is quite inert, and but slightly inflammable. For this reason efforts have been made to substitute the red phosphorus in the manufacture of matches, but owing to the difficulty of preparing the red phosphorus without some mixture of the ordinary form, the experiments have as yet been attended with but partial success.*

Arsenic.

Symbol, As; *Equivalent*, 75; *Specific gravity*, 5.8.

456. Description.—Arsenic is a grey substance, of metallic luster, and for this reason commonly classed among the metals. On the other hand, in view of the compounds which it forms, and especially in view of the fact that its oxygen compounds are acids, and not oxides, it is more properly classed among the metalloids. Its analogies to phosphorus are most striking, and it is for this reason here introduced, in immediate connection with that element.

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456. Why is arsenic introduced among the metalloids?

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* The manufacture of matches is attended with considerable danger both on account of the inflammable nature of the materials employed, and also from the fact that the vapor of phosphorus attacks the carious teeth of the workmen, and produces a disease which extends to the jaw-bones, producing extreme suffering and often terminating in death.

457. Analogies to Phosphorus.—Arsenic unites with oxygen in the same proportions as phosphorus, forming similar acids. These in turn form salts resembling each other most perfectly in external appearance and in crystalline form. It also combines with three atoms of hydrogen to form arseniuretted hydrogen, a gas analogous to phospuretted hydrogen, to be hereafter described. Of the two principal oxygen compounds of phosphorus, the higher or phosphoric acid is the more important, and was therefore more particularly considered. On the other hand, the lower or arsenious acid is the more important of the acids of arsenic.

458. Preparation.—Metallic arsenic is sometimes found native; but more frequently it is combined with other metals, as iron, nickel, cobalt, copper or tin. It is obtained in large quantities from an ore called *Mispickel*, which is an arsenical sulphuret of iron. It is also obtained from the arsenical sulphurets of other metals. The arsenical sulphurets are roasted in furnaces having flues connected with large chambers. The sulphur and arsenic are burned in the furnace and pass off in the form of oxides. The oxide of sulphur (sulphurous acid) being very volatile passes off through the chambers and escapes into the open air, while the less volatile oxide of arsenic (arsenious acid) is condensed in the chambers to which it is conducted forming a thick vitreous crust, which is removed by workmen encased in leather to protect them from the corrosive

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457. In what respect do phosphorus and arsenic resemble each other?
458. How is arsenic prepared?

[illegible] works the vegetation [illegible]
of all the [illegible] when their
[illegible] were [illegible]
of condensation [illegible]

action of the poisonous material they are handling. They breathe through wet cloths, to protect their lungs from the poisonous dust, and they look through glazed openings in the mask which covers the face. The crude arsenious acid thus obtained is purified by resublimation and forms the white arsenic or arsenious acid of commerce. The sublimed arsenious acid is then powdered and heated with a large proportion of carbon, as in the case of phosphorus, before described. Beside mixing with carbon, it is best, also, to cover with the same material, and heat from above, downwards. The metal passes off as vapor, and condenses in the cooler part of the tube, or other vessel in which the experiment is performed, as a steel grey incrustation. Arsenic is very volatile, forming a colorless vapor ten and a-half times as heavy as air, which is easily recognized by its powerful alliaceous odor. Arsenic may be melted in close vessels but when heated in the open air it volatilizes before it melts.

127

[illegible]

Arsenious Acid. AsO_3

459. Ratsbane.—The ordinary white arsenic of the shops, also known as *ratsbane*, is a white and nearly insoluble substance, possessed of a slightly sweetish taste. It is not properly arsenic, but arsenious acid. It contains three atoms of oxygen to one of metal.

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459. What are the properties of arsenious acid?

Has some [illegible] in [illegible]
[illegible]

Although sweet, it is called an acid because it possesses the chemical characteristic of an acid, viz.: the capacity of uniting with bases to form salts. Arsenious acid is the compound obtained in the first stage of the process for manufacturing metallic arsenic, as above described.

460. ARSENIC ACID, AsO_5.—Is another oxide of arsenic containing five atoms of oxygen to one atom of the metal. Its composition is analogous to that of phosphoric acid.

461. OTHER COMPOUNDS OF ARSENIC.—Sulphur and arsenic may be melted together in all proportions, but they form several well defined compounds, the most important of which are the bisulphide of arsenic called realger, and the tersulphide or orpiment. *Realger* contains one atom of arsenic united with two atoms of sulphur. It is occasionally found in the form of ruby-red crystals. It is sometimes used as a pigment. It forms one of the ingredients of *white Indian fire*, which is often used as a signal light. This compound consists of 7 parts of sulphur, 2 of realger, and 24 of nitre.

Orpiment is a yellow compound of sulphur and arsenic containing three atoms of the former and one of the latter. A mixture of arsenious acid and orpiment forms the beautiful pigment known as *King's yellow.*

Arseniuretted hydrogen is a gaseous compound containing one atom of arsenic united with three atoms of

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460. What is arsenic acid? 461. What other compounds of arsenic are worthy of special notice?

Never buy these colors
use is prohibited in Europe
com[illegible] papers [illegible]

hydrogen. It is a highly poisonous gas of great interest in chemical analysis, and especially in a form in which arsenic is obtained in medico-legal investigations. This gas is formed when arsenic or arsenious acid is thrown into a bottle containing zinc and chlorohydric acid. It burns with a bluish white flame which deposits metallic arsenic upon cold bodies, like porcelain, held in the flame, and white arsenic (arsenious acid) upon those held above. Nov 10th

[illegible]

462. Properties of Compounds of Arsenic.—Arsenic forms with most of the metals alloys, which are brittle and easily fusible, hence it becomes important that such metals as iron copper and zinc should be thoroughly purified from arsenic.

All the soluble compounds of arsenic are highly poisonous, and often prove destructive of animal life. Paper hangings, ornamented with the beautiful pigment known as Scheele's green (an arsenite of copper), produce serious disease in the occupants of rooms where they are used. Arsenic preserves animal substances from decay, and also by its poisonous properties protects them from the ravages of insects. A few grains of white arsenic added to bookbinder's paste preserves the books from the ravages of insects in hot climates. Arsenical soap is employed by the taxidermist to preserve the skins of stuffed birds and other small animals.*

462. What are the properities of compounds of arsenic?

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* Arsenical soap is prepared by mixing 100 parts of hard soap, 100 parts of arsen-

463. ARSENIC AS A POISON was formerly much employed for criminal purposes. But the CERTAINTY OF ITS DETECTION, and the entire demonstration of its presence in the body after death, or in materials which have been ejected from the stomach, now strikes a just terror into the minds of those who would otherwise be tempted to use it for evil purposes.

464. ANTIDOTES FOR ARSENIC.—The best antidote for arsenic is the hydrated sesquioxide of iron in the moist state, which forms with arsenious acid an insoluble arsenite of iron. Pure calcined magnesia may also be used for the same purpose. Either of these remedies may be taken freely as an antidote to arsenic. The white of eggs, milk, and sugar are also good remedies, and should be taken in considerable quantity when arsenic has been swallowed. If the poison can be removed by vomiting that is always the first remedy, and the others may be given afterwards.

465. DETECTION OF ARSENIC.—No one but a professional chemist should undertake the detection of arsenic in criminal cases, involving, as it does, the issues of life and death. No one else, indeed, can be qualified to

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463. What fact tends to prevent the use of arsenic for criminal purposes? 464. What is the antidote for arsenic? 465. What is said of its detection?

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ious acid, 36 carbonate of potash, 15 camphor, and 12 of quick-lime. The soap is to be scraped and dissolved in a little water with a gentle heat, then add the potassa and the lime, and mix all well together. The arsenious acid should then be added gradually, and well incorporated, and, when the mixture is cold, the camphor, previously dissolved in a small portion of alcohol, is to be thoroughly mixed with the compound. A portion of this soap, dissolved in water, applied with a brush to the objects to be preserved, effectually destroys all insects and their eggs.—DUMAS.

guard, with certainty, against the presence of arsenic in the chemicals which are used in the process, or in other respects, to bring the inquiry to that point of absolute demonstration, which is always required in judicial investigations. But the methods of detection, being simple, and a subject of interesting and instructive experiment to the student, will be briefly described in the paragraphs which follow.

If a few drops of a solution of chloride of arsenic* be added to the liquid from which hydrogen is being evolved from a vial, by the ordinary process, the nascent hydrogen decomposes the chloride of arsenic and carries off the metal in the form of a gas. On subsequently kindling the hydrogen jet, and bringing down upon it a cold white surface, like that of a plate or saucer, the metal is again given up, and reveals itself as a brownish black and highly lustrous stain. The process may be conducted in an ordinary vial, to which a pipe stem, or glass tube has been fitted, by the method before described.

128.

In cases of suspected poisoning the contents of the stomach are subjected to some process to destroy all the organic matter, and bring the whole into a state of solution. After filtering the suspected liquid, it is acidulated with muriatic acid, and submitted to a test like that above described, in an apparatus

How is arsenic detected?

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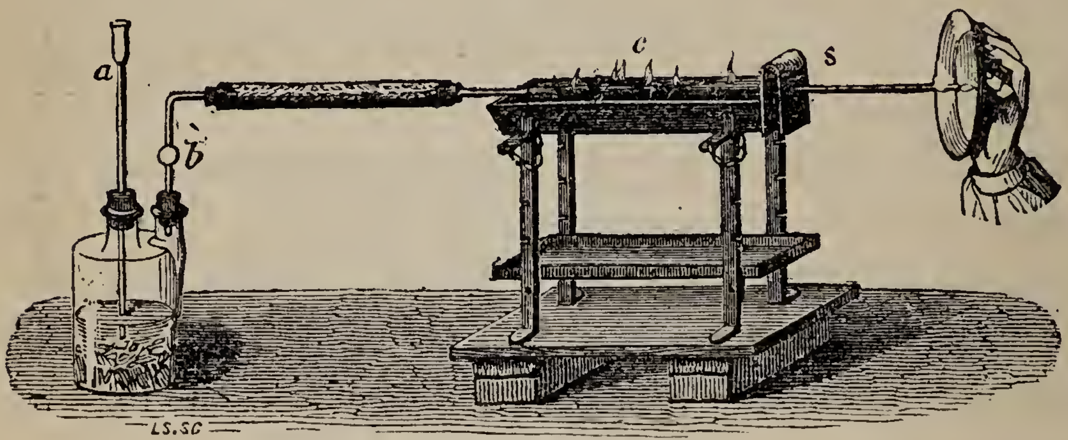
* Such a solution is prepared by dissolving white arsenic in hydrochloric acid.

especially fitted for the purpose. The amount of arsenic in such cases is usually small, and special precautions are required to exhibit the characteristic reactions with the smallest appreciable quantity of the poison.

129.



In the two-necked bottle, figure 129, are placed granulated zinc and dilute sulphuric acid; the bulb, *b*, is to condense the moisture, and the tube $CaCl$, is loosely filled with chloride of calcium to absorb the particles of fluid that would otherwise be carried over; a tube of hard glass, *c*, made without lead, is placed over a dish of burning charcoal. If, after a few minutes, the tube is not soiled, and the saucer held in the flame of the burning hydrogen is not tarnished, the apparatus and materials for making hydrogen are known to be free from arsenic. The suspected liquid is then poured through the funnel, *a*, when, if arsenic is present, a metallic ring will soon appear in the capillary tube beyond the screen, *s*, or if the fire is removed, and the escaping jet is inflamed, a *tarsh*, or stain, of metallic luster will appear upon the saucer held in the flame.

The above method of detection is called Marsh's test. In a case of suspected murder by poison, the moment of the introduction of the pure porcelain into the flame becomes one of the most intense interest. The gathering stain is at once the emblem of guilt and sentence of ignominous death.

466. Explanation.—In the above experiment nascent hydrogen effects the decomposition of the acid by a double action; on the one hand uniting with the metal to form arseniuretted hydrogen, which escapes, and, on the other hand, with its chlorine to form hydrochloric acid, which remains behind. The mirror of metal is deposited upon the plate or saucer, because the introduction of the cold body into the flame, so lowers its temperature that the metal itself cannot burn. If the jet of gas is left to burn without interference, both of its constituents are consumed together, and the flame assumes a blue color, from the burning arsenic.

467. Distinction between Arsenic and Antimony Stains.—If, in testing for arsenic, by the method above described, a metallic spot is obtained, the evidence of the presence of arsenic is not entirely conclusive. A solution of antimony, if substituted for arsenic in the experiment, will give rise to the production of somewhat similar stains. But the experimenter will find, on comparing the two kinds of spots, that they are quite different in appearance. Those of antimony are

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466. Explain the above process. 467. How are arsenic and antimony stains distinguished?

of deeper black, and fainter luster. Again, those of arsenic are much more readily removed by heat. "Chloride of soda," is a still more conclusive means of distinguishing them. A solution of this substance will dissolve the arsenic stains, while it leaves those of antimony unaffected. The "chloride of soda," to be used in the experiment, is prepared by adding an excess of carbonate of soda to a solution of "chloride of lime," and then filtering the liquid.

468. Additional Tests for Arsenic. — A second test has already been given in the paragraph on the preparation of metallic arsenic, to which the student is referred. The formation of a yellow precipitate, on the addition of hydro-sulphuric acid to a solution, also renders it highly probable that arsenic is present. If on drying the precipitate, and heating it with a mixture of cyanide of potassium and carbonate of soda, a metallic mirror is obtained, the inference of the presence of arsenic is confirmed. The process is to be conducted as directed in paragraph 458. In this experiment, the cyanide of potassium has the effect of retaining the sulphur, while it allows the volatile arsenic to pass and deposit above.

469. Still another evidence of the presence of arsenic, is afforded in the characteristic garlic odor which is emitted by the flame produced by burning arsenic, in the experiment previously described, called Marsh's

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468. Mention some additional tests for arsenic? 469. What is said of the garlic odor?

test. The same odor is also obtained on sprinkling a little arsenious acid upon burning charcoal.*

470. Preparations for the Arsenic Test.—Before proceeding with the chemical experiments for the detection of arsenic, some preliminary labor is commonly required, to bring the material to be tested into proper form. It commonly consists of matters which have been ejected from the stomach, or of the contents of the stomach itself. If the student wishes to begin at this point in his experiments, he may add a small portion of arsenic to some bread and water and proceed with this paste in his investigation. This mixture is to be diluted with water and saturated with chlorine, as in the process for preparing a solution of this gas. Chlo-

130

470. Mention the preparations for the arsenic test?

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* The Subtlety of Poisons—At a recent discussion before the Society of Arts in London on the detection of arsenical poisoning, Dr. Letheby traced the progress of toxicological research from the trial of Donald, in 1815, up to the present time. A little while before that period, *ten grains* of arsenic were required to make a metallic test satisfactory in a court of law. Afterwards Dr. Black improved the process till he could detect the poison if he had *one grain* to operate upon. It was then thought a marvel of toxicological skill when Dr. Christison said he only required the sixteenth of a grain; but now we can trace the presence of the 250,000,000th of a grain of arsenic! It is to be feared that the detection of this particular poison has reached an almost dangerous degree of delicacy, and extreme caution is necessary in examination for its criminal administration. We live surrounded by means of unconsciously absorbing traces of arsenic; we breathe arsenicated dust from the green wall papers of our rooms; the confectioners supply it wholesale in their cake ornaments and sweetmeats; the very drugs prescribed for our relief are tainted with arsenic; nay, more, even our vegetable food, as Professor Davy has lately pointed out, may be contaminated with arsenic; and there is probably no drinking water containing iron without a trace of arsenic as well. The poison may thus be stored up in the system until in the course of years, the amount becomes appreciable.

rine has the effect of destroying a certain portion of the organic matter, and rendering the rest floculent, so that the liquid may be easily separated from it by filtration. It also brings the arsenic perfectly into solution, as a chloride. This solution is then filtered and treated as directed in the preceding paragraphs.

471. Arsenic Eaters of Austria. — In the mountainous portions of Austria, bordering on Hungary, the peasantry are given to the strange habit of eating arsenic. It is said to impart a fresh, healthy appearance to the skin, and also to make respiration freer when ascending mountains. Those who indulge in its use commence with half a grain, and gradually increase the dose to four grains. If this habit is regularly indulged, its injurious effects are said to be long retarded. But as soon as the dose is suspended, the symptoms of poisoning by arsenic immediately manifest themselves.

Carbon.

Symbol, C; *Equivalent*, 6; *Specific Gravity*, 3.5.

472. Common Forms of Carbon. — Carbon in the form of coal is a well known black and brittle solid. Bituminous and anthracite coals exist in immense quantities buried in the earth in various countries. Bituminous coal differs from anthracite in that it contains a considerable quantity of volatile oil. Anthracite is supposed to have been deprived of volatile oil by

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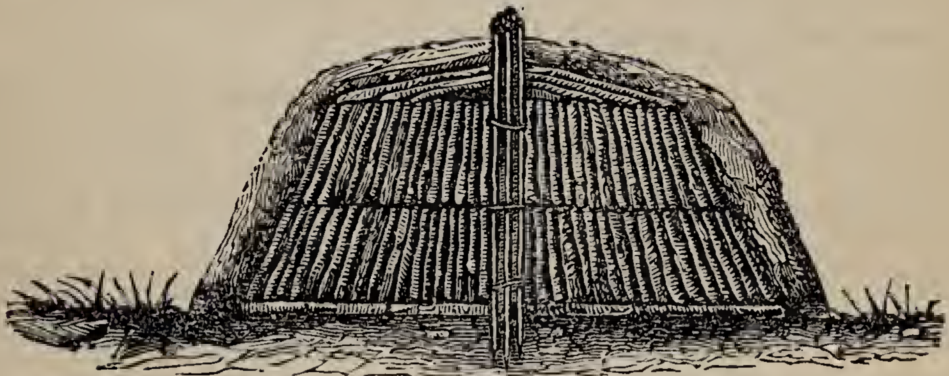
471. What is said of the arsenic eaters of Austria? 472. What are the common forms of carbon?

Hydrogen is necessary for the
production of flame. Either
pure or from [illegible]

the action of subterranean heat which has accumulated those vast stores of rock oil which are becoming of so much importance in commerce. When bituminous coal is heated in retorts for the purpose of obtaining illuminating gas there is left a loose brittle residue, called coke, which differs from anthracite only in form. Charcoal and plumbago are other common forms of carbon.

473. PREPARATION OF CHARCOAL.—Charcoal is commonly made by burning wood in large heaps or pits covered with earth or sod. The arrangement of these heaps is shown in the accompanying figures. Upright bundles of wood in the center serve the purpose of a

181



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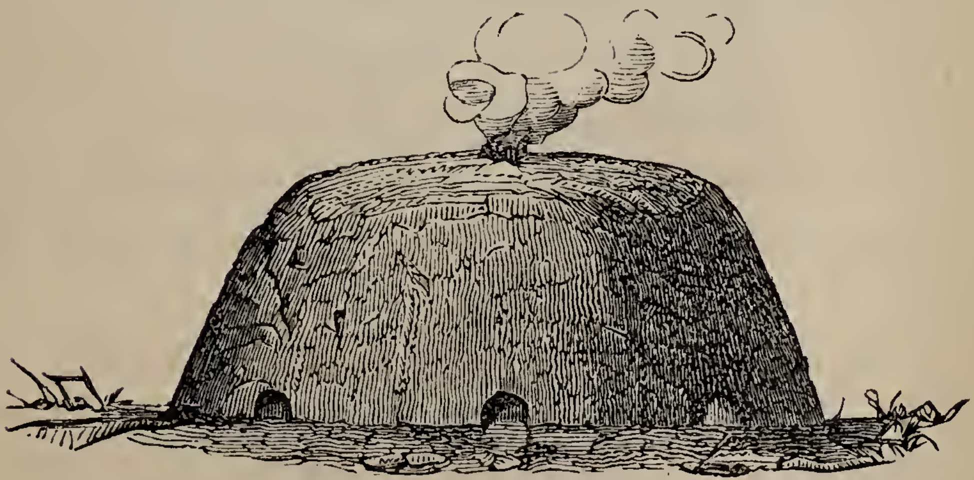

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473. How is charcoal prepared?

carbon - [illegible] heated to

chimney and air is admitted by convenient openings around the base. The whole pile should be thoroughly dried before burning as it makes from 15 to 25 per cent. more charcoal than when green wood is employed. In charring green wood much of the fuel is consumed in driving away the moisture and other gases which combine with it. When the pile is sufficiently charred the openings are closed and the fire being smothered dies out. The whole operation requires from two to four weeks for its completion. Charcoal for the manufacture of gunpowder and for some other purposes is prepared in iron retorts.

474. Smoke is carbon in a finely divided state carried upward by the heated vapor and gases which escape during combustion. The formation of smoke depends upon imperfect combustion, occasioned by insufficient supply of air in the burning fuel. To prevent the formation of smoke it is necessary to supply the fuel in small quantities, so arranged that the air may have ready access to all parts. A strong blast of air driven through the fuel facilitates combustion and prevents the formation of smoke. It is much easier to prevent the formation of smoke than to consume it after it is formed.

475. Lampblack — Ivory-black. — Lampblack is a form of carbon prepared by collecting the smoke of rosin or oil in chambers constructed for the purpose. It consists of unburned particles of carbon. It is used,

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474. What is smoke? and how may its formation be prevented? 475. What is lampblack? What is ivory black?

[illegible]

extensively, as a pigment. India ink is made from the finest quality of lampblack. *Bone black* or *ivory black* is made by heating bones in closed vessels. It is a sort of charcoal produced from the gelatine of bones.

476. Purifying Properties of Charcoal.—Charcoal absorbs gases, and retains them in its pores, in large quantities. Tainted meat, and musty grain, intimately mixed with it, become sweet. The charcoal removes the unpleasant gases proceeding from them. The absorbent power of charcoal may be illustrated, by holding a paper moistened with ammonia, in a vial, until the air within it has acquired a strong ammoniacal odor. On afterward introducing some powdered charcoal and shaking the vial, the odor will be removed.

477. Preservative Properties of Charcoal.—Charcoal may be used as a preventive, as well as a corrective of decay. Posts, if charred at the bottom before they are set, are rendered more durable. Water will keep longer in vessels charred on the inside than in those which have not been thus prepared. The decay of meats and vegetables is retarded by packing them in charcoal. Charcoal is itself one of the most unchangeable of substances. Wheat and rye charred at Herculaneum 1800 years ago, still retain their perfect shape.

478. Decolorizing Effects of Charcoal.—Charcoal has, also, the effect of removing coloring matters,

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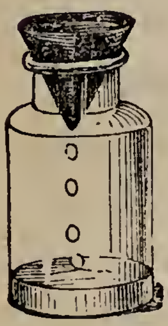
476. Describe the purifying properties of charcoal. 477. Illustrate the preservative properties of charcoal. 478. Describe its decolorizing power.

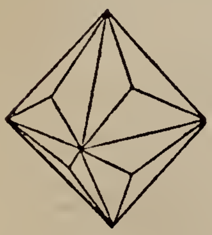
and bitter and astringent flavors from liquids. Thus, ale and porter lose both color and flavor by being filtered through charcoal. Sugar refiners take advantage of this property in decolorizing their brown syrups. Animal charcoal or bone black is best adapted to these uses. As an illustration of the decolorizing effect of charcoal, let water, colored with a few drops of ink, be filtered through bone black. The color will be found to disappear in the process.

131.



479. The Diamond is the purest form of carbon, being often perfectly transparent. It is found in the form of an octahedron—a solid, formed of two square pyramids joined together by their bases. It is also found in other secondary forms derived from the octahedron by beveling its edges and removing its solid angles. The figure shows a common form, bounded by 24 triangular faces. The surface of diamonds is frequently, more or less, rounded by the action of sand and gravel, with which they have been transported.

132



480. Uses of Diamonds.—The diamond is the hardest substance known. Its most important use is for cutting sheets of glass. For this purpose a natural angle is employed, set in a convenient handle. The diamond can only be cut or abraded by its own dust; stones of inferior quality being broken up for this pur-

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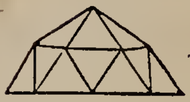
479. What is the purest form of carbon? 480. What are the uses of the diamond?

pose. Diamonds are cut for jewelry in two forms called the rose, figure 134, and the brilliant, figure 133. By cutting, the weight of the diamond is diminished nearly one-half.


133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481. **Value of Diamonds.**—The diamond is the most costly of all gems. The weight of diamonds is estimated in carats.* Small diamonds, unfit for cutting, such as are used by glass-cutters and glaziers, are worth from two and a half to four dollars per carat, and still smaller ones are worth less; they are now employed by lithographers for their engravings and etchings.

A diamond cut for setting, weighing one carat, is worth from 36 to 50 dollars, depending on its color and transparency. The value of diamonds increases in proportion to the square of the weight. A diamond weighing 10 carats is worth 100 times as much as a diamond of one carat, and for diamonds weighing more than 100 carats, when properly cut, the estimated value is much greater than this proportion would indicate. The great diamond belonging to the crown jewels of England, called the Kohinoor (or Mountain of Light), weighs 103 carats, and is valued at from three to ten million of dollars. There are only about thirty diamonds known which weigh over 100 carats each. The finest diamonds are obtained from Golconda in India. But

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481. How is the value of diamonds estimated?

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* The *carat* is a weight of four grains.—*Feuchtwanger's* "Treatise on Gems."

diamonds are obtained in greater quantity from Brazil. The average product being about 15 pounds of diamonds annually.

482. Combustion of Carbon.—All of the forms of carbon are combustible. The combustion of charcoal in air is a familiar fact. Its combustion in oxygen has been already shown. Carbon burns as a spark; it is not changed into a gas until it unites with oxygen, it has, therefore, a greater illuminating power than other substances. This property will be more fully explained further on. The diamond and plumbago will also burn in a vial of oxygen gas, if first intensely heated. The product of their combustion, is precisely the same as that of charcoal. From the carbonic acid, which is produced in the combustion, the carbon may be obtained in the form of lamp black. The nature of the diamond is thus conclusively established.

135

483. Reduction of Ores by Charcoal.—The affinity of carbon for oxygen, at a high temperature, is very intense. It deprives most ores of their oxygen, and converts them into metals. An agent which thus produces metals from their compounds, is called a reducing agent, and the process is called *reduction*. Gaseous carbonic oxide has the same effect as carbon, because the affinity of its carbon for oxygen is only partially satisfied. In the process of reduction, these

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482. What is said of the combustion of carbon? 483. How does charcoal reduce metals.

reducing agents are themselves converted into carbonic acid, by the oxygen with which they combine. Hydrogen gas, in consequence of its strong affinity for oxygen, is also a powerful reducing agent. The reducing power of carbon may be illustrated by sprinkling a little litharge on ignited charcoal, and blowing upon it at the same time, to maintain its heat. The litharge or oxide of lead will thus be partially converted into globules of metal.

Carbonic Acid. CO_2

484. DESCRIPTION.—Carbonic acid is a colorless gas, without much taste or smell, and about one and a half times as heavy as air. Other properties are illustrated in the experiments which follow. This gas is found in many mineral waters, and frequently escapes from fissures in the earth. It is a constituent of all limestones and shells, and forms $\frac{1}{2500}$ part of the atmosphere. It is exhaled from the lungs of all animals, and is a product of the combustion of coal and wood.

485. PREPARATION.—Carbonic acid may be prepared by burning charcoal in oxygen gas, as directed in paragraph 352. Or it may be made by hanging a lighted candle, as long as it will burn, in a bottle filled with ordinary air. In this case, the carbon of the candle is converted into carbonic acid, by the oxygen of the air.

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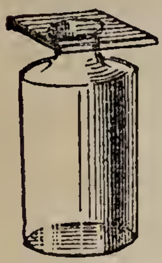
484. What is carbonic acid? Where does it occur? 485. How is carbonic acid prepared?

But neither of these methods gives the unmixed gas, and that which follows is therefore to be preferred.

486. Another Method.—Pour a tea-spoonful of muriatic acid into a large-mouthed half-pint vial, and then add bits of marble, chalk, or carbonate of soda until effervescence ceases. The vial will then be filled with carbonic acid.

136.



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For most of the experiments that follow, the second simple method of collection is sufficient, and the gas need not be transferred to another vessel. When it is desired to obtain it separate from the materials from which it is produced, the apparatus represented in the figure may be employed.

487. Carbonic Acid Prepared in Quantity.—

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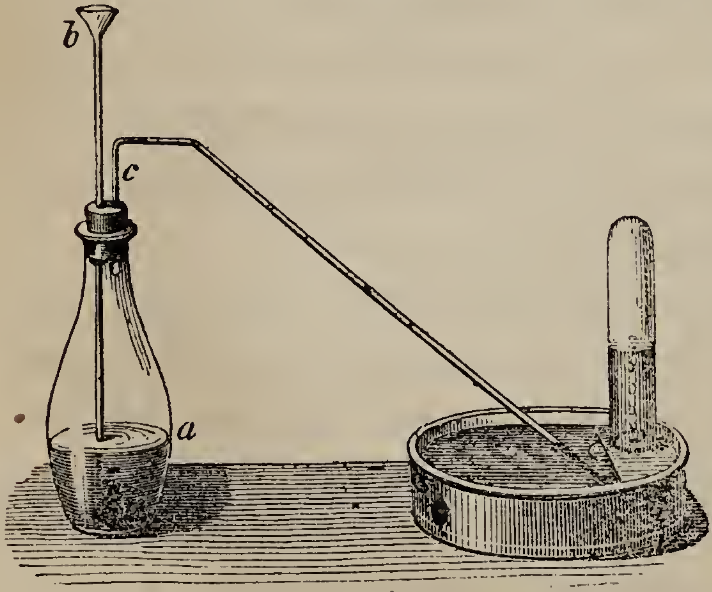

When larger quantities of this gas are required in a very pure state, the fragments of marble are placed in a bottle, *a*, the dilute acid is poured in through the

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486. Give the second method of preparing it. 487. Describe another method of preparation.

funnel, *b*, the gas escapes by the tube, *c*, and is collected in a jar placed over a tub of water as shown in the figure.

488. Explanation.—Chalk and marble are both carbonate of lime. As soon as they are dropped into muriatic acid, this stronger acid combines with the lime and retains it, setting the carbonic acid at liberty in the form of a gas. The gas as it accumulates, expels the air from the vial and completely fills it. It is obvious that in this method we do not make carbonic acid, but use that which nature has already made for us and imprisoned in the marble.

489. Carbonated Waters.—Water absorbs its own volume of carbonic acid and thereby acquires an acid taste. The so-called "soda water" or "mineral water," is prepared by confining water in a strong metallic vessel, and forcing into it gaseous carbonic acid, by means of a forcing-pump. The increased quantity which it is thus made to absorb is in precise proportion to the pressure employed. Neither of the above names give a correct notion of the nature of the effervescent drink referred to. It is simply carbonated water, to which soda is sometimes added.

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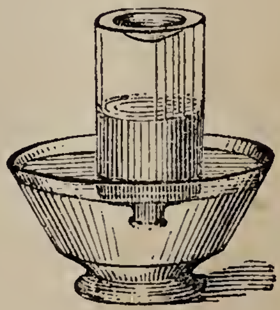

490. The absorption of carbonic acid by water may be shown, like that of chlorine, by the method illustrated in the figure. It may also be shown by pouring a gill of water into a half-pint vial of carbonic acid and then

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488. Explain the above process. 489. How are carbonated waters made?

shaking it. The palm of the hand being pressed closely upon the mouth of the vial, the flesh will be more or less drawn in, to take the place of the gas absorbed. The vial may be supported by this attachment.

491. Effervescent Drinks.—Champagne, sparkling beer and mead, Congress water, and similar drinks, owe their effervescent qualities to this gas held in solution. On exposure to the air, the gas gradually escapes, and the liquids become insipid to the taste. The air enters and takes its place, expelling sixty or seventy times its own volume of gas. This effect may be hastened by striking, with the hollowed palm of the hand, upon the top of a glass partly filled with one of these liquids; thereby compressing the air, and forcing it to enter rapidly. The carbonic acid immediately escapes with renewed and rapid effervescence.

492. Flame Extinguished by Carbonic Acid.—Lower a lighted taper, candle, or splinter of wood into a vial of carbonic acid, prepared as above directed. The flame will be immediately extinguished, as if it had been dipped in water.

493. Or the same experiment may be performed by pouring the gas into a vial, at the bottom of which is a bit of

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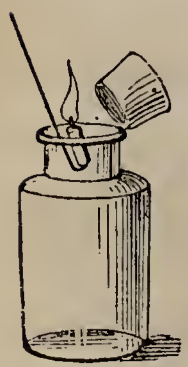

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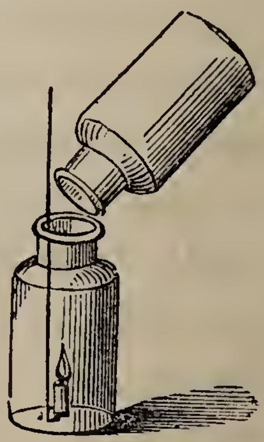

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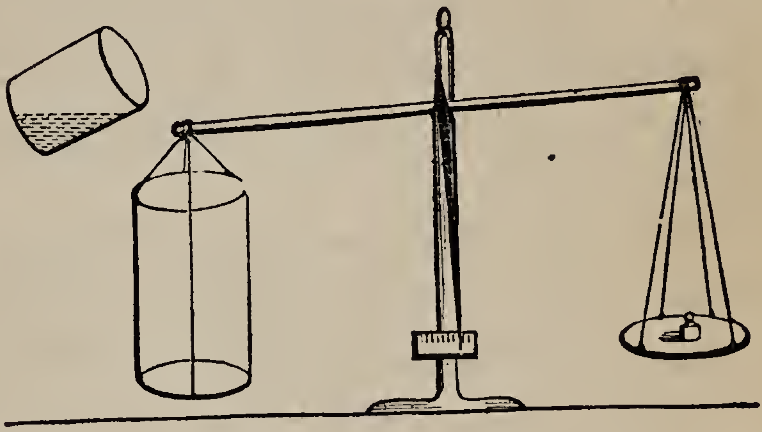
491. What is said of effervescing drinks? 492. What effect has carbonic acid on flame? 493. Give another method of performing the experiment.

lighted candle. Nothing will be seen to flow from one vessel into the other, but the effect will be the same as before.

494. Carbonic Acid heavier than Common Air.—Soap bubbles filled with common air float in carbonic acid gas. If we pour carbonic acid into a light jar poised upon a balance it causes that arm of the balance to descend because the carbonic acid is heavier than the air which it contained when the equilibrium was adjusted.

142



495. Carbonic Acid is Food for Plants.—Carbonic acid is one of the principal elements of the food of plants. The leaves absorb it from the air, and the roots from the earth, and convert it into wood and fruit. The subject is further considered in the latter part of this work.

496. It is Poison for Animals.—Water impregnated with carbonic acid is a healthful drink; but the same gas when taken into the lungs, produces death. It operates negatively, by excluding the air, and also positively, as a poison. Being heavier than the air,

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494. How is carbonic acid shown to be heavier than air? 495. Of what use to plants is carbonic acid? 496. What is the effect of carbonic acid on animals?

lakes of this gas sometimes collect in the bottom of caverns. There is a grotto of this kind in Italy, called the Grotto del Cane, or "dog's grotto." A man walking into it is safe, but his dog, whose head is below the surface of the gaseous lake, is immediately suffocated. Butterflies and other insects can be readily suffocated, without injury to their delicate organs or their beautiful colors, by placing them in a jar filled with carbonic acid. Baths of carbonic acid have recently been employed, with advantage, in the treatment of rheumatism and other similar affections, and in cases of enfeebled vision.

497. How Removed from Wells.—Carbonic acid often collects in the bottom of wells, and occasions danger, and sometimes death, to workmen employed in cleaning them. A candle previously lowered into the well will indicate the danger, if it exist. The flame will burn less brilliantly, or be entirely extinguished, if much of the gas is present. By repeatedly lowering pans of recently heated charcoal into the well, and drawing them up again, the gas will be absorbed and removed. The charcoal is first heated, to increase its absorbing power. In this condition it absorbs thirty-five times its own bulk of gas. Dry slaked lime will also rapidly absorb carbonic acid. Exciting currents in the air of the well, as by throwing down buckets of water, or drawing water from the well causes the noxious gas to rise into the atmosphere. The gas may even

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497. How is carbonic acid removed from wells?

be drawn up in buckets and poured away like so much water.

498. CHARCOAL FIRES IN CLOSE ROOMS.—Fatal accidents not unfrequently occur from inhaling the fumes of charcoal burned in close unventilated rooms. These fumes consist of mingled carbonic acid and carbonic oxide. The latter gas will be hereafter described.

499. RECOVERY FROM POISONING BY CARBONIC ACID.—Persons who have become insensible by the action of carbonic acid may be resuscitated by dashing cold water upon them, rubbing the extremities and by the application of a warm bath if the body is cold.

500. SOLIDIFICATION OF CARBONIC ACID.—One of the most interesting of all chemical experiments, is the solidification of carbonic acid. By combined cold and pressure, this transparent gas, which, under ordinary circumstances, is so thin that the hand, passed through it, does not recognize its presence, can be converted into a solid snow. This is done by bringing into a strong iron cylinder, connected by a tube with a second similar receptacle, the material for making more of the gas than there is room for in the two vessels. The cylinders being closed, and the gas produced by the agitation of the materials, it is evident that they must burst, or the gas must pack itself away in some more condensed form. The second vessel is surrounded by ice, and kept extremely cold, during the process. In

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498. How does burning charcoal cause fatal accidents? 499. How may persons poisoned by carbonic acid be resuscitated? 500. How may carbonic acid be solidified

this colder vessel the gas assumes a liquid form. Being removed in this condition, one portion of the liquid evaporates so rapidly as to freeze the rest. An explosive expansion of the liquid into gas would naturally be anticipated, but this does not occur. The materials used in the process are sulphuric acid and carbonate of soda. This experiment is attended with considerable danger and should only be performed in apparatus of great strength constructed for the purpose.

60 **501.** Carbonic Oxide.—When carbonic acid is passed through hot coals, it loses half of its oxygen and becomes carbonic oxide. This takes place in coal fires. The coal in the lower part of the grate, where air is plenty, receives its full supply of oxygen and becomes carbonic acid. The hot coals above, where the supply of air is limited, take half of the oxygen from the carbonic acid, and reduce it to this oxide, converting themselves partially into carbonic oxide at the same time. The new gas passes on to the top of the fire, and there, where air is again abundant, it burns with a blue flame, and reconverts itself into carbonic acid. This gas is much more poisonous than carbonic acid, and is one source of the danger which arises from open fires in close rooms. One-two-hundredth of it makes the air, if inhaled for any considerable time, a fatal poison.

502. Economy of Fuel.—A stove called the "*American Gas Burner*," furnishes several jets of heated air which enter the fire just above the burning coal, con-

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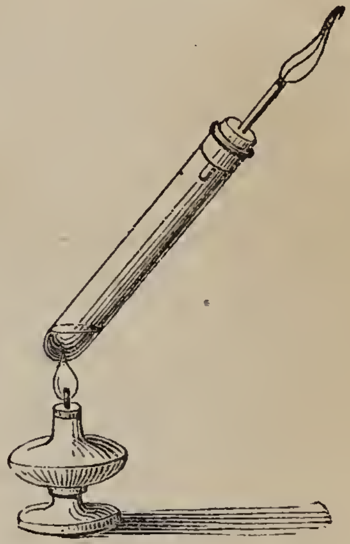
501. How is carbonic oxide formed? 502. How may the most heat be obtained from a given amount of coal?

verts all the carbonic oxide into carbonic acid, and for this reason furnishes more heat from the same fuel than if the carbonic oxide passed unburned into the chimney.

503. Combustion of Carbonic Oxide.—For small experiments, the gas is best prepared by covering a half tea-spoonful of oxalic acid* with oil of vitriol, and heating them together in a test-tube. The gas, on being kindled at the mouth of the tube, burns with a beautiful blue flame. The experiment is rendered more striking by producing a jet, as represented in the figure. The gas thus obtained is really a mixture of carbonic oxide with carbonic acid, but the admixture does not materially affect the experiment.

143



504. Explanation.—Each molecule of oxalic acid contains carbon, oxygen and hydrogen, in the proportion to form one molecule each, of water, carbonic oxide and carbonic acid. Through the agency of sulphuric acid this decomposition is effected. The water remains with the acid while the gases are evolved.

505. It produces Metals from Oxides.—With the help of a high temperature, carbonic oxide takes oxygen from oxides, and converts them into metals. It

503. How is carbonic oxide best prepared? 504. Explain the formation of carbonic oxide. 505. What is the effect on metallic oxides?

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* This acid has the appearance of salt and is poisonous.

contains oxygen already, but its chemical appetite is only half satisfied with that element. It is this gas, produced in the fire, as before described, which converts iron ores into metal, in the smelting furnace. It is itself converted into carbonic acid at the same time.

Nov 13th to May 1st

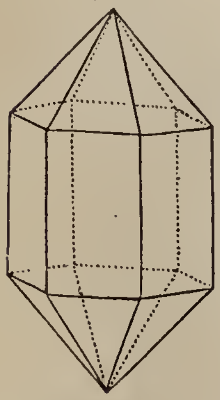
Silicon.

Review June 1st [illegible]

Symbol, Si; *Equivalent*, 14.

506. Description.—Silicon is a dark gray substance, possessed of metallic luster, but classed with the metalloids because it resembles them in its compounds. It is also called silicium. It is prepared from silica, by the method hereafter described for the production of calcium from lime.

144



507. Silicic Acid or Silica.—Quartz or rock crystal is nearly pure silica. It crystallizes in six sided prisms terminated by six sided pyramids. These crystals are sometimes called diamonds, but real diamonds are never found in this form. Transparent and colorless rock crystal is used for jewelry. In the form of Scotch pebbles it is used for spectacles. Sea-sand, flint, opal, jasper, agate, cornelian, amethyst and chalcedony, are other forms of the same substance, colored by the presence of some metallic oxide. It also forms part of a

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506, What is silicon? 507. What is silica very abundant class of rocks, called *silicates*, and probably constitutes one-sixth of the mass of the earth. Silica occurs in many plants as in the cuticle of the scouring rush, in most of the grasses and grains, and in the bamboo, which belongs to the same family as the common grasses. Silica is an important ingredient in the manufacture of glass.

508. Soluble Silica may be dissolved in water, by first fusing it with a large proportion of potash. On then adding acid, to neutralize the potash, the silica precipitates in the form of a jelly. Place a solution of silicata of potash in a cylindrical vessel formed of vegetable parchment (See Part IV); place this cylinder in a vessel of water and add to the silicate muriatic acid sufficient to neutralize the potash; the muriate of potassa will all pass through the parchment into the outer vessel while the silica will remain in a state of solution. By keeping the apparatus perfectly quiet a solution containing nearly thirty per cent. of silica may be obtained. On agitating the solution it will at once assume the gelatinous form. By this circuitous process the most gritty sand is converted into a soft jelly. A singular application of this rock-jelly, in the adulteration of butter, has recently been detected in England. Dissolved silica also occurs in nature, and hardens into agates, onyx, and other precious stones.

509. Petrifactions.—As wood wastes away in cer-

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508. How can silica be made soluble? 509. What is the cause of petrifaction?

tain silicious waters, the particles of silica take, one by one, the place of the departing atoms, and thus copy the wood in stone. Such copies are called petrifactions.

Boron.

Symbol, B; *Equivalent*, 10.9;

510. Description.—Boron is a brown powder, never seen except in the chemist's laboratory, and of no practical value. It occurs in nature, combined with other elements, as borax and boracic acid.

511. Boracic Acid.—This acid is commonly seen in the form of white pearly scales, which have a greasy feel. Dissolved in alcohol it burns with a green flame. It exhales with volcanic vapors which issue from the earth in Tuscany. These vapors are condensed in water, and the solid acid is obtained by evaporating the solution. It is bitter, rather than sour, to the taste, but is called an acid because it forms salts.

Boracic acid communicates to its compounds the property of ready fusibility, and on this property its value chiefly depends. Many of the borates are used as fluxes, which are applied as glazing for porcelain and in the melting of gold and silver. If steam at a high temperature is transmitted over boracic acid, the acid is volatilized in considerable quantities. It is in this way raised to the surface of the earth in Tuscany by the jets of steam which issue from the strata below.

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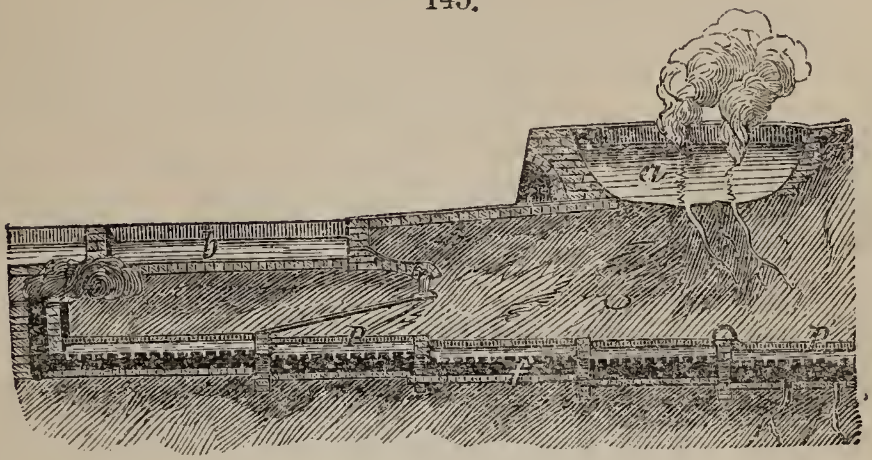
510. What is boron? 511. How is boracic acid formed?

These vapors are condensed by artificial pools of water, *a*, figure 145, into which they are received. The solution is still further condensed in other shallow basins, *b*,

145.



and afterwards evaporated in shallow pans, P P, by the heat of jets of steam issuing from the earth through flues, *f*, under the evaporating pans. About two thousand tons of the crude acid are thus procured in Tuscany. It is also obtained in Thibet as a biborate of soda called *tincal.* Combined with lime and magnesia boracic acid is obtained in South America.

Hydrogen.

Symbol, H. *Equivalent* 1. *Specific Gravity,* 0.0692 (Air being =1).

512. Description and Occurrence.—Hydrogen is a colorless gas, about one-fifteenth as heavy as the air. It is of such extreme tenuity, that it may be blown through gold leaf and kindled on the opposite side. One-ninth part of the ocean, and the same proportion

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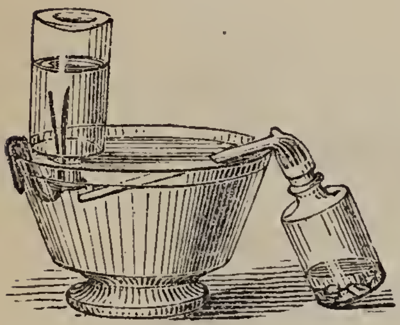
512. What is hydrogen? Where does it occur?

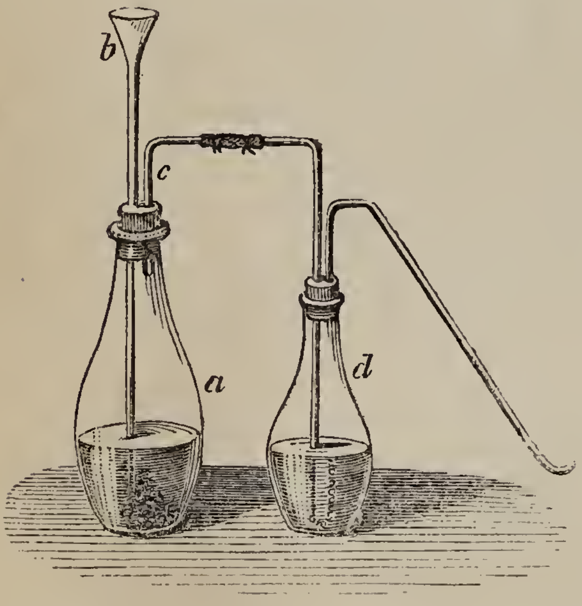
of all water in existence, is hydrogen gas. It enters, also, largely into the composition of all animal and vegetable matter, and forms the basis of most liquids.

146



513. PREPARATION.—Introduce a few bits of iron or zinc into a vial one-third filled with water. Add a tea-spoonfull or more of common sulphuric acid, and attach to the vial a bent tube or a clay pipe, as represented in the figure. The evolution of the gas immediately commences. The first portions, which contain an admixture of air, are allowed to escape; the pipe-stem is then brought under the mouth of the vial, and the gas collected.*

147



When a considerable quantity of hydrogen is required, the apparatus shown, in figure 147, is more convenient, and the gas is collected in jars over water. If a considerable

513. Describe the methods of preparing hydrogen.

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* When a taper can be applied at the mouth of the pipe-stem without explosion, it may be certainly known that an unmixed gas is in process of evolution. A cloth should be thrown over the vial and this test made before commencing the collection. The connection of the apparatus in the above experiment is made with a paper stopper, formed on a bit of pipe-stem or glass tube.

quantity of acid and zinc is placed in the jar, *a*, the evolution of gas becomes so rapid that the dilute acid is carried over with the gas. The tube, *b*, extending below the fluid in *a*, renders it easy to add the acid in small quantities, so as to keep up a moderate and continuous evolution of hydrogen. A wash bottle, *d*, contains potash dissolved in alcohol to absorb acid vapors, sulphuretted hydrogen and carbonic acid, which are frequently produced by impurities in the materials employed for preparing hydrogen. One ounce of zinc is sufficient to liberate 2½ gallons of hydrogen.

514. Explanation.—Water is composed of oxygen and hydrogen gases. Each would be a gas, but for the other, which holds it in the liquid form. In the above process for preparing hydrogen, the zinc is, as it were, the ransom paid for its liberation. The oxygen combines with the zinc, and the hydrogen escapes.

515. Pure water will not suffice in the process. It must contain acid, to unite with the oxide of zinc, as fast as formed. The presence of an acid, for which the oxide has great affinity, seems to stimulate its formation. It may, indeed, be regarded as a general law, that the presence of acids promotes the formation of oxides, and *vice versa*.

516. Another Method.—Hydrogen may also be made by passing steam through a heated gun-barrel containing bits of iron. Bundles of knitting needles are commonly employed for the purpose. The steam

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514. Explain the formation of hydrogen? 515. What purpose is served by the acid? 516. Give another method of preparing it.

leaves its oxygen, combines with the iron, and escapes as hydrogen gas.

NOTE.—Although red hot iron thus decomposes vapor of water, forming oxide of iron, yet if hydrogen is passed over red hot oxide of iron, the hydrogen takes the oxygen from the iron and forms water, leaving the iron in the metallic state. The affinity of iron and hydrogen for oxygen is so nearly balanced that whether the iron or hydrogen shall hold the oxygen depends upon the relative temperatures and the abundance in which one or the other substance is present.

517. WATER GAS.—When vapor of water is passed over charcoal heated to redness, the water is decomposed, and the hydrogen is set free. The oxygen of the water unites with the carbon to form carbonic acid, CO_2, and a small quantity of carbonic oxide, CO, together with a little light carburetted hydrogen, C_2H. The mixed gases are then passed through milk of lime, to remove the carbonic acid, and the remaining gas, which is mostly hydrogen, is employed for heating and illuminating purposes under the name of *water gas.* A jet of burning hydrogen gives but little light, and the same is true of the water gas; but if the flame is enveloped with a cage of platinum wire a brilliant light is produced. If the water gas is passed through rock oil a part of the oil is carried in a state of vapor with the gas and greatly increases the brilliancy of the light. But the volatile oil carried over with the gas is soon deposited and clogs the gas pipes.

518. COMBUSTION OF HYDROGEN.—Bring a dry cold

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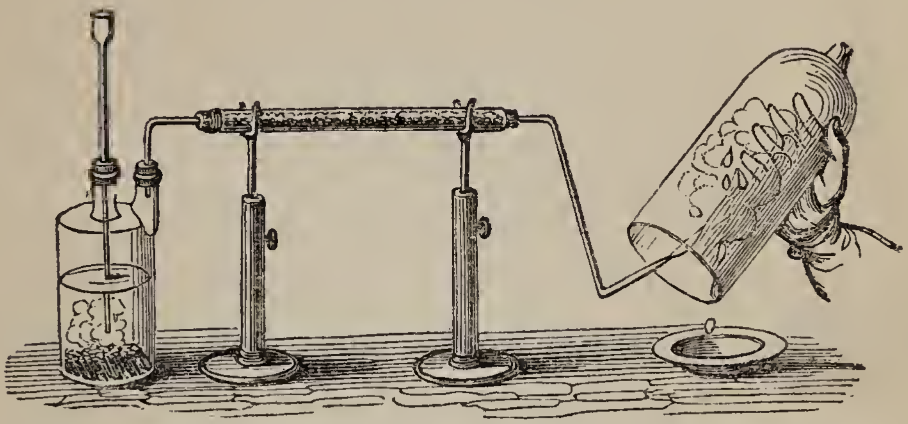
517. How is the material called water gas produced? 518. What is produced by the combustion of hydrogen?

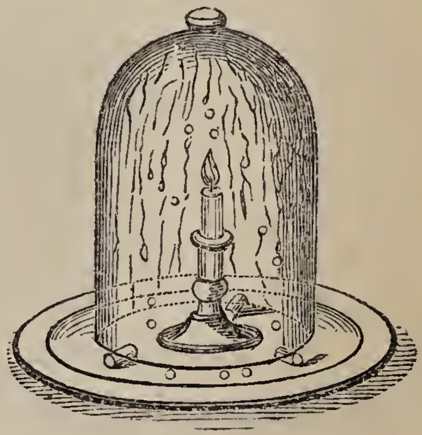
tumbler over a burning jet of hydrogen. The vessel will soon become moistened on the interior. The water thus produced, is a result of the combination of hydrogen with oxygen of the air. But for the cold surface, with which it is brought into contact, it would have escaped into the air as vapor.

148



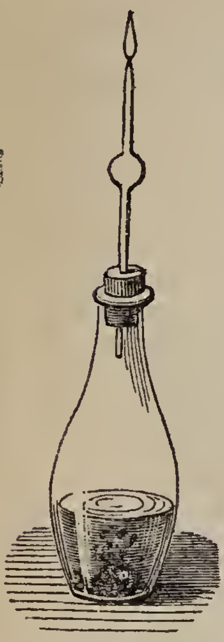
In the experiment shown in the figure, the hydrogen is first passed through a tube filled with chloride of calcium to absorb any traces of moisture which might pass over from the bottle in which the hydrogen is generated. The water formed is seen trickling down the sides of the bell glass into the dish placed to collect it.

149.



The composition of water was shown in Part I., (§ 268,) by Galvanic decomposition. It is here demonstrated by combining its elements and thus reproducing it. Water is also formed in the combustion of any substance containing hydrogen as one of its constituents. The above experiment may therefore be made with a lighted lamp or candle, as well as with the jet of pure hydrogen. This experiment shows that the candle contains hydrogen.

150.



519. Philosopher's Lamp.—If a tube is inserted into the mouth of a vial or flask containing the materials for producing hydrogen, the gas as it issues may be ignited, when it will burn with a delicate and almost invisible flame. This apparatus, which is shown in the figure, is called the philosopher's lamp. The gas should always be allowed to issue several minutes before it is ignited, so that all the air in the bottle may pass off; otherwise an unpleasant explosion might occur.

520. Explosion of mixed Oxygen and Hydrogen.—Allow oxygen to flow into an inverted vial, as directed in paragraph 343, until it is one-third full. Fill it up with hydrogen, collected as shown in Sec. 513. Cork the vial under water. It is now filled with an explosive mixture, which may be fired by the application of a taper. To secure against accident, the precaution should invariably be observed of winding the vial with a towel, before the discharge.

151

521. Explanation.—The explosion results from the fact that all of the hydrogen in the vial burns at once, causing great heat, and sudden expansion of vapor. The combustion is thus simultaneous, because oxygen,

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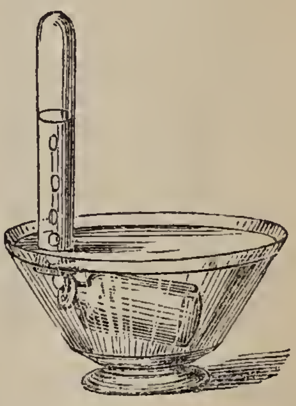
519. Describe the philosopher's lamp. 520. How is an explosive mixture prepared? 521. Why does this mixture explode?

the supporter of combustion, is present at every point. When on the other hand a jet of hydrogen is kindled, no explosion occurs, because the combination is gradual. Combustible hydrogen meets with oxygen in this case, only on the surface of the jet.

522. The Hydrogen Gun.—The experiment for the explosion of mixed hydrogen and oxygen gases, may be made in a strong tin tube, provided with a vent near the closed end. Such a tube, about an inch in diameter, and eight inches in length, is called the *hydrogen gun.* In loading it, the vent is stopped with wax, the tube filled with water, and the gases, previously mixed in the right proportion, poured upward into it, as indicated in the figure. The gun, being thus loaded, is tightly corked under water, and afterward fired at the vent. The explosion is sufficient to expel the cork with violence, accompanied by a loud report. The vial from which the tube is loaded must not be too large, or it will not be practicable to turn it and pour upward, as desired. This difficulty may also be obviated, by the substitution of a water-pail, for the bowl represented in the figure.

152



523. Charge of Air and Hydrogen.—As air contains uncombined oxygen, a mixture of air and hydrogen also forms an explosive mixture. But, as air is only one-fifth oxygen, five times as much of it must be

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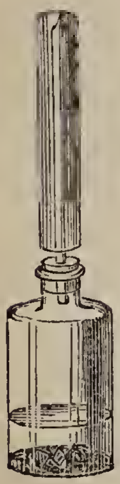
522. Describe the hydrogen gun, and the method of charging it. 523. Describe another explosive mixture.

used; in other words, five parts of air are required, for every two parts of hydrogen. To make the mixture, hydrogen may be led, as before, into an inverted vial a little more than two-thirds full of air. The exact proportion is not essential in this, or any similar case of explosive mixture.

524. A Simpler Method.—A simpler method of loading the gun, or charging the vial with the explosive mixture, is to invert it over a jet of hydrogen, as represented in the figure. The pipe-stem, or tube, which conveys the gas, is previously wound with paper, until it occupies about two-thirds of the inner space of the gun. Escaping hydrogen fills the remainder. On withdrawing the tube, air enters to take its place, and the gun is thus charged with mixed air and hydrogen, in the right proportions. It is then corked and fired. This experiment may also be made with a test-tube, discharging it at the mouth. Explosions with mixed air and hydrogen, are, of course, less violent than when pure oxygen is used instead of the diluted oxygen of the air.

153



525. Production of Musical Tones.—When a jet of hydrogen escaping from a small aperture is set on fire it burns with a tranquil and almost invisible flame, as in the case of the philosopher's lamp; but if an open glass tube is held over the jet so as to form a chimney,

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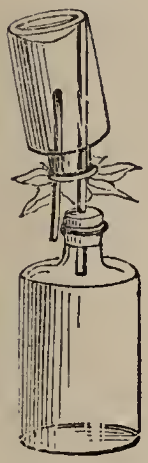
524. Give a simpler method of loading the gun. 525. How are musical tones produced by burning hydrogen?

the hydrogen will burn with a flickering flame. A succession of little explosions is produced which follow each other so rapidly as to produce a continuous sound or musical note. The longer and narrower the tube the more acute will be the note produced. By using a series of tubes of proper diameters and lengths all the notes in the musical scale may be produced.

526. HYDROGEN WILL NOT SUPPORT COMBUSTION.—Flame is extinguished in hydrogen, as it would be in water. Re-charge the gas bottle, if necessary, and hang a second large-mouthed vial above it, as represented in the figure. After a few minutes, it may be presumed that the upper vial is filled with hydrogen. Apply a lighted match to its mouth, and the gas will inflame and continue to burn with a faint light. Introduce a taper into a jar of this gas as represented in figure 155. It will be kindled at the mouth of the jar, and again extinguished above. The match is extinguished, figure 154, because, a little above the mouth of the vial, there is no oxygen to support the combustion of the carbon and hydrogen of which it is composed.

154



155

527. HYDROGEN MADE BY THE METAL SODIUM.—Another very beautiful but more expensive method of making hydrogen gas, is as follows. Fasten a piece of

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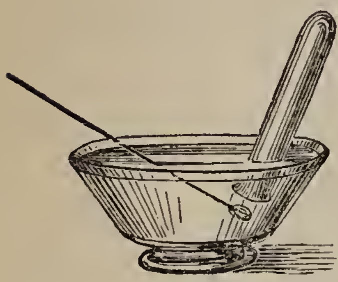
526. Does hydrogen support combustion? 527. Describe the preparation of hydrogen by sodium.

metallic sodium, of the size of a pepper-corn, upon the end of a wire and thrust it suddenly under the end of a test-tube filled with water, and held very near the surface, as represented in the figure. The metal melts as soon as it touches the water, and rises to the top of the tube. Hydrogen is immediately formed, and displaces the water, filling the tube rapidly with the liberated gas.

156



528. Explanation.—Sufficient heat is evolved by the action of sodium on water to fuse it at once. The metal is lighter than water, and therefore rises to the top of the tube. At this point the chemical process begins. Sodium has the most intense affinity for oxygen, and therefore combines with this element of the water, setting its hydrogen at liberty. No acid is required as in the case of zinc. Metallic potassium may also be used in this experiment. To avoid its ignition by contact with the water, it is to be wrapped in paper, and the twisted end of the wrapper used as a holder, with which to thrust it under the mouth of the tube.

Nov. 13th

Water.

Silicates Carbonates & Nitrates

Symbol, HO; *Equivalent*, 9; *Specific Gravity*, 1.

529. Composition.—Many important properties of water have already been illustrated in the chapter on Vaporization. Others will be mentioned below. It is

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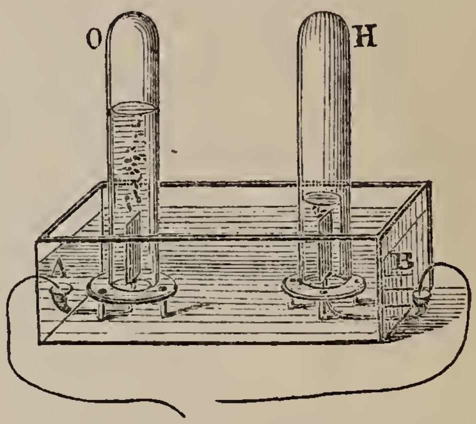
528. Explain the process. 529. Of what is water composed?

composed of oxygen and hydrogen, as has already been proved both by analysis and synthesis. These gases are condensed in combination to about $\frac{1}{2000}$ of their original volume. It remains to show how the exact proportion in which they enter into the composition of water is ascertained.

530. First Method of Proof.—One method is to decompose water by the Galvanic process, and collect and weigh the gases obtained. Two jars or tubes are filled with water and inverted in the pneumatic cistern. Under the tubes are metallic plates connected by wires with the cups A and B which are filled with mercury. The positive pole of a Galvanic battery is placed in A and the negative pole in B. When the connection is formed the water is decomposed the oxygen collects in O and the hydrogen in H. The oxygen is found to weigh eight times as much as the hydrogen. Water is thus shown to be composed of eight parts of oxygen, by weight, to one part of hydrogen. In other words, nine pounds of water contain eight pounds of oxygen and one pound of hydrogen.

157



531. Second Method.—Another method is to *measure* the gases obtained by the same method of decomposition. Two measures of hydrogen are thus obtained

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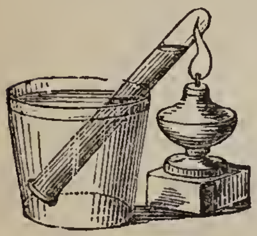
530. Describe the method by Galvanic decomposition. 531. Show how composition by weight may be calculated from measure.

for every single measure of oxygen. The chemist then proceeds to calculate the relative weight. Knowing beforehand that hydrogen is the lighter gas, weighing but one-sixteenth as much as the same quantity of oxygen, he infers that the double volume obtained in the above experiment, weighs but one-eighth as much as the oxygen obtained in the same decomposition. The result of this indirect process is the same as that stated at the conclusion of the last paragraph.

532. Third Method. — A third method consists in reproduction of water from mixed hydrogen and oxygen, observing at the same time the quantities in which they combine. This may be readily effected in a test-tube. The gases being introduced into the tube in about the right proportion, and in small quantity, its extremity is then intensely heated. A slight explosion and combination of the gases is the result, and the water rises to take their place, mingling with the small quantity of water produced in the experiment. Any excess of either gas remains uncombined. Whether this surplus is oxygen or hydrogen, may be readily proved by methods previously given. This excess being substracted from the quantity of the same gas originally used, shows the proportion in which the combination has occurred.

158



533. The explosion may be avoided, and a gradual combination of the gases effected, by evaporating a few

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532. Describe the third method. 533. How may the explosion be avoided?

drops of platinum solution in the test-tube, and igniting the residue previous to the commencement of the above experiment. A ball of fine iron wire is then crowded into the end of the tube. The mixture of gases being finally introduced, the least touch of flame upon the end of the tube is sufficient to effect a gradual combination. For an explanation of the agency of platinum in the above experiment, the student is referred to the chapter on metals. The iron wire serves to prevent ignition, and consequent explosion, by appropriating part of the heat produced by the combination of the gases. The form of the experiment last described, is the only one that can be recommended to the student. With the security against explosion which it affords, a test-tube filled with the mixed gases may be submitted to experiment. Where very accurate results are sought, the process must be conducted in a carefully graduated tube. By employing mercury instead of water, the water produced in the experiment may be seen.

534. Fourth Method.—Still another method is illustrated in the figure. It consists essentially, in the production of water from its elements as before; furnishing, at the same time, the means of ascertaining the proportional weight of the gases which have taken part in its formation. By means of an aspirator, a current of perfectly pure and dry hydrogen gas is made to pass over a weighed portion of oxide of copper at a red heat; the hydrogen, at a high temperature, takes away

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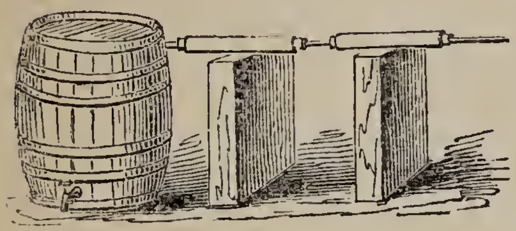
534. Give the method by oxide of copper

the oxygen from the oxide of copper, and, uniting with it, forms water, which is absorbed by a tube containing fragments of pumice stone saturated with oil of vitriol. The aspirator* shown in the figure, affords the means of drawing the gas through the tubes, as in the analysis of air (§ 436). Both tubes are afterward weighed, and their gain or loss determined by comparison with their weight before the commencement of the process.

159



535. The loss of weight in the one tube, expresses the weight of the oxygen which it has furnished for the formation of water; the gain in the second tube gives the weight of the water thus formed. The difference of the two, gives the weight of the hydrogen which has been appropriated in its passage, and now makes part of the newly formed water. For every nine grains of water thus produced, it is found that eight grains of oxygen, and one of hydrogen have been consumed. Its precise composition is thus demonstrated by another and quite distinct process.

536. Solution.—Water is a very general solvent. The disappearance of salt or sugar, in water, is an example.† Transparency is essential to a solution.

535. How are the results calculated? 536. What is said of solution?

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[*] A vessel employed, as in the present instance, to produce a current of air or gas, is called an aspirator.

[†] Water also dissolves many gases. The ammonia of the shops is prepared by passing gaseous ammonia into water.

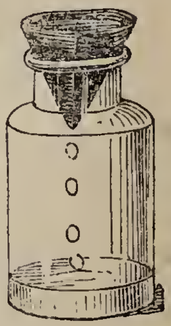
Where the particles of a solid are distributed throughout a liquid, as when chalk is stirred with water, it is said to be diffused, instead of dissolved. The solvent action of water plays a most important part in nature, as will be seen in another chapter of this work. The subjects of solution and precipitation, are more fully considered in the chapter on salts.

537. PRECIPITATION.—Where a substance which has been dissolved is re-converted into a solid form, it is said to be *precipitated*. Thus, when air from the lungs is blown through a pipe-stem into lime-water, the lime combines with the carbonic acid from the lungs, and falls to the bottom of the vessel, in the form of solid particles of chalk. The solid thus produced is called a *precipitate*.

160

The addition of a few grains of alum to a barrel of water coagulates organic matter which it often contains, and causes it to settle to the bottom. River water is often purified in this manner.

161



538. FILTRATION.—Filtration is the separation of a precipitate from the liquid in which it is contained. This is effected by throwing the mixture into a paper cone, which retains the solid, while the liquid passes through its pores. Such a filter is prepared by folding unsized paper into the shape of a quadrant, which is then opened, so as to

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537. What is precipitation? 538. What is filtration, and how is it effected?

form a cone, commonly supported in a glass funnel. It is possible, in small experiments to dispense with the funnel, as is done in the figure, and even to use ordinary newspaper in the place of that especially prepared for the purpose.

Matter actually dissolved in water is not affected by filtration. No repetition of filtration would withdraw the salt from seawater and make it fresh. Hence the impregnation of peaty matter, which river water generally contains, and to the greatest extent in summer when the water is concentrated by evaporation, is not removed by filtering.

539. Purity of Water.—In nature water is never found entirely pure. Rain-water contains air and other gases in a state of solution, as well as considerable dust collected from the atmosphere. So also various mineral substances which are carried into the air in a state of vapor, are found condensed and dissolved in rain water. River-water contains considerable vegetable matter which it has dissolved as it has flowed over the hills and fields from whence it has been collected.

The presence of vegetable and animal matter in river-water often renders it injurious to health until it has been kept in tanks or reservoirs and undergone a species of fermentation by which organic matter is reduced to the inorganic condition and separated by precipitation.

Spring-water in addition to air and carbonic acid in

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539. What is said of the purity of natural waters?

a state of solution* always contains more or less mineral matter dissolved in it. When spring-water contains so much mineral matter as to give it a decided taste the spring from which it comes is called a mineral spring.

540. Hard and Soft Water.—Water which contains lime or magnesia in solution in any appreciable quantity is called hard water. The familiar method of determining the presence of these substances is by the action of the water upon soap which is curdled by both lime and magnesia. Water which curdles soap is called hard and that which has no such action is called soft water. Soft water has a greater solvent power over most substances than hard water, it is therefore more suitable for washing and other domestic purposes than hard water. Soft water acts upon lead pipes dissolving the oxide of lead formed upon its surface, which imparts poisonous properties to the water. Hard water is less injured by contact with lead. All extracts and soups are best prepared with soft water, while vegetables boiled in hard water, or water to which salt has been added, retain their flavor better than if boiled in soft water. Yet beans and peas which require to be made

540. When is water said to be hard? and when soft?

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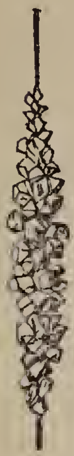
* Water at 32° F. dissolves 1.8 its own volume of carbonic acid, 0.04 of oxygen and 0.02 of nitrogen, while at 59° F. it dissolves one volume of carbonic acid, 0.03 of oxygen and 0.015 of nitrogen. It will be seen that this is a much greater proportion of oxygen and carbonic acid and less nitrogen than is found in common air. From the gases thus dissolved fishes obtain oxygen and plants carbonic acid. At an altitude of 6 or 8000 feet water contains only one-third the usual amount of air. Hence fishes cannot live in Alpine lakes as the water does not contain sufficient air to sustain their respiration.

soft by boiling should be cooked in soft water, or water to which a little soda has been added.

162



541. Crystallization.—Dissolve half a pound of alum in a pint of boiling water, and hang a cotton cord in the vial. As the water cools, crystals will form on the thread. Bonnet wire may be bent into the shape of baskets, miniature ships, &c., and covered by this means, with a beautiful crystallization.

542. Explanation.—Hot water has for most substances greater solvent power than cold water. In the case of alum, for example, water slightly warmed will dissolve twice as much as cold water. It follows, that as the hot water becomes cold, part of the alum must become solid again. In so doing, the particles, in obedience to their mutual attraction, arrange themselves in crystals, as described in Chapter III.

543. Snow Crystals.—Snow flakes are always either grouped or single crystals, and their form may often be distinctly seen with the naked eye. They are best observed by catching them upon a hat, or other dark object, and inspecting them in the open air.

163

544. Chemical Combinations.—Water unites with both bases and acids, to form *hydrates*. Thus, with lime, it forms hydrate of lime; with sulphuric acid,

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541. How may crystals of alum be obtained? 542. Explain the process. 543. What is said of snow crystals? 544. What is said of the combinations of water?

hydrated sulphuric acid. Most of the oxygen acids, in the form in which we employ them, contain water in a state of combination, and are therefore hydrated acids. They may also be regarded as salts, of which oxide of hydrogen or water is the base.

545. Relations to Life.—Water forms, by far, the greater part of all animal and vegetable matter, as will be more fully seen in the portion of this work which treats of organic chemistry. To water the leaf of the vegetable and the muscle of the animal, owe, in a great degree, their pliancy and freedom of motion. In view of these and other relations to life, the negative properties of water are not the least important. Had it taste or odor, however exquisite, we should soon weary of them. And but for its mild and neutral character, it would irritate the delicate nerves and fibers which it bathes.

Water exists in organized bodies in two different states. In one it may be considered as an essential part of the structure which cannot be removed without destroying the compound body of which it forms a part. In the other condition it is merely diffused through the structure and may be removed by drying.

Water is the medium in which the food both of plants and animals is diffused and circulated through their systems and from which the nutriment is deposited in the growing parts.

546. At very high temperatures the vapor of water

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545. What is said of water in its relations to life? 546. What is the effect of water at high temperatures?

decomposes many minerals, and expels strong acids from their compounds. Under the stimulating influence of heat, this neutral liquid becomes a chemical agent of extreme energy. Such decompositions as are here referred to, are without doubt, constantly going on beneath the surface of the earth.

547. Fog—Vesicular Vapor.—Fog is supposed to consist of water in the form of hollow vesicles filled with air. When the vapor of water is mixed with air it is believed to have a tendency to condense in vesicles which (like soap bubbles) contain air; forming in this condition visible vapor, as fog, mist, or masses of clouds which float in the atmosphere from the lightness of the vesicles. The air within is rendered lighter than the surrounding air by the condensation of the watery envelope which emits the heat previously latent when the water existed in the form of steam. Vesicles of this kind may be observed by a lens of one inch focal length over the dark surface of hot tea or coffee together with an occasional solid drop which contrasts with them. Vesicles of mist vary from $\frac{1}{4500}$ th to $\frac{1}{1200}$ th of an inch in diameter, and it has been computed that it would require 200,000,000 fog globules to make a drop of rain one-tenth of an inch in diameter. Watery vesicles of which the clouds are composed are said to be condensed by collision into solid drops and fall as rain, but in some states of the atmosphere these drops are again evaporated as fast as they are formed. It is proper to add, that Prof. J. Forbes and several

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547. What is the condition of water in fog, or mist?

other eminent meteorologists disbelieve entirely the existence of vesicles in watery vapor.

Nov 15th [illegible]

Compounds of Hydrogen, with Chlorine, Bromine, Iodine, Fluorine, and Sulphur.

548. Under this head are to be described a new series of acids, distinguished from all which have hitherto been mentioned by the absence of oxygen. The molecules of each, like those of water, are composed of single atoms of their constituents.

They are all gaseous, and are sometimes called *hydracids*, from the hydrogen which enters into their composition. Their salts are described in Chap. III.

May 13th

Hydrochloric Acid.

Symbol, HCl; *Equivalent*, 37.

549. Description.—Hydrochloric acid is a colorless gas, fuming by contact with the air. It sometimes issues from volcanoes, but is, for the most part, an artificial product. Its solution in water is known as muriatic acid.

550. Preparation.—Gaseous hydrochloric acid may be produced, like water, by the direct combination of its elements. For this purpose, equal volumes of the two gases are mixed by candle-light or in carefully covered bottles, and then exposed to the direct rays of the sun. The action of the light is so intense, that on throwing

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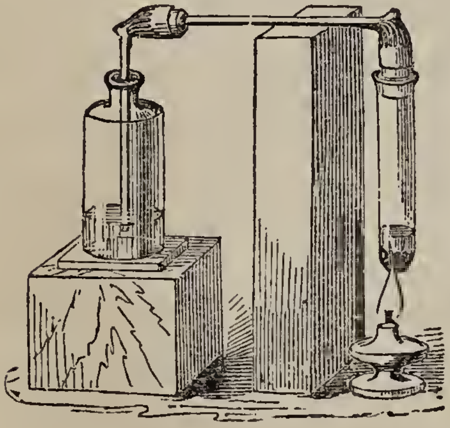
548. What are hydracids? 549. What is hydrochloric acid? What is said of its occurrence? 550. Describe its preparation.

a bottle thus filled from shadow into sunlight, it immediately explodes. The explosion is a consequence of the energetic union of the two gases, under the influence of the chemical rays of the sun. The acid produced is at once dissipated in the air. Great caution should be used in this experiment, for even the diffused light of day has been known, in some instances, to occasion explosion.

551. Another Method. — Hydrochloric acid may also be made from common salt, which furnishes the chlorine, and ordinary hydrated sulphuric acid, which furnishes the hydrogen. A tea-spoonful of common salt is introduced into a test-tube with about the same bulk of water. Half as much acid is added, the mixture then gently heated, and the acid gas led into water, as shown in figure 164. Water absorbs, at ordinary temperatures, 480 times its own volume of the gas. Figure 165 shows a convenient form of apparatus for performing this

164



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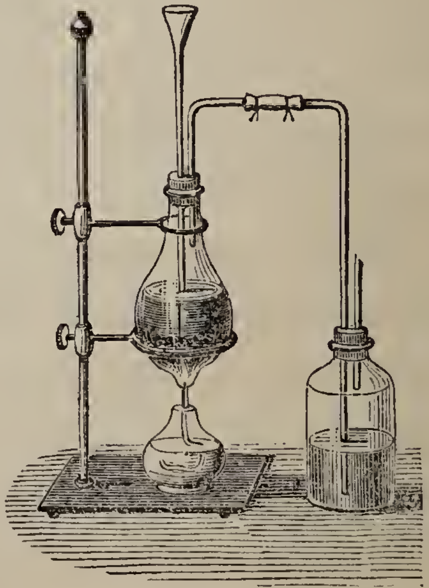

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551. Describe another mode of preparing it?

experiment on a larger scale. There is no occasion, for the purpose of experiment, to carry on the process till it is thus saturated. A few minutes will suffice to make an acid strong enough to dissolve zinc.

552. Explanation.—Hydrated sulphuric acid has always a strong tendency to form metallic salts. In this case it takes the metal, sodium, from the common salt, and thereby converts itself into sulphate of soda. At the same time it gives back hydrogen to the salt, in place of its lost sodium, converting it, by the exchange, into hydrochloric acid. The process just described, is the one always employed in the manufacture of hydrochloric acid.

553. Action of Hydrochloric Acid on Metals.—Hydrochloric acid dissolves tin and all of the metals which precede it in the chapter upon metals. For tin, a hot and concentrated acid must be employed.

554. The solution depends on the fact that the metals take chlorine from the hydrochloric acid, thereby converting themselves into soluble chlorides. The hydrogen then assumes the gaseous form, and escapes with lively effervescence. An experiment may be best made with zinc, covered with a little dilute acid.

555. Aqua Regia.—On mixing nitric acid with half of its bulk of strong hydrochloric acid, *aqua regia* is produced; so called, from its regal power over the noble metals. When nitric and muriatic acids are

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552. Explain the process. 553. What metals does hydrochloric acid dissolve? 554. On what does the solution depend? 555. What is aqua regia?

mixed they mutually decompose each other. The quantities necessary to render the decomposition complete are one equivalent of each. The quantities required will therefore depend upon the relative strength of each acid employed. Acids of the strength usually sold require one measure of nitric to two measures of muriatic acid. When the stronger acids are mixed a considerable portion of chlorine escapes and is lost. Gold and platinum, which are not affected by either acid alone, dissolve readily in aquia regia. The solvent power of aqua regia depends, as before explained, on the nascent chlorine which it supplies.

556. Hydrobromic and Hydriodic Acids. — These acids are of interest to the chemist only. They resemble hydrochloric acid, in being colorless gases, strongly acid, soluble in water, and capable of dissolving many metals.

Hydrofluoric Acid.

Symbol, HF; *Equivalent*, 39.

557. Description.—Hydrofluoric acid is a colorless, corrosive gas, acting on glass and many minerals which other acids do not affect. It condenses into a liquid at the freezing point of water. It is not known to occur ready formed in nature.

558. Preparation.—Hydrofluoric acid is made from

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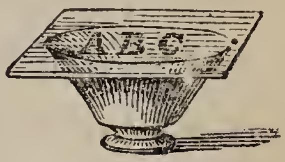
556. What is said of hydrobromic and hydriodic acids? 557. What is hydrofluoric acid? 558. How is hydrofluoric acid prepared?

a mineral called *fluor spar*, by the same means employed to make hydrochloric acid. On account of its corrosive action on glass, vessels of lead or platinum are employed in the process. This gas is so poisonous, when inhaled, and its solution so corrosive to the skin, that its preparation, in any considerable quantity, should be left to the experienced chemist.

559. Explanation.—In the above process, the fluor spar, which is a fluoride of calcium, furnishes the fluorine, and hydrated sulphuric acid, the hydrogen. The remaining constituents unite to form sulphate of lime, which remains in solution.

160



560. Etching on Glass.—It has already been stated that hydrofluoric acid attacks glass and many minerals. By covering with wax, they may be protected against the corrosion. Advantage is taken of these two facts in etching upon glass. The surface is first slightly warmed and rubbed with beeswax, and then warmed again, to produce an even coating. Figures or letters are then drawn upon the glass, through the wax, with a pen-knife or other pointed instrument. The plate being now exposed for a few minutes to the fumes of hydrofluoric acid, and the wax subsequently removed, is found to be deeply etched. Fumes of hydrofluoric acid for the purpose, are best obtained by placing a half tea-spoonful of pulverized fluor spar in a warm tea-cup, and covering the powder with oil of vitriol.

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559. Explain the process? 560. Give the process for etching upon glass.

A little ether or potash will be found of use in removing the last portions of wax from the plate.

561. EXPLANATION.—As oxygen combines with carbon to form carbonic acid, so the hydrofluoric acid eats out the silicon of the glass, where it is exposed, and passes off with it, in the form of a new and more complex gas. A solution of the gas may be prepared by the process employed for hydrochloric acid. Bottles of vulcanized India rubber or gutta percha may be used in keeping the solution.

Hydrosulphuric Acid.

Symbol, HS; *Equivalent,* 17.

562. DESCRIPTION.—Hydrosulphuric acid is a colorless gas, also known as *sulphuretted hydrogen.* It has a putrid odor and feeble acid properties. Like the rest of the series, it is soluble in water. It occurs in many natural waters, called sulphur springs. It is one of the products of the decomposition of animal matter, and the source of much of the disgusting odor which they emit during putrefaction.

563. PREPARATION.—It is made from sulphuret of iron, as hydrochloric acid is made from common salt, and hydrofluoric acid from fluor spar. In the above process, sulphuret of iron furnishes the sulphur, and

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561. Explain the above process. 562. What is hydrosulphuric acid? 563. How is it prepared?

hydrated sulphuric acid, the hydrogen. The remaining elements unite to form sulphate of iron, which remains in solution. On account of the disgusting smell of the gas, it is best to prepare it only in small quantities.

564. Discoloration of Metals and Paints.—The blackening of silver watches and coins, in the vicinity of sulphur springs, is an effect of hydrosulphuric acid gas. Its discoloring effect may be illustrated, by pouring a little dilute sulphuric acid upon a few grains of sulphuret of iron, in a tea-cup, and holding a bright moist coin in the fumes. Its effect on paints may be shown by exposing a piece of paper, moistened with solution of sugar of lead, in the same manner. The white paper immediately assumes a dark metallic stain. Paper moistened with a solution of tartar emetic, takes a deep orange hue. This experiment is often varied, by drawing amusing figures on paper with lead solution, and bringing them out by exposure to the gas.

565. Explanation.—The change of color in each case, is owing to the formation of a metallic sulphide, having a different, and generally a darker color. Zinc is not blackened, because its sulphide happens to be white. For this reason, chemical laboratories and other places where hydrosulphuric acid is likely to be evolved, should be painted with zinc paints, instead of those containing lead.

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564. What effect has it on metals, etc.? 565. Explain the cause of the change of color.

566. Relations to Life.—Sulphuretted hydrogen, if inhaled in any considerable quantity, acts as a poison. Caution should therefore be observed in experiments with this gas. The mixture of gases which is given off from recently ignited coal, contains sulphuretted hydrogen gas in large proportion, and owes its deleterious qualities, in considerable part, to this admixture.

Ammonia, *Spirits of Hartshorn.*

Symbol, H_3N; *Equivalent*, 17.)

567. Description.—Ammonia is a colorless gas, of pungent smell, and alkaline properties. It is exhaled from volcanoes, and is a product of the decomposition of all vegetable and animal matter. Its molecule contains one atom of nitrogen to three of hydrogen.

568. Production from its Elements.—Although nitrogen and hydrogen gases are the sole elements of ammonia, they cannot, under ordinary circumstances, be made to unite directly and form it. Heat does not stimulate their affinities sufficiently to bring about this result. Electrical sparks passed, for a long time, through a mixture of the gases, cause them to combine to a limited extent.

569. Production from Nascent Elements.—Iron, at a high temperature, expels hydrogen from ordinary

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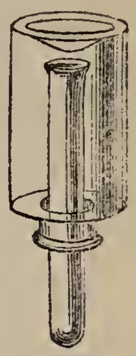
566. What is the effect of sulphuretted hydrogen on animals? 567. What is ammonia? Where does it occur? 568. What is said of its production from nitrogen and hydrogen? 569. Production from its nascent elements.

hydrate of potassa, and nitrogen from nitre. If heated with both together, it expels both nitrogen and hydrogen, and the two nascent elements unite, to form ammonia. The experiment may be performed by covering bits of potash and nitre with iron filings, and heating them in a test-tube. Another method of producing ammonia, through the agency of platinum sponge, is described under the head of Platinum.

570. PREPARATION.—Ammonia is commonly made from salts that contain it, by using some strong base to retain the acid, and set the gas at liberty. Potash or lime may be used for this purpose. Introduce into a test-tube about half an inch of a stick of fused potash, and cover it with powdered sal-ammoniac. On the addition of water to dissolve them, ammonia will be immediately evolved. Rest the tube on the table, and place a wide-mouthed vial over it to collect the gas. This gas cannot be collected over water, as it would be rapidly absorbed. It must therefore be collected over mercury, or by displacement as shown in the figure.

167



571. SOLUTION IN WATER.—AQUA AMMONIÆ.—Bring the mouth of the vial filled with ammoniacal gas, quickly, into a bowl of water. The water will swallow up the gas so rapidly as to rise and fill the vial, producing a weak solution of ammonia or hartshorn. If only a small portion of water be allowed to enter, and

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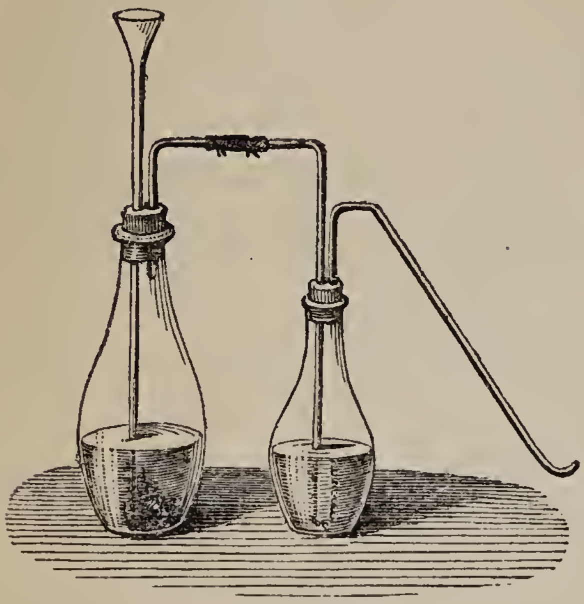
570. How is ammonia commonly prepared? 571. How is its solubility in water proved?

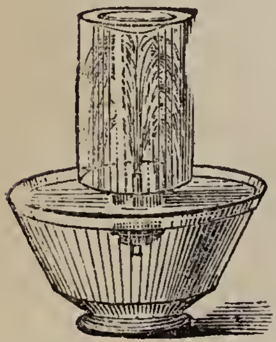
the vial be then removed from the bowl and shaken, the hartshorn obtained will be comparatively strong. For the preparation of the solution in large quantity, the apparatus shown in figure 168 may be used. Water will absorb 670 times its own bulk of ammoniacal gas, forming the fluid known as aqua ammonia. Newly slaked lime may be substituted for potash.

168



572. A Miniature Fountain.—Fill a pint vial with ammonia, by the method above given, and immediately introduce, air-tight, into its mouth, a moist paper stopper with a bit of pipe-stem run through it. Then invert the bottle into a bowl of water. The absorption by the first portions of water that enter will be so complete as to produce a vacuum, into which more water will rise, in a jet, as represented in the figure.

169



573. Alkaline Properties.—Bring the material for making ammonia into a tea-cup or similar open vessel. Hold a strip of litmus paper, previously reddened by an acid, in the gas, as it is evolved. The acid will be

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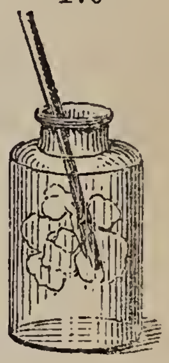
572. How may ammonia be employed to produce a jet of water?
573. Explain its action on acids.

neutralized by the ammonia, and the paper restored to its original color. Any substance which is very soluble and neutralizes strong acids, is called an *alkali.* As ammonia has this property, and is also volatile, it is therefore called a *volatile alkali.* The same experiment with litmus paper, may be also made with the hartshorn obtained in the last experiment.

574. It fumes with Acid Vapors.—Moisten a piece of paper with strong muriatic acid, and wave it to and fro through the gas. White fumes are produced by the union of the muriatic acid and the ammonia. In uniting, they form small particles of muriate of ammonia, or sal-ammoniac, in the air. It is of these that the fumes consist. It will be observed, that in this experiment the material from which the ammonia was originally prepared is reproduced. The same fumes are formed on waving a paper moistened with muriatic acid through the atmosphere of a stable. Ammonia is constantly evolved in such places, from the decomposition of animal matter.

170



Phosphuretted Hydrogen.

Symbol, H_3P; *Equivalent,* 34.

575. Description.—Phosphuretted hydrogen is a colorless gas, of an odor that has been compared to that of putrid fish. It is spontaneously inflammable by contact with the air. In the relative proportion of its elements, it corresponds with ammonia. This gas

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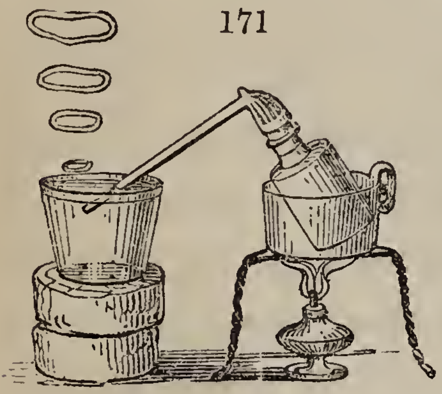
574. Its effect on acid vapors. 575. What is phosphuretted hydrogen?

is sometimes produced in the decay of vegetable and animal matters. The *jack-o-lantern*, or *will-o-the-wisp*, sometimes seen in swamps and grave-yards, is supposed to have its origin in the spontaneous production and combustion of this gas.

576. Preparation.—Phosphuretted hydrogen is made from phosphorus, with the help of water and an alkali. Water furnishes the requisite hydrogen, if lime or potash is at the same time present. Introduce into a small vial two-thirds full of water, a stick of ordinary fused potash, broken in pieces, and a bit of phosphorus of the size of a pea. On the application of heat, this gas is evolved. It is carried through a pipe-stem, and allowed to bubble up through water contained in a tea-cup or bowl, as represented in the figure. If the atmosphere is still, the bubbles, as they burst and inflame form beautiful white rings which rise in succession into the air. These rings consist of particles of phosphoric acid, produced by the combustion of the phosphorus which is contained in the gas. In order that the gas may be safely evolved, it is best to heat the vial in a tea-cup containing salt dissolved in three times its bulk of water. The addition of salt has the effect of raising the boiling point. The comparatively high temperature required, may thus be obtained without exposure of the vial to the direct flame of a lamp.

171



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576. How is phosphuretted hydrogen prepared?

577. Explanation.—In the action which occurs in making phosphuretted hydrogen from potash, water, and phosphorus, the latter plays the part of an extremely rapacious element. It makes no distinction in the objects of its appetite, but seizes upon both the oxygen and hydrogen of the water, two substances as widely different from each other as possible. It forms with the one, phosphuretted hydrogen, and with the other, what might be called phosphuretted oxygen, but is, in fact, an acid. Potash is employed in the process, to promote the formation of this acid. In its absence, water resists the affinities of the phosphorus, and neither acid nor phosphuretted hydrogen is obtained.

Compounds of Hydrogen with Carbon.

578. Most of the compounds of carbon and hydrogen belong to the vegetable world, and will therefore be more properly considered in the chapter on organic chemistry. Only two of them, which exist ready formed in nature, will be here mentioned.

Light Carburetted Hydrogen.

Symbol, C_2H_4; *Equivalent,* 16.

579. Description.—Light carburetted hydrogen is a colorless, inodorous, inflammable gas, about half as heavy as air. Its molecule contains two atoms of carbon to four of hydrogen. It is produced in ponds and marshes, by the decomposition of vegetable matter

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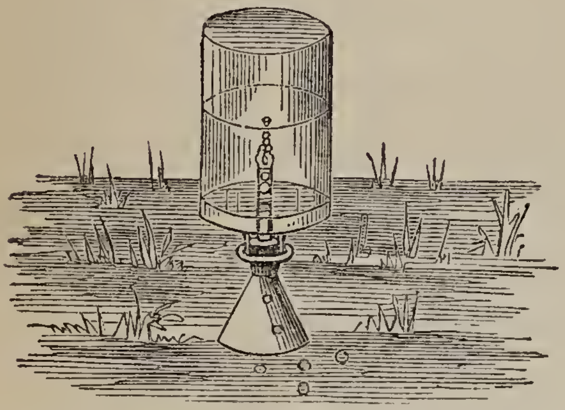
577. Explain the above process. 579. What is light carburetted hydrogen? Where does it occur?

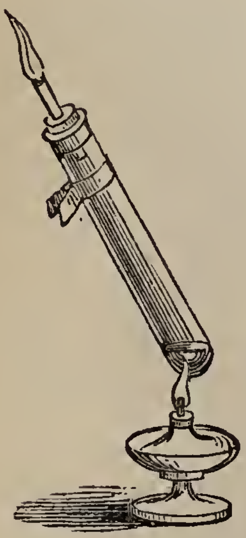
under water, as will be more fully explained in Part IV. From this circumstance it is also called *marsh-gas*. It may be collected by stirring up the mud under the mouth of a funnel leading into a jar or jug as shown in the figure. Mixed with other gases, it issues from fissures in coal mines, forming the *fire-damp* formerly so much dreaded on account of its explosive properties. As coal is of vegetable origin, the gas of the mines which proceeds from it is also traceable to the vegetable world. In some districts, particularly in regions where borings are made for salt, it issues from the earth in sufficient quantity to form the fuel required to boil down the brine, or even to illuminate villages.

172



580. Preparation.—An impure, light carburetted hydrogen, is obtained from wood by simple heating. For this purpose, saw-dust or bits of shaving are heated in a test-tube. The gas may be burned in a jet as fast as formed. The product thus obtained is not pure, but mixed

173



580. How is light carburetted hydrogen prepared?

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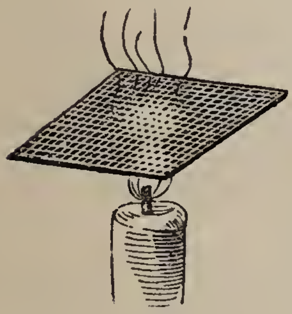
* Boussingault has discovered that under the influence of direct sunlight the leaves of aquatic plants give off a notable proportion of carbonic oxide and carburetted hydrogen. He thinks that the carbonic oxide thus gven off may be one cause of the unhealthiness of marshy districts.

with olefiant and other gases which make the flame more luminous. The pure gas may be made from strong vinegar, (acetic acid,) by the agency of heat and potash, as will be explained in the latter part of this work.

581. Explosions in Mines.—Marsh gas forms, with air, an explosive mixture before alluded to, which is often the occasion of fearful accidents in mines. The experiment may be made with olefiant gas, which has the same explosive property. This property belongs, indeed, to most gases and vapors which contain hydrogen; as for example, to the vapors of ether, alcohol, camphene, and "burning fluid."

582. Davy's Safety Lamp. — The distinguished English chemist, Davy, devised a method of security against these explosions. It consists in surrounding the miners' lamp with wire gauze, which will admit air through its insterstices, but will not let out flame to ignite the explosive atmosphere of the mine. The flame of the lamp is surrounded with glass to allow the light to be seen while the gauze protects the lamp from currents

174



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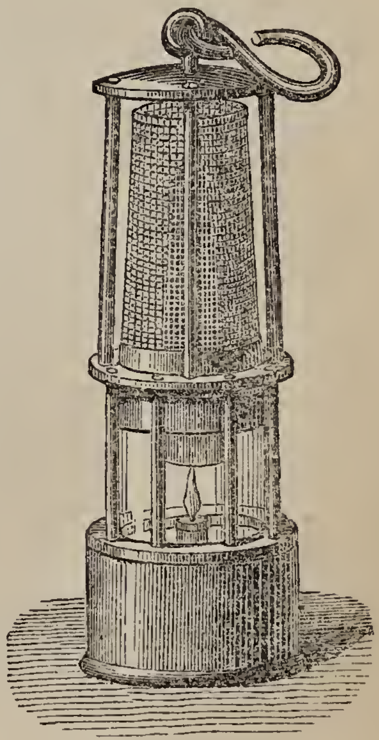

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581. Explain the cause of explosion in mines. 582. Describe Davy's safety lamp.

of gas above or below. This effect may be illustrated, by holding down a piece of wire gauze upon the flame of a candle. If the gauze is fine, the flame will not pass through it. This effect is owing to the reduction of temperature which the wire occasions. The subject will be better understood by reference to the paragraphs which follow, on the nature of flame.

Heavy Carburetted Hydrogen. *Olefiant Gas.*

Symbol, C_4H_4 *Equivalent,* 28.

583. Description.—Heavy carburetted hydrogen is a colorless gas, of peculiar sweetish odor, also known as olefiant gas. It is nearly twice as heavy as the light carburetted hydrogen just described, and contains twice the quantity of carbon. It forms a small proportion of the *fire-damp* of mines and salt borings, before described. The foul air left after the explosion of fire-damp is called *after-damp.*

584. Preparation.—Heavy carburetted hydrogen is made from alcohol, by the decomposing action of sulphuric acid. Bring into a test-tube a tea-spoonful of alcohol, with a little sand, and add four times as much oil of vitriol. On heating over a spirit lamp, the gas is evolved, and may be burned like the gas just described, at the mouth of the tube. The acid employed has the effect of retaining part of the elements of the

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583. What are the properties of olefiant gas? 584. How is it prepared?

alcohol, and allows the rest to escape as olefiant gas. The reaction* is more fully explained under the head of organic chemistry.

585. Illuminating Gas.—Gas for illumination is commonly prepared from bituminous coal. Such coal is principally composed of carbon and hydrogen. A portion of these elements pass off under the influence of a high temperature, in the form of gas. The product is rather a mixture of gases, among which light and heavy carburetted hydrogen are the principal. To illustrate this process fill the bowl of a tobacco pipe with pieces of bituminous coal not larger than peas; cover the top with clay well pressed down, and place the bowl in a fire so that the stem may project. In a short time a dark-colored smoke will issue from the pipe stem to which set fire, and you will obtain a gas flame, producing a good light. If the heat is intense, coal tar will be produced at the same time. The illuminating power of gas is principally derived from heavy carburetted hydrogen. Its quality, within certain limits, depends on the relative proportion of this constituent.

586. Purification.—The gas as it rises, contains ammonia and sulphuretted hydrogen, two impurities which it is essential to remove. If the materials for making the gas are placed in a test tube the ammonia may be stopped in its passage, by a loose wad of

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585. How is illuminating gas made? 586. How is it purified.

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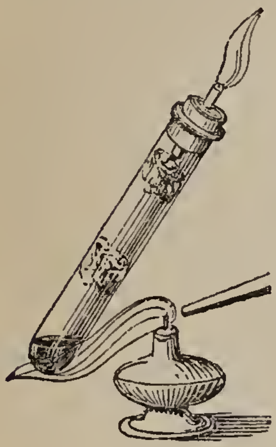
*The term *reaction*, signifies, in chemistry, the mutual action of chemical agents.

of moistened paper; the sulphuretted hydrogen, by a similar wad, moistened with solution of sugar of lead. The papers having been introduced, the pipe-stem is fitted to the tube with a paper stopper, and the tube heated over the alcohol flame with the help of a blow-pipe. When the coal has become red hot, the gas will pass off in sufficient quantity to be ignited at the extremity of the tube.

176



587. At the conclusion of the process, the upper wad contained in the tube will be found blackened by the sulphuretted hydrogen which it has retained. On removing the second one, it will be found to smell of ammonia. The presence of this body may also be shown, by the fumes which it yields with muriatic acid.

588. Arrangements in Gas Works.—The process in gas works is essentially the same, as that above described. The coal is heated in iron retorts. The tar collects in pipes leading from it. Carbonate of ammonia is washed out by a jet of water, which plays in an enlargement of the pipe. Lastly, sulphuretted hydrogen is removed by the retentive power of a metallic base, lime being generally employed for this purpose. From ten to twelve thousand cubic feet of gas are obtained from a ton of coal.

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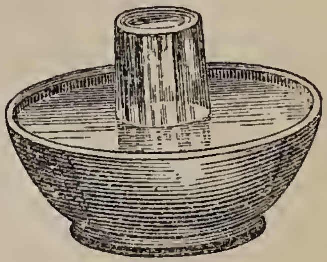
587. How are the impurities shown? 588. Describe the process in gas works.

589. Collection and Distribution.—After purification, the gas is collected in large iron holders called *gasometers*, which are iron cylinders of great size. These may be represented by the inverted tumbler in figure 177. Gas pouring in from below would lift and fill it. If an orifice were made in the top, the tumbler would immediately settle into the water. The air would, at the same time, escape through the orifice. The distribution of illuminating gas, from public gas works, is effected on the same principle. The weight of the sinking gasometer, is sufficient to press it through pipes, to all parts of a large city.

177



590. Gas from Wood.—Gas may be made from wood by the same means above given. Only a moderate heat is required, in this case, to produce tar at the same time. Gas of higher illuminating power than that prepared from wood or coal may also be made from oil, fat or rosin. Even refuse vegetable substance may be employed. A pound of dried grape skins have been found to yield 350 quarts of excellent illuminating gas. The dried flesh of animals has sometimes been used for its manufacture.

591. Other Compounds of Carbon and Hydrogen. India-rubber, gutta-percha, naptha or rock-oil, coal-tar and oil of turpentine are other well-known compounds of carbon and hydrogen.

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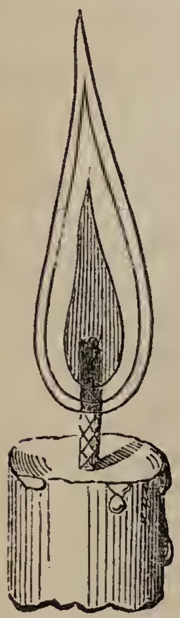
589. How is illuminating gas collected and distributed? 590. How may gas be made from wood? 591. What other compounds of carbon and hydrogen are mentioned?

Flame.

592. Flame.—Nothing in nature is, to the uninstructed eye, more mysterious than flame. It is, seemingly, body without substance, and shape, without coherence. It is created by a spark, and annihilated by a breath. Invulnerable itself, it destroys whatever it touches. Divided and subdivided, it is still the same, yet endowed with the power of resolving other materials into their elements. Chemistry resolves this mystery, and gives us the satisfaction of definite knowledge in its place. But, as in all similar cases, while satisfying the understanding, it opens new fields to the imagination. The subject of combustion, as involved in flame, introduces us, for example, to a knowledge of the grand system of circulation of matter as set forth in the last chapter of this work.

178



593. Structure of Flame. — Explanation.—Every lamp or candle is a gas factory, in which gas is first produced out of oil or fat, by the fire which kindles it, and afterward by the heat of its own flame. A flame, if carefully observed, will be found to consist of three distinct parts; a dark center, a luminous body, and a faint blue envelop. The dark center is filled with the gas as it arises from decomposition of the oil or fat of which the candle is composed.

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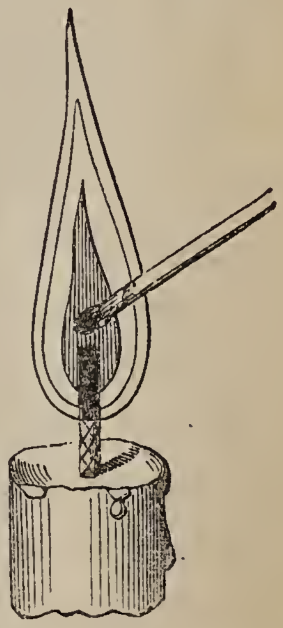
592. What is said of flame? 593. Explain the structure of flame.

In the luminous envelop the hydrogen and carbon are separated, the hydrogen first unites with the oxygen of the atmosphere and forms water, at the same time it produces an intense heat by which the liberated carbon in solid particles is raised to a red or white heat. As this heated carbon flows outward and upward until it meets a sufficient supply of atmospheric air it forms carbonic oxide, and at length, when fully oxidized, carbonic acid, assuming first a faint blue color, and in the form of carbonic acid becoming entirely invisible.

In the dark center no air or oxygen is found. In the luminous envelop there is an insufficient supply of oxygen which is principally taken up by the hydrogen because oxygen is more powerfully attracted by hydrogen than by carbon. In the outer or blue envelop there is an abundant supply of oxygen in a heated state and it attacks all bodies with great energy which are brought in contact with it.

179



594. Oxygen essential to ordinary Combustion.—The student will already have found abundant evidence that air or oxygen is essential to ordinary combustion. A still more striking illustration of the subject remains to be given. A phosphorus match, if suddenly introduced into the interior of a flame, notwithstanding the high temperature in its vicinity, is not ignited. The

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594. How is the nature of flame further illustrated?

[illegible] [illegible] [illegible] of [illegible] – a [illegible] flame. [illegible] [illegible]

wood burns off, but the phosphorus of the match does not undergo combustion. The same principle may be illustrated by holding a match for a moment through the body of the flame. It is consumed at the sides, while the center remains unburned.

595. Combustion without Oxygen. — It has been shown in section 371 that many metals in a finely divided state take fire spontaneously in chlorine gas. The same effects are produced with bromine. If sulphur is heated in a flask to its vaporizing point it forms a dark amber-colored vapor in which copper foil burns with great splendor, producing sulphide of copper. It is thus evident that oxygen is not in all cases necessary to combustion. The phenomena of light and heat which attend combustion depend on intense chemical action, and are not dependent exclusively upon any peculiar form of matter.

596. Effect of Flame on Metals.—If a tarnished penny be held perpendicularly in the flame of a lamp or candle, the portion within the flame will lose its coating of oxide, while the exterior portions at the same time become more deeply oxidized, and consequently, darker colored. It is because there is an excess of carbon and hydrogen in the interior of the flame, to take oxygen from the metal, by their superior affinity, and pass off with it as gas or vapor. In the outside, on the other hand, there is an abundant supply of air to impart oxygen, or, in other words, to oxidize.

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595. Give examples of combustion without oxygen. 596. What is the effect of flame on metals?

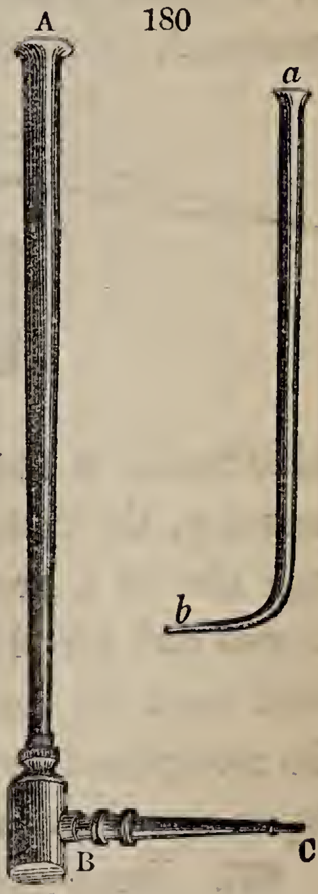
[illegible] more oxygen and [illegible]
lamp [illegible] the same flame

By moving the coin to and fro after it is once thoroughly heated, the instantaneous conversion of metal into oxide, and oxide into metal, may be readily observed. A beautiful play of colors, like those upon a soap bubble, will be found to attend the transformation. The flame of a spirit lamp is, in some respects, preferable for this experiment.

597. Oxidizing Flame. — The blue envelop of the flame, which, with the hot air adjacent, has the property of oxidizing metals, is called the oxidizing flame.

598. Reducing Flame. — The body of the flame, which, with the heated gas within it, has deoxidizing effects, and reduces oxides again to the metallic form, is called the reducing flame. The process of deoxidizing is called *reduction*.

180



599. The Blow-Pipe.—The peculiar effects of both the oxidizing and reducing flame, may be still better obtained by help of the simple mouth blow-pipe. A, B, C, figure 180, shows the best form of the blow-pipe. At B is a chamber to retain the moisture from the mouth. The mouth-piece A, is often made of glass or ivory. A simple form of blowpipe is shown at *a b*. In want of a metallic tube, a common tobac-

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597. What is the oxidizing flame? 598. What is the reducing flame? 599. Describe a blow-pipe of simple construction?

[illegible]

Blue flame due to carbonic oxide
acid [illegible]

co-pipe, to the bowl of which a piece of a second stem is fitted, as represented in the figure, may be made to answer the purpose. With its aid, a lamp or candle flame is converted into a miniature blast furnace. The mouth is applied at the end of the long stem, while the shorter one carries the blast to the flame. The orifice of the latter should be extremely small. It may be so rendered, by filling with clay and then piercing it with a needle.

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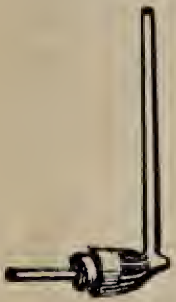
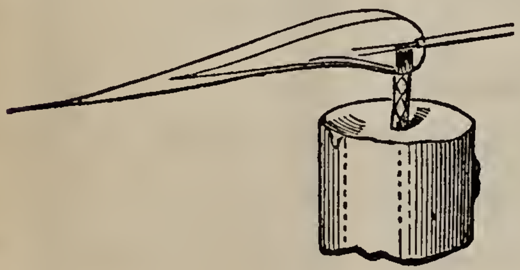


600. Oxidizing Blow-Pipe Flame.—To oxidize with the blow-pipe, the flame, mixed with a large proportion of oxygen, is blown forward upon the metal, or other material, subjected to experiment. This is effected by introducing the extremity of the blow-pipe, a little within the flame. The air of the lungs becomes thus mixed with the rising gases. The result is a slender, blue flame, at the point of which, within its fainter blue envelop, the metal is to be held. A piece of lead, of the size of a grain of wheat, placed on charcoal, hollowed out for the purpose, and exposed to the flame, will soon be converted into litharge. The oxide will be recognized by the yellow incrustation which it forms upon the charcoal support.

183



601. Reducing Blow-Pipe Flame. — To convert

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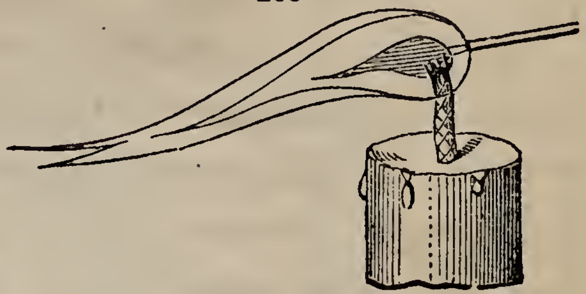
600. How is the blow-pipe used for oxidation? Give an example. 601. How is the blow-pipe used for reducing metals?

[illegible]

oxides into metals, or in other words, to *reduce* with the aid of the blow-pipe, the gases of the flames are blown forward, upon the substance, mixed with little air. The extremity of the blow-pipe is placed against the outer wall of the flame, a little higher than in the previous case. The flame thus produced is yellow, and of the shape represented in the figure, The oxide to be reduced, is to be placed within the yellow body of the flame, but near its termination. The litharge produced in the last experiment, may be re-converted, by this means, into metallic lead.

183



602. HEATING BY THE BLOW-PIPE FLAME.—The concentration of flame upon a small object by means of the blow-pipe produces a very great degree of heat, which is employed for soldering metals, and for other important purposes in the arts. The rapid supply of oxygen to the burning gas in the flame causes this great increase of heat.

603. THE OXYGEN BLOW-PIPE. — If a bladder, V, filled with oxygen, furnished with a stopcock, *r*, and a small tube, *t*, is employed to blow the lamp as shown in figure 184, the heat will be much greater than where common air or air from the lungs is used. The heat obtained by this means is sufficient to melt wire of

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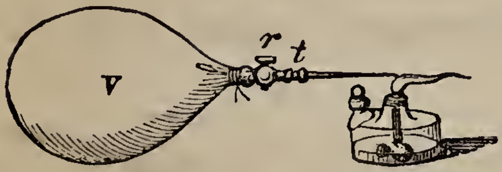
602. What is said of the heat produced by the blow-pipe?

platinum. The bladder is filled with oxygen gas from the jar, *c*, with its stopcock, *s*, as shown in figure 185, standing over the pneumatic cistern. A still greater degree of heat is obtained by means of the oxyhydrogen blow-pipe described in the next section.

184



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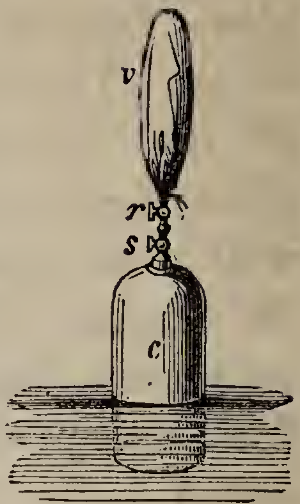

604. Oxyhydrogen Blow-pipe.—The compound or *oxyhydrogen* blow-pipe, as commonly constructed, consists of two gasometers, containing, the one, oxygen, and the other hydrogen gas; tubes, *r* and *s*, leading from these, are brought together at their extremity, and the two gases are burned in a single jet. One tube is inclosed within the other so that the two gases do not mingle until they reach the extremity of the tube. By this arrangement all danger of explosion is avoided. The heat thus produced is the most intense that has ever been realized except by Galvanic means. Iron, copper, zinc, and other metals, melt and burn in it readily; the former, with beautiful scintillations, and the latter, with characteristic colored flames. With a sufficiently constant flame platinum also may be readily fused. The apparatus for making oxygen

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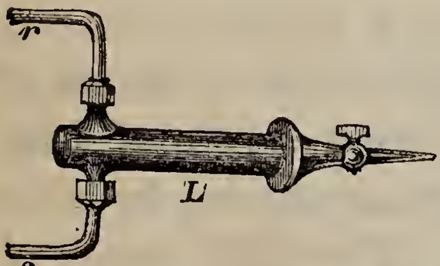

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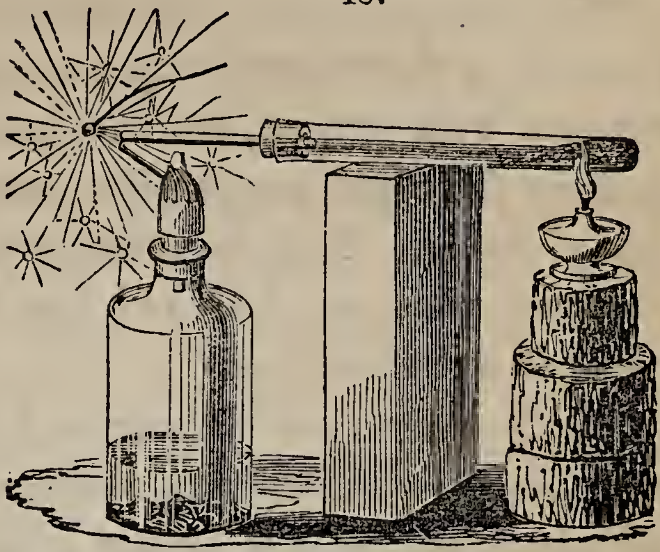
604. Describe the oxyhydrogen blow-pipe.

and hydrogen as represented in the figure, furnishes a simpler means of obtaining similar results. An abundant flow of hydrogen is required, and a pint bottle should, therefore, be employed in its preparation. To retain it free from water, which would tend to reduce the heat of the flame, a little cotton may be introduced into the bowl of the pipe through which it passes. In evolving the oxygen, only a part of the tube should be heated at a time lest the gas should be too rapidly evolved.

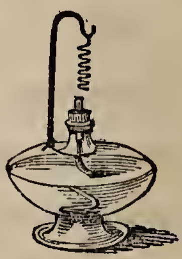
187



605. Flameless Lamps.—Place a little ether in a wine-glass and suspend in it a coil of platinum wire heated to readness, combustion of the ether will proceed without flame and the heat evolved will keep the platinum wire red hot for hours, or as long as vapor of ether is supplied with free access of air. This experiment may be varied by suspending the coil of platinum wire heated to redness over the wick of a lamp filled with ether. The wire will glow emitting a steady light without flame. To com-

188

189



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605. Describe the flameless lamp.

mence the combustion in either case, the wire must be heated to redness.

606. Explanation.—The heated wire raises the temperature of the ethereal vapor to the point where it can combine with oxygen, but the heat is not sufficient to produce the rapid combustion essential to the production of flame. That is to say, the heat is sufficient to keep the platinum coil red hot but not to make the vapor of ether red hot.

607. Non-luminous Flame.—A jet of burning hydrogen, like the philosopher's lamp, section 519, gives out so little light that it is almost invisible in the daytime. Burning alcohol also emits but very little light. If common illuminating gas passes up through a tube open both at bottom and top and is ignited at the top, it burns with an almost invisible flame, although it gives out a very high degree of heat. Bunsen's lamp is constructed on this principle. Even the flame of the oxy-hydrogen blow-pipe emits scarcely any light although the heat is so great as to cause the most refractory metals to melt like wax.

608. Incandescence. — Combustion always implies chemical action with the evolution of heat, and this heat is attended with a certain quantity of light; but a body may evolve heat and light without undergoing combustion or any chemical change. Platinum wire, fibers of asbestos, or a piece of lime exposed to the strong heat of invisible flame, as burning hydrogen,

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606. Explain the operation of the flameless lamp. 607. How may we obtain a flame nearly invisible? 608. What is incandescence?

may be heated to whiteness so as to evolve both heat and light of surprising intensity. This condition is called ignition or incandescence. The body evolves light as the result of its high temperature without its molecules being materially altered in their physical or chemical relations. The greater the amount of heat which a body can sustain without physical change the more intense will be the light emitted. Solids, liquids and gases may all be rendered incandescent by a sufficient degree of heat, but gases require for this purpose a higher temperature than can be obtained by ordinary means, and volatile liquids follow the same law. The vivid luminosity and varied color of lightning is probably dependent on the incandescence of the gases and vapors of the atmosphere.

If we pass a gentle current of air through a porcelain tube at a white heat, the air issuing from it is not luminous even in the dark, but if finely divided solid particles are projected into the escaping jet of heated air, they are immediately rendered luminous.

609. CARBON AS A SOURCE OF ILLUMINATION.—Carbon is the most infusible substance known and uncombined with other elements it never assumes a gaseous form. Carbon is therefore the most valuable source of illumination yet known. Tallow, oils and burning fluids of all kinds owe their illuminating powers to the carbon which they contain, while the hydrogen and other elements serve only to elevate the temperature of the carbon.

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609. Why is carbon the most valuable source of illumination?

610. CALCIUM LIGHT.—When the non-luminous flame of the oxyhydrogen blow-pipe is directed upon a cylinder of lime (oxide of calcium) a more intense light is produced than by any other artificial means except the most powerful Voltaic current. This light is sufficient to illuminate whole streets of cities and is of great value for light-houses. This is often called the Drummond light, from the name of the inventor.

611. COLOR OF FLAME. — Flame assumes different colors according to the chemical nature of the different substances projected into it, modified by the temperature to which they are elevated. The salts of lithia and strontia impart a red color to flame; baryta and boracic acid impart a green tint; salts of copper give a blue color; soda flame is yellow, while the flame of potassa is of a beautiful violet color. Between the poles of a powerful Voltaic battery zinc gives a blue color in strata or bands; antimony a lilac color; mercury a pale blue; cadmium an intense green; arsenic a magnificent lilac; and bismuth a variety of colors undergoing rapid changes.

612. SPECTRA OF METALS.—It has been already stated that the flames of different metals produce characteristic colored bands in a spectra produced by their own light (46). Sodium, for example, produces in the spectrum a double yellow line and copper a band of brilliant green. A flame containing several metals gives, at one and the same time, the characteristic bands of all. If

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610. What is the calcium light? 611. What causes the varied colors of flames?

these metallic flames be employed as media instead of sources of light, and if the light of an electric lamp be passed through them, they occasion dark stripes in the spectrum precisely corresponding to the colored bands before described. In other words, while transmitting the larger portion of the light, they absorb from it precisely that class of rays which when used as the sources of light they originate. Figuratively speaking, instead of painting their images they now cast their shadows in the spectrum. The correspondence between the dark lines which a given metal thus occasions by absorption and the bright lines which it produces by radiation is, perfect in numbers, breadth, and position. The shadow, as we have termed it, equally with the image, is peculiar and characteristic. Let us illustrate by an example. About sixty bright lines have been determined as belonging to the iron flame when used as a source of light. When light from an electric lamp is passed through a flame containing iron, sixty dark lines precisely corresponding are found in the spectrum. These sixty dark lines with their peculiar grouping are therefore no less than the bright lines, characteristic of iron. If found in any spectrum it may be inferred that the light which produces it has passed through flame or vapor containing that metal.

613. THE SOLAR ATMOSPHERE.—These lines characteristic of iron are found with all their peculiarities among the dark lines of the solar spectrum (45). It is

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3. What is said of the constitution of the solar atmosphere?

hence inferred that the solar light on its way to the earth has passed through a vapor containing this metal. And as this could only occur within its own atmosphere, the conclusion is warranted that iron is a constituent of the photosphere or luminous envelope of the sun.

The dark lines belonging to calcium, magnesium, sodium, chromium, and certain other metals are also found in the solar spectrum. Like those of iron they are found there in the precise position required to render them characteristic. These metals also are, as a consequence, inferred to be constituents of the solar atmosphere.*

CHAPTER II.

METALS.

614. Definition of Metals.—Metals are opake bodies possessing a peculiar luster and a great readiness to conduct heat and electricity. Fifty metals are known to chemists, but many of them are of no special interest to the ordinary student.

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614. What are metals?

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* For further information on this curious subject, the student is referred to the *Smithsonian Report* for 1861, and to *Brande & Taylor's* Chemistry.

615. Physical Properties of Metals.—*Color.* The color of most metals is white, gray or bluish, but gold is yellow and copper red.

Opacity. While most metals are opake, gold may be beaten so thin as to transmit green light, or blue if alloyed with silver.

Hardness and *Brittleness.* Most metals are regarded as hard bodies, but potassium and sodium are soft like wax. Some other metals, as lead, may be readily cut with a knife. Antimony, arsenic and bismuth are easily pulverized. Zinc is brittle at common temperatures, but at the temperature between 200° and 300° it may be rolled into thin plates or drawn into wire.

Malleability. Gold may be hammered so thin that 200,000 leaves are required to measure an inch. Some metals become hard and brittle by hammering and require to be softened by heating before the hammering can be continued. Gold is the most malleable of all metals; after it, in the order of their malleability, stand silver, copper, aluminum, tin, cadmium, platinum, lead, zinc and iron.

Ductility. Platinum may be drawn into wire not exceeding $\frac{1}{30,000}$th of an inch in diameter. The order of ductility is, gold, silver, platinum, iron, copper, aluminum, zinc, tin and lead. Aluminum, a very light metal, only about two and a half times as heavy as water, has recently been drawn into wire so fine that it is made into lace work, epaulettes, embroideries and head-dresses.

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615. Mention some of the physical properties of the most common metals?

Tenacity, or strength, is another important property of metals. In reference to tenacity, metals may be arranged as follows: iron, copper, palladium, platinum, silver, gold, zinc, tin and lead. Iron has the greatest tenacity of all metals, being capable of supporting 25 times as great a weight as a lead wire or rod of the same dimensions. An iron wire one-tenth of an inch in diameter will support 550 pounds, copper 302, platinum 274, silver 187, gold 150, zinc 100, tin 35 and lead 28 pounds.

Fusibility. All the metals may be melted by a sufficient degree of heat. Mercury is fluid at all ordinary temperatures and only becomes solid at 40° below zero of Fahrenheit's scale, while platinum requires for its fusion the highest heat of the oxyhydrogen blow-pipe.

Volatility. Mercury passes into vapor at any temperature above 40°. Potassium, sodium, zinc and cadmium are volatile at a red heat; gold and silver waste by evaporation in melting and there is no doubt that all the metals would be volatile with the highest degree of heat.

Relation to Electricity and Magnetism. Silver is the best conductor of electricity and mercury the poorest. All metals conduct electricity best when cold. Platinum becomes red hot by the transmission of a current of electricity that produces scarcely any effect upon a silver wire of the same dimensions. Next to silver copper is the best conductor of electricity. Mercury is used for uniting the poles of Voltaic batteries, not because it is a good conductor but because it forms a very complete connection between the different parts of the apparatus.

It has long been known that iron is attracted by the magnet and that steel may be rendered permanently magnetic. When a bar of iron is placed between the poles of a magnet it places itself parallel to the axis of the magnet; the same effect is produced with nickel, cobalt and platinum. But other metals when properly suspended take a direction at right angles to the magnetic axis. Such substances are called *diamagnetics.* Various solid liquids and gases are found in both these divisions. Iron, nickel, cobalt, manganese, chromium, palladium, platinum and osmium are *magnetic*, while bismuth, antimony, zinc, tin, cadmium, sodium, mercury, lead, silver, copper, gold and arsenic are *diamagnetic.*

Crystallization. Many metals on cooling from the fluid state, or during decomposition from chemical combinations, assume the crystalline form. If melted metal is allowed to concrete externally and the crust is then pierced and the fluid metal is poured out, the cavity so formed will generally be found lined with crystals. Bismuth treated in this manner appears in the form of cubical crystals. Copper, gold, silver and iron become brittle and lose much of their tenacity when they become crystallized. Extreme cold and rapid vibration cause the axles of railroad cars to assume a partial crystalline texture, which often occasions serious accidents.

616. CLASSIFICATION OF METALS. — The metals may

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616. How may the metals be classified?

be arranged in groups or classes, according to their affinity for oxygen. Those which tarnish or rust most readily, come first in order, while the last group is made up of the noble metals, which retain their brilliancy unimpaired.

617. CLASS I.—POTASSIUM AND SODIUM.—These two metals combine with oxygen so eagerly, as to tarnish instantaneously on exposure to the air. They even seize on that which is contained in water and expel its hydrogen. The hypothetical metal ammonium, is described in connection with this group, because of the similar properties of its compounds.

618. CLASS II.—BARIUM, STRONTIUM, CALCIUM, MAGNESIUM.—The metals of this class show their affinity for oxygen in the same manner as those of Class I. But they are inferior, in this respect, to both potassium and sodium. Either of these metals can deprive them of the oxygen with which they may have combined.

619. CLASS III.—ALUMINUM, MANGANESE, IRON, CHROMIUM, COBALT, NICKEL, ZINC, CADMIUM.—The metals of this class tarnish less rapidly than the foregoing, by exposure to the air. In order that they may decompose water, and appropriate its oxygen, they require the stimulus of an acid, or of heat. Except in the case of manganese, the heat must be sufficient to convert the water into steam. Strictly speaking, therefore, they do not decompose water, but steam.

620. CLASS IV.—TIN AND ANTIMONY.—Tin and anti-

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617. Describe the metals of Class I. 618. Describe Class II. 619. Describe Class III. 620. Describe Class IV.

mony tarnish less readily than the metals of the previous class. To enable them to decompose water, and appropriate its oxygen, they require the stimulus of a red heat. An acid, or moderate heat will not suffice.

621. CLASS V.—BISMUTH, COPPER AND LEAD.—Although copper and lead become tarnished, or covered with a thin film of oxide, rather more readily than the metals of the last two groups, their affinity for oxygen under other circumstances is less. This is evident in the fact that a red heat enables them to decompose water and appropriate its oxygen but feebly. Acids will not suffice. Bismuth doos not tarnish so readily as copper or lead.

622. CLASS VI.—MERCURY, SILVER, GOLD, AND PLATINUM.—The metals of this class do not tarnish, and do not decompose water under any circumstances. Even if made to combine with oxygen by other means, they yield it again very readily, and return to the condition of metals. They are called the *noble* metals.

CLASS FIRST.

Potassium.

Symbol, K (Kalium); *Equivalent,* 39; *Specific Gravity,* 0.865.

623. DESCRIPTION.—Potassium is a bluish white metal, lighter than water, and soft, like beeswax. Like wax, it is also converted by the heat of an ordinary fire

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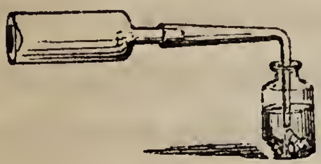
621. Describe Class V. 622. Describe Class VI. 623. What is potassium? Where is it obtained?

into vapor. Water and acids dissolve it readily. The metals of this and the following groups, were discovered by Sir Humphrey Davy, early in the present century. They were first produced by the Galvanic process. Potassium is a constituent of many rocks, of all fertile soils, and of the ashes of plants. The more important minerals which contain it, are alum, feldspar, and mica. As these rocks are disintegrated to form soil, the potash they contain becomes soluble and is taken up by plants. From the ashes of plants we obtain nearly all our supply of potash, which is an oxide of potassium.

190



624. Preparation.—Potassium is made from carbonate of potassa, by removing its carbonic acid and oxygen. This is accomplished by heating intensely with charcoal, which removes both in the form of carbonic oxide. The metal which accompanies the gas, in the form of vapor, is condensed by naptha, instead of water. The process is essentially the same as that for preparing phosphorus, but requires apparatus beyond the reach of the ordinary experimenter. *Cream of tartar*, if heated, is converted into a nearly suitable mixture of carbonate of potassa and pure carbon, for this purpose. The tartaric acid is decomposed into carbonic acid and free carbon, the carbonic acid unites with the potash and each atom of carbonate of potash has an atom of carbon in contact with it in a free state. The carbon

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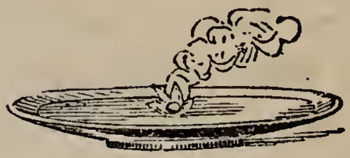
624. How is potassium prepared?

is more intimately mixed with the potash than it could be by any mere mechanical means. A small quantity of charcoal, in fragments, is added, and the whole heated intensely in an iron retort.

625. Combustion on Water.—Potassium, if thrown upon water, is immediately ignited and burns beautiful violet flame. Strictly speaking, it is not potassium which burns, but the hydrogen which it sets at liberty. Owing to its strong affinity for oxygen, it takes this element from water, liberating, and at the same time kindling, the hydrogen with which it was before combined. The color of the flame is due to a small portion of vaporized potassium which burns with this gas as it is evolved. The globule of metal used in this experiment gradually disappears, because the potassa which it forms by uniting with oxygen is soluble in water.

191



626. Setting a River on Fire.—Put two or three small pieces of potassium in a teaspoonful of ether and throw the contents into a pail of water, the whole surface of the water will appear in a blaze. By making the experiment on a larger scale, we may accomplish the feat of "*Setting a river on fire.*" During the Crimean war Mr. McIntosh proposed to destroy the shipping and harbor of Sebastopol by firing bombshells filled with ether and containing pieces of potassium. The use of such shells would doubtless have been very

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625. Explain the action of potassium on water. 626. How can a river be set on fire with potassium? How could potassium be used in war?

[illegible] gluten stand
substance cannot be easily

destructive, but the British government feared that carelessness on the part of the sailors might lead to the destruction of their own shipping also. In trying this experiment, even on a small scale, the student should be extremely careful and keep at a distance from the water lest the potassium should fly into and injure the eye. Care also should be taken lest the ether should take fire from a lamp or gas-light, if any is near.

192

627. Combustion in Carbonic Acid.—Potassium has such a powerful affinity for oxygen that it will even take it from carbonic acid gas. Place a small piece of potassium in an iron spoon, and after heating it, insert it in a jar of carbonic acid gas, as shown in figure 192, it readily takes fire and burns with a purple flame.

628. Uses of Potassium.—Potassium has not been applied to important uses in the arts, but is a valuable agent in the hands of the chemist. It is a key which unlocks many substances from the prison in which nature has confined them. Through its agency, brilliant metals may be obtained from lime, magnesia, and common clay.

629. This effect depends on the superior affinities of potassium, which enable it to appropriate oxygen, chlorine, and other substances, with which the above and several other metals are combined in nature, and to isolate the metals themselves. The potassium is at the

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627. How can potassium be made to burn in carbonic acid? **628.** State the uses of potassium. 629. On what does its action depend?

Phosphorus oxidated as oxygen [illegible]
represented

same time converted into oxide or chloride of potassium, both of which are soluble in water, and may be washed away from the metal which has been produced.

Sodium.

Symbol, Na (Natrium); *Equivalent*, 23; *Specific Gravity*, 0.972.

630. Properties.—The metal sodium is similar in its properties to potassium. It is prepared by similar means, from carbonate of soda, and may be employed by the chemist, for the same purposes. In color it resembles silver but like potassium it readily tarnishes on exposure to the air. It softens at 122°, melts at 200°, and at a white heat it is changed into a colorless vapor. It burns in the air with a yellow flame. Thrown upon water, it decomposes it, without however igniting the hydrogen which is evolved.* Sodium is readily soluble either in water or acids.

631. Sodium occurs in the mineral kingdom, but its great storehouse is the ocean from whence it is obtained in the form of common salt. It occurs also in sea-weeds and largely abounds in animal fluids. It is perhaps the most abundant metal upon the globe, as it constitutes about two-fifths of sea salt and is a large ingredient of rocks and soils.

630. Sodium — description, preparation, solvents, and properties? 631. Where is sodium found?

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* If sodium is wrapped in paper, to prevent waste of heat, it burns with flame, like potassium, upon water.

632. USES OF SODIUM.—Sodium is now prepared in large quantities, in France, as a material to be used in the manufacture of the metal *aluminum.* Its cost, a few years since, was ten dollars an ounce. It can now be procured in Paris for less than a dollar per pound.

Ammonium.

Symbol, H_4N; *Equivalent,* 18. (*Hypothetical.*)

633. AMMONIUM is a compound of nitrogen and hydrogen, which is presumed to be a metal. Its molecule contains one atom of nitrogen, to four of hydrogen. If a metal, it differs from all others, in being a compound, and not a simple element. There are, however, good grounds for believing in the existence of such a compound gaseous metal. The chloride of ammonium is named in accordance with this view. Judging from the properties of the salt, we might reasonably expect, by removal of its chlorine, to obtain from it a substance with metallic properties, as well as from chloride of sodium or common salt. But the experiment does not justify the expectation. As soon as the chlorine is removed, the metal also decomposes, and a mixture of gases is the result. The principal ground for attributing a metallic character to the combination of nitrogen and hydrogen gases, in the preparation above stated, has been already indicated. They supply, in certain salts, the place which known metals fill in the other and

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632. For what purpose is it used? 633. What is said of ammonium?

similar compounds. A confirmatory experiment is described in the succeeding paragraphs.

634. Ammonium Amalgam. — Another ground for believing in the existence of ammonium with true metallic properties, is found in the following experiment: If chloride of ammonium is mixed with an amalgam of sodium and mercury, a double decomposition ensues. The chlorine and sodium unite to form common salt, while the mercury combines with the ammonium without losing its metallic luster. But there is no instance of this retention of metallic properties in the combination of mercury or any other metal with any non-metallic substance. The inference is that ammonium is a metal. But any attempt to isolate it by removal of the mercury from the amalgam is ineffectual. As soon as this is done the ammonium is resolved into gaseous ammonia and hydrogen. This change takes place, indeed, spontaneously.

193

635. In performing the above experiment, a small globule of potassium or sodium is heated with a thimble full of mercury in a test-tube, and a strong solution of sal ammoniac added. The mercury increases in bulk without losing its luster, and continues to expand until it fills the tube or glass with a light pasty amalgam.

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634. State another reason for believing in the existence of a metal ammonium. 635. How is the amalgam experiment performed.

CLASS SECOND.

Barium.

Symbol, Ba; *Equivalent,* 69; *Specific Gravity,* 1.5.

636. BARIUM is an ingredient of the well known and abundant mineral, sulphate of baryta or heavy spar, which is found in beautiful white tabular crystals, and is much used mixed with carbonate of lead for white paint. Barium is a soft silvery metal, easily tarnished in the air. It is made from baryta, by the process already described in the section on potassium. It may also be procured by passing potassium or sodium in vapor over baryta heated to redness in an iron tube. Its compounds, including baryta, from which it is prepared, are hereafter described. Barium is soluble in most acids. It decomposes water at ordinary temperatures, evolving hydrogen and forming a solution of oxide of barium called baryta.

Strontium.

Symbol, Sr: *Equivalent,* 44; *Specific Gravity,* 2.5.

637. STRONTIUM is very similar to barium, but darker in color. It is produced from strontia by a similar process. Its solvents are also the same as for barium. strontium decomposes water without combustion, setting free hydrogen, and forming a soluble protoxide.

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636. In what form does barium occur? How is it separated? What are its solvents? 637. Strontium—description, production and solvents?

Calcium.

Symbol, Ca; *Equivalent,* 20; *Specific Gravity,* 1.57

638. The metal calcium is similar to barium, and is made from lime by the use of potassium, as before described. Its solvents are the same as those of the metals above-named.

Magnesium.

Symbol, Mg; *Equivalent,* 12, *Specific Gravity,* 1.74.

639. MAGNESIUM is a soft, silvery, white metal, prepared from its chloride instead of the oxide, by means of potassium. Water oxidizes magnesium as it does the other metals of this class, but converts it into an insoluble white powder. Most acids dissolve it. None of the metals of this class have as yet been applied to any useful purpose in the arts, except magnesium. Magnesium is malleable and ductile, and volatile like zinc. It does not decompose water and oxidizes but slowly even in moist air. It is readily dissolved by acids.

640. MAGNESIUM LIGHT.—When magnesium is heated in the air it burns with great brilliancy, evolving a white light of great intensity. A magnesium wire one twenty-fifth of an inch in diameter coiled upon a spool is moved by clockwork and projected into the flame of an alcohol lamp. It burns with a remarkably

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638. Calcium—description, production and solvents? 639. Magnesium—description, preparation, solvents and occurrence? 640. Describe the magnesium light.

even and tranquil flame, especially adapted for photographing by night or in any dark or subterranean locality. Such a light as here described is equal to 74 stearine candles. At present its cost, which is about ten dollars an hour, forbids its use except for the most important purposes. But there is no doubt that means will yet be found of producing magnesium at prices which will allow of the extensive employment of this magnificent light, so portable and so convenient for use in the arts. A light of almost any degree of intensity might be obtained by burning larger wires, or by burning several smaller wires at the same time.

CLASS THIRD.

Aluminum.

Symbol, Al; *Equivalent,* 14; *Specific Gravity,* 2.56 to 2.67.

641. ALUMINUM derives its name from alum of which it forms an important ingredient. The ruby, sapphire, topaz, corundum and emery, all owe their peculiar hardness to alumina which is an oxide of aluminum. Aluminum is also an essential ingredient in common clay and therefore a part of all fertile soils and the rocks that produce them. By its discovery every clay bank is converted into a mine of valuable metal. Aluminum is a bluish white malleable and ductile metal, similar in appearance to silver and possessing about the same degree of hardness. Its specific gravity when

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641. In what minerals does aluminum occur? What are its properties?

cast is two and a half times greater than water, and 2.67 when rolled. It is only about one-third as heavy as iron. It fuses at the same temperature as silver, and preserves an untarnished surface in the air. It does not decompose water, even with the aid of boiling heat. Alloyed with iron, it protects the latter from the action of the air.

642. Preparation.—Aluminum is prepared by passing chloride of aluminum in a state of vapor over melted potassium or sodium. The latter metal is commonly employed. The fluoride may also be used in the process, or the mineral *cryolite*, which is a compound of fluoride of aluminum with fluoride of potassium. The latter constituent interferes in no wise with the process. The method of preparing the chloride, as a material for the production of the metal, is given in the section on chlorides.

643. Action of Acids.—Muriatic acid is its proper solvent, and forms with it a colorless solution. Nitric acid whitens it, if previously dipped into strong potash or soda. Dilute sulphuric acid is without action. Aluminum may be poured from one vessel to another in a fused condition without oxidation. Like silver it may be deposited by the galvanic process.

644. It is highly sonorous, and therefore adapted to the manufacture of bells. This metal is now prepared in France at about ten dollars per pound. The French government propose to use it for helmets and cuirasses,

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642. How is aluminum prepared ? 643. What is the action of acids on it ? 644. Mention its other properties.

for which it is especially fitted by its lightness and tenacity. For other uses of aluminum, *see Alloys*, § 747.

Manganese.

Symbol, Mn; *Equivalent*, 28; *Specific Gravity*, 8.

645. MANGANESE.—Manganese is a gray brittle metal, produced from its oxide by heating with charcoal. It is found in nature as black oxide of manganese and as a constituent of many other minerals. It enters also in small proportions into the composition of soils. Diluted sulphuric and muriatic acids are its proper solvents, forming with it pale rose-colored solutions. The black oxide serves as a source of oxygen, and is also employed in the preparation of chlorine gas. It is also used in the production of artificial amethysts, and also to impart to glass the same violet tint. An alloy of manganese and iron is harder and more elastic than iron alone. Manganese is used as a flux in the preparation of cast steel, and it furnishes a useful mordant to the calico printer when precipitated upon the fiber in the form of a brown hydrate. Manganese is speedily oxidized when exposed to the air; it must therefore be preserved in sealed tubes or under naphtha. The pure metal is slightly magnetic and is hard enough to scratch steel.

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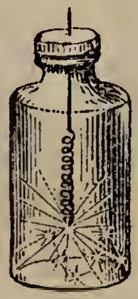
645. Manganese—description, production, occurrence, solvents and uses?

Iron.

Symbol, Fe, (Ferrum); *Equivalent*, 28; *Specific Gravity*, 7.84.

646. Description.—Pure iron is nearly white, quite soft, exceedingly malleable and highly tenacious. It may be rolled into leaves so thin that a bound book containing forty-four such leaves shall be only one-fifteenth part of an inch in thickness. In the condition of perfect purity it is never seen except in the chemist's laboratory. Even the purest iron of commerce contains traces of other substances. Dilute sulphuric and muriatic acids are its proper solvents, forming with it green solutions. The addition of nitric acid or chlorine changes the color to red. Iron may be readily burned, as has already been shown in the section on oxygen.

194



647. Occurrence.—Iron is a most abundant metal, but is rarely or never found in the metallic form, excepting as meteoric iron. In this condition it is always alloyed with nickel. The latter metal being uniformly combined with it in masses known to have fallen to the earth as *meteors*, its presence in similar masses discovered on the surface of the earth, is regarded as evidence of their metoric origin. Iron is a constituent of a great variety of minerals, of all soils and plants, and even of the blood of animals. The peroxide of iron, the mag-

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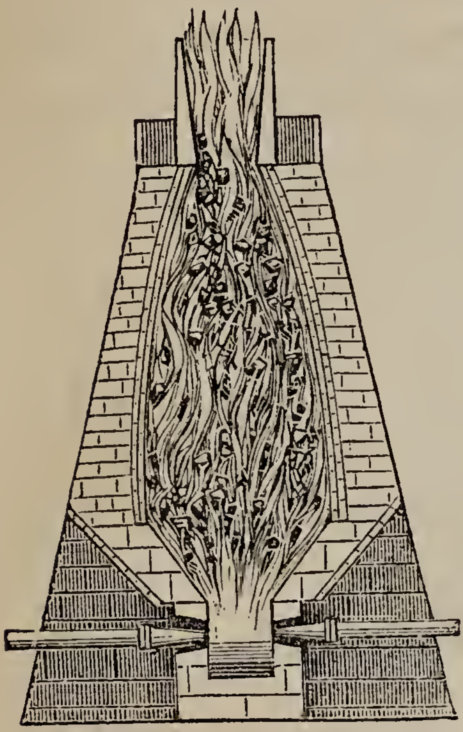
646. Mention some properties of iron. 647. Does metallic iron occur in nature?

netic oxide, and *clay iron stone*, are its principal ores. Whole mountains of the magnetic oxide exist in Missouri and in Sweden.

648. Production.—Iron is produced from its ores, which are impure oxides, by heating with lime, to remove the impurity, and at the same time with coal and the gases proceeding from it, to remove the oxygen. A smelting furnace, such as is represented in the figure, being previously heated, is charged with the material in layers, and the heat maintained by the coal of the mixture. In the upper part of the furnace the materials are thoroughly dried. As they gradually settle, they become more thoroughly heated, and meet carbonic oxide from the coal below, which robs the iron of its oxygen, and converts it into particles of metal. Still lower down, the lime combines with the earthy portions of the ore, forming a liquid glass. The reduced iron thus liberated, collects, fuses, and sinks to the bottom of the furnace. From this point it is run off into channels of sand, where it hardens into *pig iron*.

195



649. Explanation.—The ordinary impurities of the

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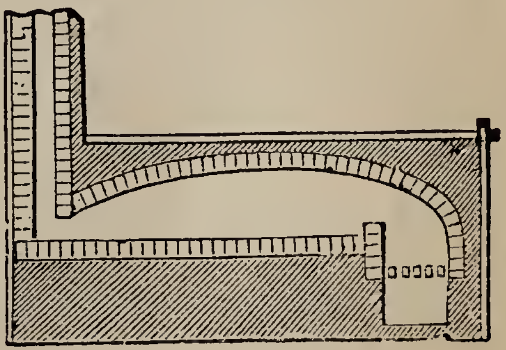
648. How is iron produced? 649. How is the slag formed? For what uses may it be employed?

ore are clay and quartz or silica. Lime has the property of forming, with both of these, a fusible glass or slag, which floats upon the melted iron. This material is of a light green color. But it may be otherwise colored to suit the taste, and cast into slabs, columns, architectural and parlor ornaments of great beauty. The process by which its brittleness is removed, and the slag adapted to the above uses, has not been made public.

650. Cast Iron.—The pig or cast iron, as it is called, which is thus obtained from the furnace, is not pure iron, but a compound of iron with carbon. It has obtained four or five per cent. of this element from the coal with which it was reduced. The addition of carbon to its composition causes iron to melt more readily. But for its absorption, the metal would not have become sufficiently soft to flow from the furnace. Carbon has also the opposite property of making iron harder and more brittle when cold. Castings of agricultural implements and other objects, are made by remelting the pig iron, and pouring it into moulds of the required shape.

196



651. Wrought Iron.—Wrought iron is made from cast iron, by burning out its carbon. This is done in what is called a reverbera-

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650. Give the composition and properties of cast iron. 651. How is wrought iron made?

tory furnace, such as is represented in the figure. The carbon is burned out by the surplus air of the flame, which is made to play upon the molten iron. From the constant stirring which is essential, such a furnace for refining iron is called a *puddling furnace.* The metal becomes stiffer as it loses carbon, and is then hammered and rolled into bars.

652. Iron Wire.—The bar of wrought iron thus produced, is highly malleable and ductile, and may be rolled into sheets, or drawn into the finest wire. Wire is made by drawing a wrought iron bar, by machinery, through a hole of less than its own diameter, and repeating the process until the required degree of fineness is attained. Wrought iron loses its tenacity, and becomes granular and brittle, like cast iron, by long jarring. This effect sometimes occurs in the wheels and axles of railway carriages, and is the occasion of serious accidents.

653. Welding.—Wrought iron becomes soft at a certain heat, without melting. This property, which adds greatly to its usefulness, belongs to no other metal excepting platinum. In the soft state, two pieces may be united by hammering. This process is called *welding.* The surfaces to be welded are sprinkled with borax, to protect them from the air, which would form a crust of oxide of iron and prevent a perfect contact. Its further action is explained in the chapter on salts. Beside

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652. Mention an important property of wrought iron. How is iron wire made? 653. How is wrought iron welded?

borax, other materials having a similar effect are frequently employed.

654. STEEL.—Steel may be made from cast iron by burning out half its carbon. Or it may be made from wrought iron, by returning half of the carbon which was removed in its preparation. The latter is the process generally pursued. It consists in burying the wrought metal in iron boxes containing charcoal and heating it for several days, until combination with a certain portion of the carbon is effected.

655. ANNEALING.—The hardness of steel depends upon the rate at which it is cooled. By heating it to redness, and cooling it slowly, it is rendered as soft and malleable as wrought iron. This process is called *annealing*. By cooling it very suddenly, it becomes as hard and brittle as cast iron. Steel instruments are commonly hammered out of the soft steel, and subsequently hardened.

656. TEMPERING STEEL.—Steel hardened as above described is too hard and brittle for most uses. Any portion of its original softness and tenacity may be returned to it, by reheating and slow cooling. To restore the whole, a red heat would be required. To give back part, and make a steel so tough as not to break readily, yet sufficiently hard for cutting, a lower temperature is employed. This process is called *tempering*. The sort of temper imparted depends upon the degree of heat which has been employed.

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654. How is steel made? 655. How is steel made soft or hard? 656. How is steel tempered?

657. The proper temperature is ascertained by the color which the steel assumes when heated. Tools for cutting metal are heated until they become a pale yellow; planes and knives, to a darker yellow; chisels and hatchets, to a purplish yellow; springs, till they become purple, or blue. In each case they are afterward slowly cooled. These colors are owing to a film of oxide of iron, which is formed upon the steel under the influence of heat. The tint is different, according to the thickness of the film. All these colors may be seen by heating a knitting-needle in the flame of a spirit lamp. Where it is hottest it becomes blue, and this color shades off into pale yellow on either side, like the colors of the solar spectrum.

658. WRITING UPON STEEL.—Nitric acid corrodes steel dissolving the iron but leaving the carbon which it contains in the form of a dark gray stain. Writing and ornamental shading upon polished steel are performed in this manner. Nitric acid leaves only a whitish green stain upon iron which may by this means be distinguished from steel.

659. IRON AS A MEDICINE.—Pure iron in a finely divided state is used in medicine as a tonic. For this purpose it is reduced from the oxide by the action of hydrogen.

660. IRON REDUCED BY HYDROGEN.—Pure oxide of iron is heated in a bulb of hard glass, A, figure 197,

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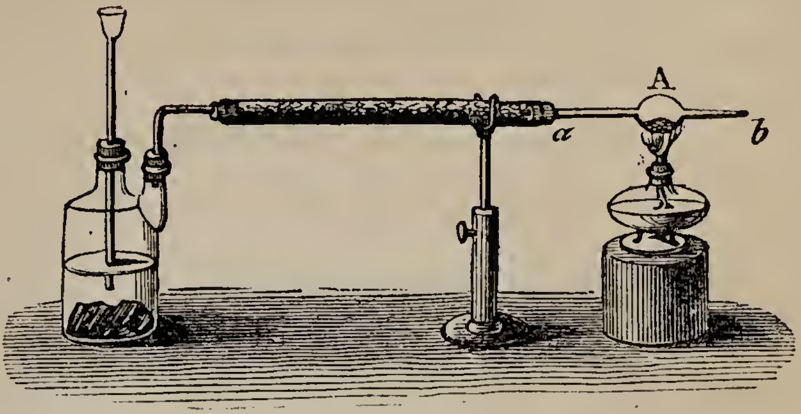
657. How is the proper heat ascertained? 658. What is the method of writing upon steel? 659. How is iron used as a medicine? 660. Describe the method of reducing iron by hydrogen

by the flame of a spirit lamp; a current of hydrogen is passed through a glass tube filled with chloride of calcium to remove all traces of moisture, after which it passes through *ab* carrying with it the oxygen which it takes away from the heated oxide. Pure iron thus obtained in a finely divided state takes fire spontaneously in the open air. It must therefore be kept in sealed tubes. If this operation is conducted in a porcelain tube at a high temperature the product may be kept in glass bottles without oxidation and is then in a suitable form to be used as a medicine.

197



Chromium.

Symbol, Cr; *Equivalent*, 26.27; *Specific Gravity*, 6.8.

661. Description.—Chromium is a grey metal, not readily tarnished and so hard as to scratch glass. It is of no use in the arts in the metallic form. It is found in combination with iron, as *chromic iron*, and also in beautiful crystals, as red chromate of lead. It may be prepared from its oxide, like iron, by heating with charcoal. Its compounds are much valued as coloring materials both in painting on porcelain and in

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661. Chromium—description, production, ores, solvents, and uses?

calico printing. Chrome green and chrome yellow are valuable pigments. Its proper solvents are the same as those of iron. The solutions of this metal are green.

Cobalt.

Symbol, Co; *Equivalent*, 29.5; *Specific Gravity*, 8.95.

662. Description.—Cobalt is another grey metal, tarnishing but slightly in the air. It is somewhat malleable. It is found combined with arsenic, as *arsenical cobalt*, and in some other minerals. As metal, it is without useful application in the arts. It may be produced like iron, by heating with charcoal, but is more readily reduced by hydrogen. A current of this gas being made to pass through a hot tube containing the oxide, it combines with oxygen, and passes off with it as water, leaving the metal in the form of a fine powder. Its proper solvents are the same as those of iron and chromium. Many of the compounds of cobalt are remarkable for the beauty and brilliancy of their color, and are used as pigments. The solutions of cobalt are pink. The oxide is employed for imparting a blue color to glass.

Nickel.

Symbol, Ni; *Equivalent*, 26.5; *Specific Gravity*, 8.82.

663. Description and Properties.—Pure nickel is a brilliant, silver white metal, hard and ductile, surpass-

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662. Cobalt—description, production, occurrence, solvents, and uses?
663. Nickel—description, production, ores, solvents, and uses?

Nickel [illegible]

ing even iron in tenacity. Nickel is not much affected by the air at ordinary temperatures. It is found in combination with copper in the mineral called *copper nickel.* It may be prepared by either of the methods used for cobalt. Its proper solvents are the same as those of the last four metals. The solutions of this metal are green. Nickel is principally used in the preparation of the alloy called German silver. This imitation of silver is brass rendered white by the proportion of nickel which it contains. The alloy is composed of one hundred parts of copper, sixty of zinc, and forty of nickel. The Chinese use an alloy consisting of 8 parts copper, 6½ of zinc, and 3 of nickel.

Zinc.

Symbol, Zn; *Equivalent,* 32; *Specific Gravity,* 6.8.

664. Description.—Zinc is a bluish white metal readily tarnished in moist air. It is brittle at ordinary temperatures, and converted into vapor at a red heat. If heated somewhat above the temperature of boiling water, it can be rolled into sheets. At a higher temperature, from 300° to 400° it again becomes brittle and may be pulverized in a mortar. It melts at 770° and is volatile at a bright red heat. Sulphuric and muriatic acids dissolve it readily, forming colorless solutions. It is not found native. The *red oxide,* and the carbonate, called *calamine,* are among its more important ores.

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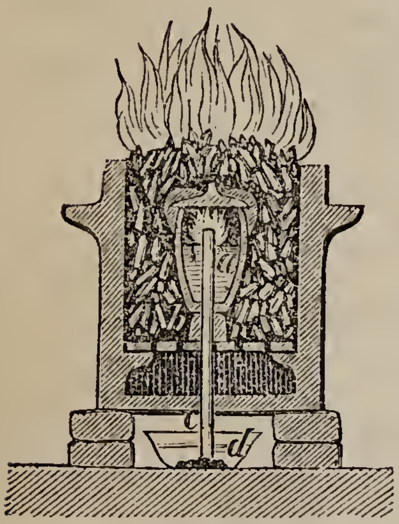
664. Zinc—description, ores, and solvents?

665. Production.—Zinc is produced from its oxide by heating with charcoal to remove the oxygen, or, in other words, to reduce it. When made from the carbonate, the ore is previously roasted, to expel its carbonic acid and bring it to the state of oxide. As the metal is volatile at the heat required in its reduction, an ordinary furnace, such as is used for making iron, cannot be employed in the process: the metal would be lost in vapor. It is therefore obtained by a process of distillation. The roasted ore mixed with powdered charcoal is placed in a covered crucible, *a*, which is placed in a furnace; a tube, *c*, passes from near the top of the crucible downward through the bottom of the crucible and furnace to a vessel of water, *d*, in which the vapor of zinc as it issues from the crucible is condensed. The metal thus produced contains some impurities, consisting of iron, lead, arsenic and cadmium some of which are separated by re-distillation. The carbonic oxide produced in the process at the same time, escapes into the air. It will be observed, that the process is essentially the same as that for producing potassium and phosphorus, as before described. Acids dissolve zinc, forming colorless solutions.

198



666. Action of Heat and Air.—Zinc may be burned

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665. How is zinc produced? Why is a clay retort used? 666. How may zinc be burned? How melted?

by heating it on charcoal in the blow-pipe flame. It melts, and converts itself rapidly in the process into white oxide of zinc. If an intense heat is employed, the vapors of the metal burst through the crust and burn to oxide, with a brilliant greenish flame. When zinc is burned in considerable quantity, in a highly heated crucible, the oxide forms flakes in the air to which the name of *lana philosophica* or philosopher's wool, was given by the alchemists. The oxide of zinc thus formed is collected and used as a pigment instead of white lead. It is cheaper than lead, not poisonous, it is not blackened by bilge water or sulphuretted hydrogen, because its compounds with sulphur are white. Zinc is the only metal which forms white compounds with sulphur. The metal may be melted over a spirit lamp, in an iron spoon.

199

667. Uses of Zinc.—Zinc is principally employed in the form of sheet zinc, for roofing and similar purposes. It is also used, like tin, as a coating to protect iron chains and other objects from rust. The coating is effected by plunging the iron into molten zinc, which forms an alloy upon its surface. The iron and zinc thus combined act as a Voltaic circle, and the oxygen which would otherwise attack and rust the iron goes to the zinc and forms an oxide of zinc. The iron is thus protected from rust as long as any clean surface of zinc remains not oxidized. The iron thus coated is sometimes called *Galvanized* iron, though without reason, as

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667. Mention the uses of zinc?

is evident from the above process, since no Galvanic action was employed in preparing this coating of zinc. Solutions of zinc are sometimes used to prevent the decay of wood, and to render it less combustible. It has also been employed with success, as a substitute for copper, in sheathing vessels.

Cadmium.

Symbol Cd; *Equivalent,* 56; *Specific Gravity,* 8.6.

668. Cadmium is found in some ores of zinc, and being more volatile than zinc the greater part passes over with the first portions of distilled metal. Cadmium is a white metal resembling tin and so soft that it leaves a trace upon paper. It is malleable and ductile, melts at 442°. It is chiefly interesting on account of the alloys it forms with other metals.

CLASS FOURTH.

Tin.

Symbol, Sn; (Stannin;) *Equivalent,* 56; *Specific Gravity,* 7.28.

669. Description.—Tin is a brilliant white metal, very soft and malleable, and not easily tarnished. When a bar of tin is bent, it gives a peculiar grating sound, fancifully called *the cry of tin.* This is a consequence of the friction of the minute crystals of tin of which it is composed. Its only ore is an oxide, called *tin stone,* of which Cornwall, England, is the principal

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668. Describe the source, appearance and properties of cadmium.
669. Describe the metal tin. From what ore is it made?

locality. The purest tin is obtained from the island of Banca, in the Dutch East Indies. This beautiful metal is one of those which have been longest known to man, as it is mentioned in the Books of Moses.

670. Production.—Tin is produced, like iron and most other metals, by heating its oxide with carbon. The materials are heated in a small blast furnace. The carbonic oxide produced in the fire, as before explained, is the reducing agent. It takes the oxygen from the ore, and passes off with it as carbonic acid, while the metal fuses and runs to the bottom of the furnace. By heating tin before the blow-pipe, it is rapidly converted into white oxide.

671. Action of Acids.—Tin resists weak acids remarkably. Dilute muriatic and sulphuric acids, which dissolve most of the metals before described, act upon it but feebly. The concentrated acids dissolve it with comparative ease. Its solution, although less poisonous than those of lead, is still injurious to health. Acid food should, therefore, never be allowed to stand for a long time in tin vessels. The solutions of tin are colorless.

200

672. Nitric acid acts upon tin with energy; but, like a ferocious animal that destroys without devouring its prey, leaves it undissolved. It converts it into a white insoluble powder of oxide of tin, with the evolution of the usual red fumes. This case is an exception to the

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670. How is tin produced? 671. How do acids act on tin? 672. What is the action of nitric acid?

usual action of nitric acid. One portion of the acid commonly acts to produce oxide, while another portion dissolves the oxide formed. The experiment for the solution of tin may be made with tin-foil, in a tea-cup or test-tube.

673. *Aqua-regia*, it will be remembered, is a mixture of nitric and muriatic acids. In most cases they act, as before described, in concert to dissolve metals that neither can dissolve alone. They act thus, also, upon tin, in small portions. But if larger quantities are employed, the mixture grows warm, and the nitric acid, as if stimulated beyond restraint, attacks the metal for itself, and converts it, as when it acts alone, into a white powder.

674. COATING PINS.—Common brass pins are coated by boiling with cream of tartar and tin-foil or bits of tin. The acid of the *tartar* acts as a solvent. Tin is then deposited on the more electro-positive brass, as in cases of galvanic decomposition. At every point where brass, tin and the liquid are in contact, a small Galvanic battery is in fact produced.

675. ORNAMENTING WITH TIN.—In India tin is applied instead of silver to steel and iron by way of ornament. The tin is melted and while still liquid is agitated in a box until it has become solid; the fine powder thus procured is separated from the coarser particles by suspension in water, and is made into a thin paste with glue; it is then applied in the desired

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673. What is the action of aqua regia on tin? 674. How are pins coated with tin? 675. How is tin used for ornamental purposes in India?

pattern; when perfectly dry it is burnished, and afterwards varnished; its brilliancy is thus preserved unchanged.

676. Tin Ware.—Tin is cast in various forms, for culinary and chemical utensils. A little lead is added to give it greater toughness. Common tin ware is made of sheet-iron coated with tin. The coating of the metal is effected by dipping well cleaned sheet-iron into molten tin.

677. Crystalline Tin.—Tin has a great tendency to assume a crystalline form. The structure may be observed on washing the surface of ordinary tin plate with *aqua-regia*, to remove the thin coating of oxide. It may be still better seen if a tin plate is heated over a lamp until the coating melts, then suddenly cooled and afterward cleaned as above directed. The whole surface is then found to be covered with beautiful crystalline forms.

Antimony.

Symbol, Sb; (Stibium;) *Equivalent*, 122; *Specific Gravity*, 6.7

678. Description.—Antimony is a bluish white and highly crystalline metal which does not tarnish in the air. It is so brittle that it may be readily reduced to powder. The ore from which the metal is produced is the grey sulphuret, or *antimony glance*.

679. Production.—Antimony may be obtained from

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676. How is tin plate made? 677. How may the crystalline structure of tin be seen? 678. Describe the metal antimony. From what ore is it obtained? 679. How is antimony produced?

its oxide by the usual process of reduction. The sulphuret is first partially converted into oxide by roasting, and still further by carbonate of soda, which is added in the subsequent process. It is then mixed with charcoal, and intensely heated in crucibles. At a white heat the metal fuses and sinks to the bottom. The soda added in the process exchanges its oxygen for the remaining sulphur of the ore.

680. Action of Heat and Air.—If heated before the blow-pipe, antimony soon melts, and burns with a white flame. It is at the same time converted into oxide. A portion of the oxide escapes into the air, while the rest forms a white coating upon the charcoal support. At the high temperature which is here produced, the affinity of the metal for oxygen is so stimulated, that the molten globule, will continue to burn, even if removed from the flame. By directing a stream of air upon it, from a pipe-stem, the combustion may be maintained until the globule is entirely consumed.

201

681. If the molten globule is allowed to fall upon the floor, it immediately divides into hundreds of smaller globules which radiate in all directions, leaving each a distinct track of white oxide behind it.

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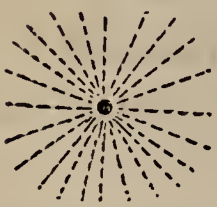

682. Action of Chlorine.—A shower of fire may be produced by sprinkling fine powder of

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680. How may antimony be burned? 681. Describe an experiment with the molten globule. 682. What is the action of chlorine on antimony?

antimony into a vial containing chlorine gas. The metal is hereby converted into a white smoke of chloride of antimony. In its relations to the principal acids, antimony resembles tin. Its solutions are colorless.

683. Uses of Antimony. — The principal use of antimony is in the preparation of alloys, to be hereafter described. Among these, type metal is the most important. Many of the compounds of antimony, like other poisonous substances, are used with advantage in medicine. Tartar emetic is one of these medicinal compounds containing antimony.

CLASS FIFTH.

Bismuth.

Symbol, Bi; *Equivalent*, 210; *Specific Gravity*, 9.8.

684. Description.—Bismuth is a brittle, crystalline metal of a reddish white color. It is used in making certain alloys. Like antimony it can be readily ground to powder. Crystals of bismuth may be obtained by the method described in the section on Sulphur, as represented in the figure. Nitric acid is its proper solvent and forms with it a colorless solution. Bismuth is found native, forming threads of metal in quartz rock. Its most productive localities are in Saxony.

203

685. Production.—The metal is procured from the

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683. What are the principal uses of antimony? 684. Bismuth—description, solvents, and occurrence in nature. 685. How is bismuth produced?

rock which contains it, by simply heating in inclined tubes. At a comparatively moderate temperature the bismuth fuses and runs down into vessels placed to receive it.

686. Effect of Heat and Air.—The same experiments before the blow-pipe, and with molten globules, which were described in the case of antimony, may be made with bismuth. The only difference is, that the metal does not burn with flame, and that the coating of oxide on the charcoal is yellow, instead of white.

204

687. Uses of Bismuth.—Its principal use is in the preparation of alloys, to be described hereafter. One of them has the remarkable property of fusing in boiling water. Several compounds of bismuth are used in medicine; the sub-nitrate is also employed as a cosmetic. This use of it is quite hazardous, as certain gases which are often present in the air, have the effect, as will be hereafter seen, of changing its color to a deep brown or black.

Copper.

Symbol, Cu, (Cuprum); *Equivalent*, 32; *Specific Gravity*, 8.8.

688. Description.—Copper is a red, malleable, and highly tenacious metal. It tarnishes in the air, but is less injured by rust than iron, and therefore more dura-

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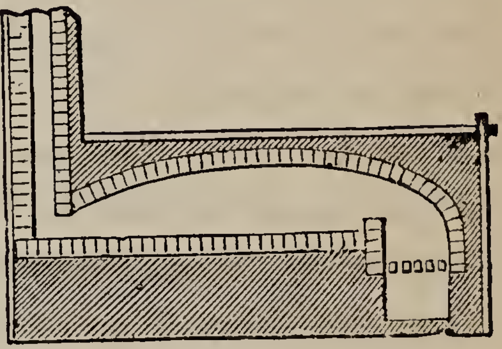
686. What is its action before the blow-pipe? 687. What are the uses of bismuth? 688. Copper—description, ores, solvents?

ble. Nitric acid is its proper solvent, and forms with it a green solution. Copper is found in abundance, in the metallic condition, on the southern shore of Lake Superior. It is chiseled out, in masses, from the rocks which contain it. The metal is more commonly obtained from a mineral called *copper pyrites*, which is a double sulphuret of iron and copper, it is also found as pure sulphuret, red oxide, and carbonate. Minute traces of copper are found in human blood.

689. Production.—Copper is prepared from the impure sulphuret, by first burning out the sulphur in the air; and secondly, heating with charcoal to remove the oxygen which has taken its place. Sand is at the same time added, to form a floating slag with the oxide of iron, and thus remove it from the molten copper. The oxide of iron thus removed, is derived from the sulphuret of iron which is a usual constituent of copper ores.

205



690. Both of the above processes of roasting and heating with charcoal and sand, must be several times repeated before pure metallic copper is obtained. It is to be remarked that the formation of a slag which shall remove this iron, depends on the fact that its oxide is by no means so easily reduced as copper. Being

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689. State briefly the mode of production. 690. State further particulars of the process.

once brought into the state of oxide, it remains in this condition and unites with the silicic acid of the sand.

691. Action of Heat and Air.—At a high temperature, copper is readily oxidized in the air. Its oxidation may be observed by holding a copper coin in the flame of a spirit lamp, as described in the section on Flame. The iridescent hues observed in the experiment, are owing to the varying depth of oxide on different portions of the coin. By long continuation of the process, the whole surface is converted into black oxide. If it is sooner suspended, and the coin plunged into cold water, a coating of red oxide containing less oxygen is obtained.

692. Uses of Copper.—Copper is used for a variety of purposes for which iron would be less suitable on account of its rapid oxidation. Its employment in sheathing ships, is an example. It is also a constituent of various alloys, to be hereafter described. Among these, all gold and silver coins, and the metal of gold and silver plate are included. Copper wire is used in telegraphic cables for conducting electricity, being a better conductor than any other metal except silver.

693. The copper of commerce often contains minute quantities of arsenic, iron and lead, and sometimes tin and silver. Copper may be obtained in a state of perfect purity by decomposing a solution of sulphate of copper by means of the Voltaic battery; it is then de-

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691. What is the effect of heat and air? 692. Mention some of the uses of copper. 693. How may pure copper be obtained?

posited in coherent plates upon the negative electrode as in the process of copying medals or in electrotyping.

694. Bronzing Copper Vessels.—Copper vessels, such as tea-urns, are often superficially coated with oxide, or *bronzed* to give them an agreeable appearance and to prevent tarnish. The copper surface is cleaned, and then brushed over with peroxide of iron (generally colcothar) made into a paste with water, or with a very dilute solution of acetate of copper; heat is then cautiously applied in a proper furnace or muffle until it is found on brushing off the oxide that the surface beneath has acquired a proper hue.

Lead.

Symbol, Pb, (Plumbum): *Equivalent*, 104; *Specific Gravity*, 11.4

695. Description.—Lead is a bluish grey metal, extremely malleable, and readily tarnished in the air. It is heavier than any other of the metals mentioned in this work except mercury, gold and platinum. Nitric acid is its proper solvent, forming with it a colorless solution. The principal ore of this metal is *galena* or sulphuret of lead. Lead is also found as carbonate, sulphate, and phosphate of lead.

696. Production.—Lead is obtained from the sulphuret by heating it with iron, to remove the sulphur. A mixture of metallic lead and sulphuret of iron is thus

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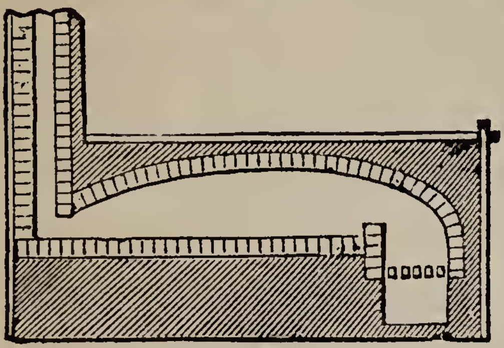
694. How is a bronze color given to copper vessels? 695. Lead—description, ores and solvents. 696. How is lead obtained?

produced, from which the lead separates by its greater specific gravity. If the oxide of lead could be readily obtained the reduction by charcoal would be as applicable here as in the case of other metals.

206



697. A SECOND METHOD.—Another method, is to heat the sulphuret with a portion of sulphate. The sulphate has a large supply of oxygen, while the sulphuret is destitute of this element. The two may be mixed in such proportions that they will together contain just enough oxygen to carry off all the sulphur as sulphurous acid. This result having been accomplished by heat, the pure metal of both remains behind. As a preparation for this process, a portion of sulphuret is converted into sulphate by heating in a reverbaratory furnace. Both parts of the process are in practice united; a moderate heat with abundant air being first supplied, a portion of sulphate is produced. This is afterwards more highly heated, with the undecomposed sulphuret which remains.

698. ACTION OF AIR AND HEAT.—If lead is heated before the blow-pipe in the oxidizing flame, it melts and disappears. The charcoal support becomes at the same time covered with yellow oxide of

207

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697. Explain another method. 698. What occurs when lead is heated before the blow-pipe?

lead or litharge. The grey coating which at first forms upon the lead, is an oxide containing less oxygen. If, on the other hand, litharge is heated in the reducing flame, it is converted into metal.

699. Action of Water.—Water, with the help of the air which it always contains, acts sensibly upon lead and becomes in consequence poisonous. This action of water is most decided when it contains no foreign matter. On being conducted through leaden pipes, it becomes therefore more impure as a consequence of its very purity.

700. The presence of sulphates and certain other salts, such as are usually contained in spring water, prevents this effect. Those substances the presence of which in water we are accustomed to regret as impurities, thus become our most efficient protectors against the poisonous effects of lead.

701. But this rule is not without exception. Certain substances seem to increase the action. It is therefore always prudent where it is proposed to conduct water through leaden pipes, to ascertain by direct experiment, whether the particular water in question acts upon the lead or not.

702. Illustration.—The difference in the action of pure water upon lead, and that which contains foreign substances in solution, may be readily proved by experiment. For this purpose, bright slips of lead may

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699. What is the action of water on lead? 700. What prevents this action? 701. Do impurities always protect? 702. Describe the experiment with lead and distilled water.

be placed in two tumblers, the one containing rain water, and the other well or spring water. The former will soon become turbid while the latter remains unaffected.

703. The presence of lead in the former case may be still more strikingly shown, by adding to the water a few drops of a solution of hydrosulphuric acid. The formation of a dark cloud will show the presence of lead and indicate the danger to be apprehended.

704. LEAD TREE.—Dissolve some crystals of sugar of lead in thirty or forty times their bulk of water, and fill a vial with the solution. A strip of zinc hung in the vial will branch out in a beautiful arborescence of metallic lead. It may be necessary to clarify the solution by the addition of a little clear vinegar or acetic acid. A day or two will be required for the completion of the experiment. The effect depends on the superior affinities of zinc for acetic acid. The zinc takes away acid and oxygen from successive portions of the sugar of lead, and leaves the particles of lead subject to the laws of crystallization. At the same time, the zinc having acquired possession of the acid and oxygen comes into solution as acetate of zinc. A similar arborescence is produced in a solution of silver by metallic mercury.

208

705. MANUFACTURE OF SHOT AND BULLETS.—Shot are prepared by pouring melted lead through perforated

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703. How may the presence of lead be better shown? 704. Describe the lead tree and the reason of its production. 705. How are shot made?

iron vessels. A small quantity of arsenic is added to the lead to increase its fluidity when melted that it may be free to take a perfectly spherical form in falling. The drops are made to fall from a great height, that they may become cooled and solidified in their descent. They are caught in water that their shape may not be impaired. Having been assorted by means of seives, they are polished in revolving casks containing a small portion of black lead or plumbago. When lead is slowly cooled it contracts during solidification; in bullets, therefore, there is generally a cavity which interferes with the rectilinear passage of the ball. Improved conical balls are therefore pressed in dies to make them perfectly solid throughout, by which the accuracy of flight is greatly increased.

706. Other Uses of Lead.—In the form of sheet lead this metal is applied to a variety of familiar uses. It is also largely employed in the manufacture of lead tubing. It is a constituent of various alloys, among which pewter and type metal are the more important.

CLASS SIXTH.

Mercury.

Symbol, Hg, (Hydrargyrum); *Equivalent,* 100; *Specific Gravity, as a solid,* 14; *as a liquid, at 32°F.,* 13.596; *as vapor,* 6.9 *times heavier than air.*

707. Description.—Mercury is a white fluid metal of high luster and beauty. It retains the fluid condition

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706. Mention other uses of lead. 707. Mercury—description, solvents, ores, discoveries.

at all ordinary temperatures. It becomes solid at 40° below zero, and boils at 660°. Nitric acid is its proper solvent. When pure mercury is shaken with water, ether, sulphuric acid or oil of turpentine, or rubbed with sugar, chalk, lard, or conserve of roses, it is reduced to a gray powder which consists of minute mercurial globules blended with the foreign body. When this is removed they again unite into fluid mercury. In mercurial ointment (a mixture of lard and mercury) the globules of mercury are so small they cannot be discerned by the naked eye. If a solution of corrosive sublimate is precipitated by protochloride of tin, the liberated mercury forms so fine a precipitate that it is perfectly black and requires several hours to collect into shining globules. Mercury is sometimes found in the metallic form, but more commonly as the sulphuret or *cinnabar*, which is its principal ore. It is said that the mines in Mexico were accidentally discovered by a native hunting among the mountains. Laying hold of a shrub to assist him in his ascent, he tore it up by the roots, and a stream of what he supposed to be liquid silver flowed from the broken ground.

708. SOURCES OF MERCURY.—The most productive mines of mercury are those of Almaden in Spain. It is also obtained from Mexico, California, Peru, China and Japan. The principal ore of mercury is the sulphuret called *cinnabar*. It also occurs as a chloride, iodide and selenide; in combination with silver it occurs in the metallic state as an amalgam.

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708. Where is mercury obtained?

709. Production.—Mercury is prepared from the sulphuret, by simply roasting in a current of heated air. This metal yields its sulphur so readily to the oxygen of the air that no other agent is essential in its production. The mercurial vapors pass along with the gas, into tubes or chambers where the temperature is lower, and are there condensed to the liquid form.

710. Mercury may also be produced from the sulphuret by the employment of iron filings to remove the sulphur, as in the case of lead. Burned lime may also be used. Its calcium combines with the sulphur and uses its own oxygen for the partial conversion of the sulphuret thus formed into sulphate of lime.

711. Action of Heat and Air.—Mercury, like water, may be boiled away and converted into vapor by the application of heat. It is always to be borne in mind in experiments with this metal and its compounds, that its fumes as well as its salts are extremely poisonous. By free access of air and moderate heat, mercury may be gradually converted into red oxide, but a higher temperature expels the oxygen thus absorbed, and the oxide is again converted into metal. This production of a metal from an oxide, by heat alone, is characteristic of the noble metals. They are loth to obscure their splendor in rust; if it is forced upon them, they need but little assistance of heat to throw it off and re-assume their original beauty.

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709. How is mercury obtained? 710. Mention other methods. 711. What is the action of heat and air on mercury?

712. Amalgams.—Glass Mirrors.—Mercury combines with many metals forming compounds which are called *amalgams.* When the mercury is in large proportion they are fluid. Gold, silver, and lead, for example, may be dissolved in mercury. This solvent power of mercury is usefully applied in extracting gold from the rocks which contain it. The gold bearing quartz is first crushed in mills and then submitted to the action of mercury, which takes up the gold, leaving the other materials entirely free from gold. The beautiful silvering of mirrors consists of an alloy of tin and mercury. Tin foil is applied to the glass, and being afterward drenched with mercury, the excess is removed by pressure. The tin thus absorbs about one-fourth of its own weight of mercury.

713. A copper coin may be similarly silvered by rubbing with metallic mercury, or keeping it well moistened for some time with a solution of mercury in nitric acid. If the solution is quite acid, it must first be nearly neutralized by ammonia. The coin is to be afterward polished. The chemical action which takes place in this case is similar to that explained in the case of the *lead tree.* By drawing a line across a thin brass plate with a pen dipped in solution of mercury, the plate will be so weakened that it may afterward be readily broken.

714. Other Uses of Mercury.—The compounds of

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712. What are amalgams? How are mirrors silvered? 713. How may a copper coin be similarly silvered? 714. Mention some other uses of mercury.

mercury are extensively used in medicine. *Corrosive sublimate*, a poisonous chloride of mercury, is employed for the destruction of vermin. It is also used in what is called the *kyanizing* process, to impregnate wood and other vegetable and animal substances, and thus prevent their decay. Another important use of mercury is found in the manufacture of barometers and thermometers. It is especially adapted to the measurement of heat, by its fluidity at low temperatures and its ready and equable expansion.

Silver.

Symbol, Ag. (Argentum); *Equivalent*, 108; *Specific Gravity*, 10.5.

715. Description.—Silver is a lustrous white metal of perfect ductility and malleability. Its loss of luster on exposure, is owing to the presence of a small proportion of sulphuretted hydrogen in the air. Nitric acid is its proper solvent, though for certain purposes oil of vitriol is preferred. Silver is often found native, but more frequently combined with sulphur as *silver glance*. Galena or sulphuret of lead always contains it in small proportion, and sometimes to the amount of one or two per cent.

716. Production.—Silver is prepared from the sulphuret, by first roasting the ore with common salt, in order to convert it into chloride. Iron is subsequently

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715. Silver—description, ores and solvents? 716. How is silver obtained?

employed to remove the chlorine and isolate the metallic silver.

717. Mercury is added with the iron, in order that it may dissolve the silver from the mass of roasted ore and iron as fast as it is formed. The materials are agitated with water for many hours together. At the end of the process the mercury, with its load of silver, is drawn off from the bottom of the cask. The solution of silver in mercury is afterward filtered through buckskin or closely woven cloth, which allows a large part of the liquid metal to pass, while the silver with a small portion of mercury is detained. The silver is then freed of its remaining mercury by heat. The above process is called *amalgamation*.

718. SILVER OBTAINED FROM LEAD.—Almost all lead, as produced from galena and its other ores, contains a certain proportion of silver. The latter metal may be freed from a large part of the lead by melting the alloy and then allowing it to cool slowly. Most of the lead solidifies in small crystals, and may be skimmed out with an iron cullender. An alloy containing silver in large proportion remains in the liquid condition. It is afterwards solidified by further cooling. The above is called Pattinson's process.

719. CUPELLATION.—The last traces of lead are removed from silver by a process called cupellation. Other base metals are removed in the same manner by first adding to the alloy a sufficient amount of lead.

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717. Give the complete process. 718. Describe the process for obtaining silver from lead. 719. How is silver purified from baser metals?

In case of base metals other than lead, if the quantity contained in the alloy is small, the silver prevents the access of air to the baser metal, or an infusible oxide forms upon the surface and prevents further oxidation. Cupellation depends upon the property which lead possesses of absorbing oxygen at a high temperature, and of forming with it an easily fusible oxide, which imparts oxygen with facility to all those metals which yield oxides not reducible by heat alone. Most of these oxides thus formed unite with the oxide of lead and form a fusible glass which is easily absorbed by a porous crucible made of burnt bones termed a *cupel*, figure 209. Several of these cupels are placed in a *muffle* which is a semi-cylindrical oven, figure 210, closed at one end and open at the other, with slits in the sides to allow the free circulation of air. The muffle is placed in a furnace, figure 211, fitted with suitable dampers and doors, D, E, F, G, I, and L, for regulating the heat to any required temperature. Fuel is thrown in at B and C, both below and above the muffle and a tall chimney, M, secures a sufficient draft and carries off all the noxious vapors formed. After the temperature is raised to bright redness, the alloy, if it contains only lead, is placed in one of the cupels. If it contains some other metal it is first laminated and wrapped in a suitable quantity of pure sheet lead and placed in the cupel. The metals soon melt and by the action of air which plays over the hot

209

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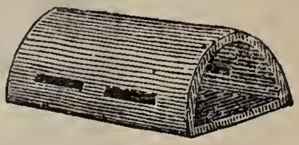

surface the lead and other base metal, if any, are oxidized, and the fused oxides are absorbed by the porous cupel.

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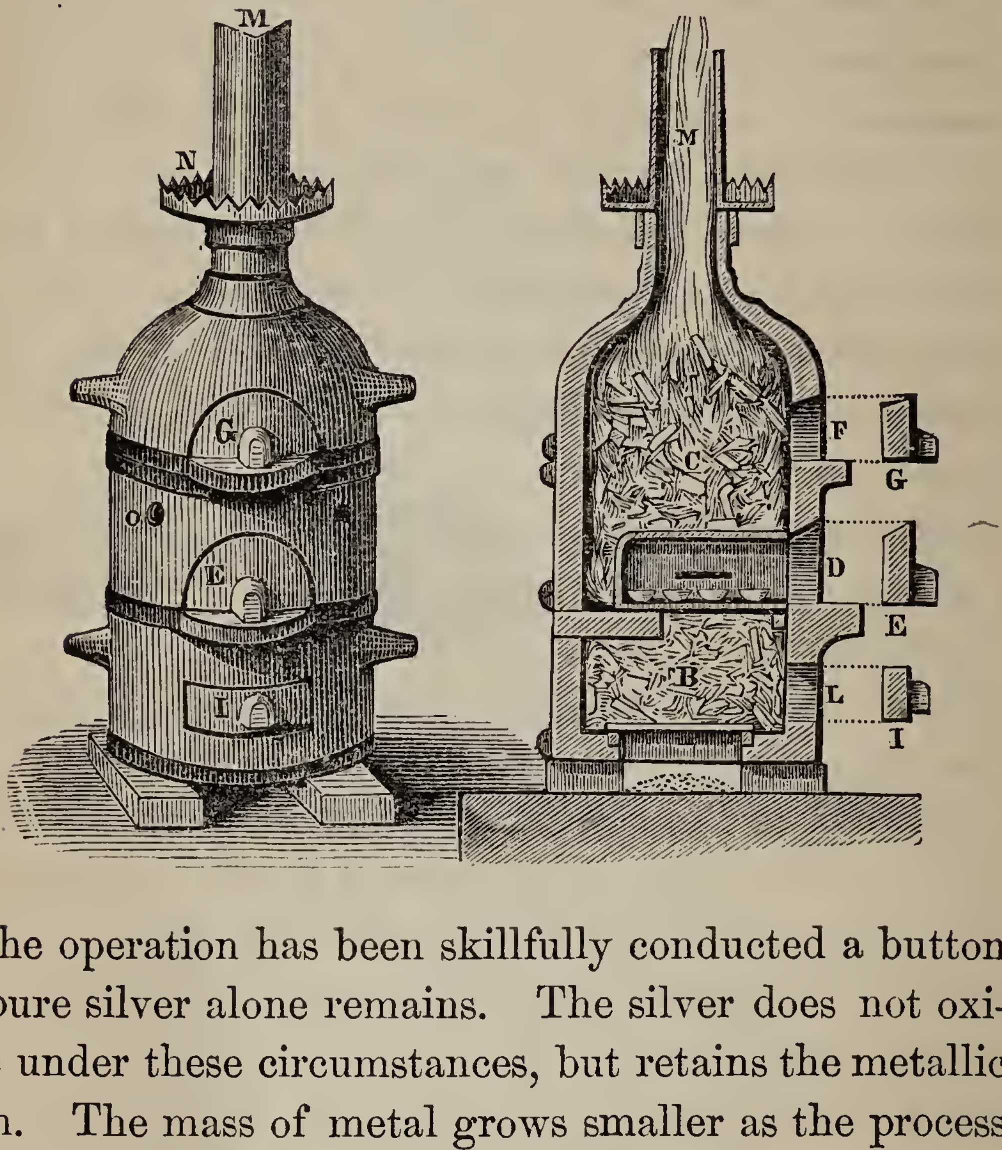

If the operation has been skillfully conducted a button of pure silver alone remains. The silver does not oxidize under these circumstances, but retains the metallic form. The mass of metal grows smaller as the process proceeds, until finally pure silver remains. The moment of its production is indicated by a beautiful play of colors and a sudden brightening of the metal. The refiner watches this process and when the globule of melted metal appears like a brilliant mirror he knows that the process is completed. The metal is then allowed to cool very gradually.

720. This process may be illustrated on a small scale, by making an excavation in a piece of charcoal, and pressing into it a lining of well burned and moistened bone ash. A globule of lead, to which a little silver has been added, is to be heated on the support in the oxidizing flame. For separating a small quantity of lead from silver, the bone ash is not essential. The process may be conducted before the blowpipe, upon the naked charcoal. A small portion of silver may often be obtained from the lead of commerce by this means.

212

721. Silver Coin.—The standard silver of the United States is an alloy containing ten per cent. of copper. Silver plate should have the same composition. The object of alloying with copper is to impart greater hardness to the metal, and secure against the gradual loss from attrition which would otherwise occur. Spanish silver often contains a small proportion of gold. The gold is left as a black powder, in dissolving such coins in nitric acid. Its color and luster may be brought out by rubbing.

722. The Silver Assay.—*Assaying* is the process by which the proportion of metals in an alloy is ascertained. In all establishments where money is coined, assaying is an important part of the work of the establishment. The precious metals, as received at the mint, commonly contain a certain proportion of other metals.

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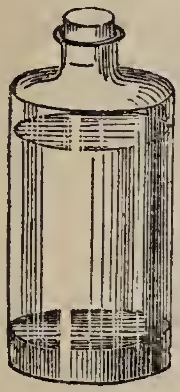
720. How may the process be illustrated? 721. What is said of silver coins? 722. What is assaying, and why necessary?

But it may be too much or too little. It is the business of the assayer to ascertain its precise composition, that the metal may be rendered purer, if necessary, or be further alloyed if found purer than the standard.

723. As a preparation for the silver assay, a sample, containing an ounce or other definite weight of the impure metal, is dissolved in nitric acid. The dissolved silver has the property of becoming solid again, and sinking to the bottom of the clear solution as a white curd, just in proportion as common salt is furnished to it. But the other metals which may be present as impurities have no such effect. It follows, that the amount of silver present, is just in proportion to the amount of salt it is necessary to supply before the precipitation or formation of the curd ceases. Now, the assayer knows beforehand, how much salt he must supply to the solution of an ounce of metal if it be all silver. If he finds that an ounce of the sample, requires to be supplied with the same quantity before the precipitation ceases, he knows that the metal is all silver; if but half as much is required, he knows that it is but half silver. Having ascertained the true proportion, the assay is completed. The salt required in the process is employed in the form of a solution, and the quantity used is known by pouring it from a graduated vessel.

213



724. EXPLANATION.—The curd which forms in the

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723. Describe the process of assaying. 724. Explain the chemical action in the above process.

above process is insoluble chloride of silver, formed from the silver of the solution and the chlorine of the salt. The nitric acid and oxygen, which were combined with the silver, at the same time unite with the sodium, forming nitrate of soda which remains in solution.

725. SILVER SEPARATED FROM COPPER.—Copper obtained from certain ores contains so much silver as to make its separation an object of importance. The method pursued is to fuse the copper with lead. As the lead flows out again by subsequent fusion, it brings with it all the silver, and the copper remains behind as a spongy mass. This process is called *liquation*. The silver is then freed from lead by the process of cupellation already described.

726. USES OF SILVER.—Most uses of silver are so familiar that they need not be here mentioned. Its employment for daguerreotype plates depends on the fact that the color of many of its compounds is readily changed by light. This subject is more fully considered in the section on Chlorides. The nitrate of silver or lunar caustic, is used in surgical operations, to burn or cauterize the flesh. In solution, it is also employed as a hair dye, and in the production of indelible ink.

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725. Describe the method of extracting silver from copper. 726. Mention some uses of silver.

Gold.

Symbol, Au. (Aurum); *Equivalent,* 197; *Specific Gravity,* 19.3.

727. Description.—Gold is a yellow metal of brilliant and permanent luster. Its extreme malleability is strikingly illustrated by the fact that it may be hammered into a leaf but a little more than $\frac{1}{300.000}$ of an inch in thickness. As the fact may be otherwise stated, a cube of gold five inches on a side could be so extended as to cover more than an acre of ground. Such gold leaf is permeable to hydrogen. A jet of this gas may be blown through it and kindled on the opposite side. Gold is proof against all ordinary acids excepting *aqua-regia.* It is found only in the metallic state, and commonly either in quartz rock or in the sands of rivers. Native gold contains from five to fifteen per cent. of silver.

728. Production.—The Refining Process.—Native gold may be freed from the silver which it contains, by the agency of concentrated sulphuric or nitric acid. A difficulty in accomplishing this result arises from the fact that every particle of silver is so perfectly surrounded by gold, that the acid does not readily reach it. This difficulty is overcome by fusing more silver into the gold, and thus opening a passage for the solvent. This being done, both the original silver and that which has been added are readily removed. The

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727. Mention some properties of gold. Its solvent, and occurrence.
728. How is pure gold produced?

above is the process at present pursued in France for refining gold.

729. Another Method.—The second method is essentially the same as that already described, with the substitution of nitric for sulphuric acid. The addition of silver, as a preliminary step, is found necessary in this process also. So much silver is added, that the gold forms but a *quarter* of the mass exposed to the action of the acid. The method is hence called *quartation.** The process involves a previous knowledge of the approximate composition of the mixed metal. This may be obtained by the *touchstone*, as hereafter described.

730. Amalgamation.—Gold may be obtained from any material which contains it, even in small proportion, by the process of *amalgamation.* This process consists in agitating the finely divided material with mercury, until the latter has extracted all of the precious metals. It is then obtained from its solution in mercury by the same means employed in the case of silver. This method is adopted in the case of the gold-bearing quartz of California. The dust of jewelers shops is similarly treated in order to save the small proportions of gold which it contains.

731. Gold from Lead and Copper.—Certain ores

729. Describe another method. 730. What is amalgamation? 731. How is gold separated from lead and copper?

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* In the practice of the United States Mint, the addition of *less* silver has been found sufficient. The proportion of gold is there increased to one-third. Nitric acid is then employed in the refining process.

of lead and copper contain so much gold that it is profitable to extract it from the metal which they yield. This is done by the processes of *liquation* and *cupellation* before described.

732. GOLD FROM SULPHURETS OF IRON, &c.—Sulphurets of iron, copper, &c., sometimes contain gold, in small quantity, and so completely disseminated that it cannot be readily extracted by mercury. It has been found advantageous to heat such ores with nitrate of soda, previous to amalgamation. The sulphurets are thus partially converted into sulphates, which can be washed out. What remains of the pulverized material is at the same time thoroughly opened to the action of mercury.

733. THE GOLD ASSAY.—Gold to be assayed contains commonly only silver and copper as impurities. By fusing the sample with lead and then removing this metal by cupellation, it carries with it the copper, into the cupel. A globule containing only gold and silver remains. The silver is then dissolved out by nitric acid. The remaining sponge of pure gold being weighed, and its weight compared with that of the original sample, the assay is completed. More silver is added in the process, for reasons stated in a previous paragraph.

734. ASSAY OF GOLD BY THE TOUCHSTONE.—Any hard and somewhat gritty stone of a dark color which

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732. How is gold obtained from certain sulphurets? 733. Describe the method of assaying gold? Why is silver added? 734. What is the touchstone and how is it used in assaying gold?

is not acted on by acids answers the purpose of a *touchstone.* The assay consists in marking upon the stone with the alloy, and judging of the purity of the metal from the color of the mark, and the degree in which it is affected by an acid. Nitric acid, to which a very small quantity of muriatic acid has been added, is employed in this test. Gold alone is proof against its action. In proportion to the permanence of the mark, is the purity of the gold which has been submitted to the assay.

735. GOLD COIN.—The gold employed for coin, plate and jewelry is always alloyed with a certain portion of copper or silver, to give it greater hardness. The standard gold of the United States is nine-tenths pure gold, the remaining tenth being an alloy of copper and silver.

736. PURITY OF GOLD.—The purity of gold is expressed in *carats*, a carat signifying, practically, one twenty-fourth. Thus, when gold is said to be sixteen carats fine, it is meant that two-thirds of it is pure gold. Gold eighteen carats fine is three-fourths pure gold and one-fourth alloy.

737. GILDING.—Gilding by the Voltaic battery has been already described. This method is, in most cases, preferable to all others. Copper jewelry is thinly gilded by boiling in a solution of gold in carbonate of soda or potash. The solution is prepared by first dissolving the gold in *aqua regia*, and afterward precipi-

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735. What is said of gold coin? 736. How is the degree of purity of gold expressed? 737. How is copper jewelry gilded?

tating and re-dissolving it by means of the carbonate above named.

738. Gilding may also be effected by an amalgam of gold and mercury. The amalgam being applied, the mercury is expelled by heat and the gold remains. This method is very frequently employed. A coating of pure gold is produced upon articles of jewelry, made of impure metal, by first heating them, and then dissolving out the copper by means of nitric acid.

Platinum.

Symbol, Pt; *Equivalent*, 99; *Specific Gravity*, 21.5.

739. Description.—Platinum is the last of the noble metals. It resembles steel in color, and possesses a high degree of malleability. It is the heaviest and the most infusible of all metals. At a white heat it may be welded like iron. Like gold it resists the action of any single acid, but may be dissolved in *aqua regia*. It is commonly found, like gold, in small flattened grains in the alluvial strata and rivers of Brazil, Peru and Mexico, and in the Uralian mountains of Siberia. It has also been found in California and Australia. Rounded masses of the metal are sometimes found as large as a pea or a small marble, and some have been found as large as a pigeon's egg. These grains usually contain also gold, iron, lead, and some other rare metals,

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738. Describe the method of gilding by an amalgam. 739. Platinum—description, occurrence, solvents?

as palladium, rhodium, iridium and osmium, which are of little interest except to the professional chemist. The value of platinum is about one-half that of gold.

740. PREPARATION.—The usual method of obtaining pure platinum is to digest the ore in nitrohydrochloric acid, decant the clear solution from the black insoluble residue and mix it with a solution of sal-ammoniac; a yellow double chloride of ammonium and platinum falls, which when well washed and heated to redness leaves a spongy mass of finely divided metallic platinum. The spongy platinum is triturated with water and then condensed in a steel mold, figure 214, until it is sufficiently compact to bear the blows of a hammer; it is then heated and forged until perfectly tough and homogenous.

214

741. DEVILLE AND DEBRAY'S METHOD OF PREPARING PLATINUM.—The prepared ore is fused with its weight of sulphuret of lead and half its weight of metallic lead; some of the impurities are thus separated in combination with sulphur, while the platinum forms an alloy with the lead, which is freed from the scoriae, and subjected to the joint action of heat and air, until the greater part of the lead is oxidized into litharge, so that the residuary alloy only retains about 5 per cent. of lead. It is then subjected to the intense heat of an oxyhydrogen flame in a furnace

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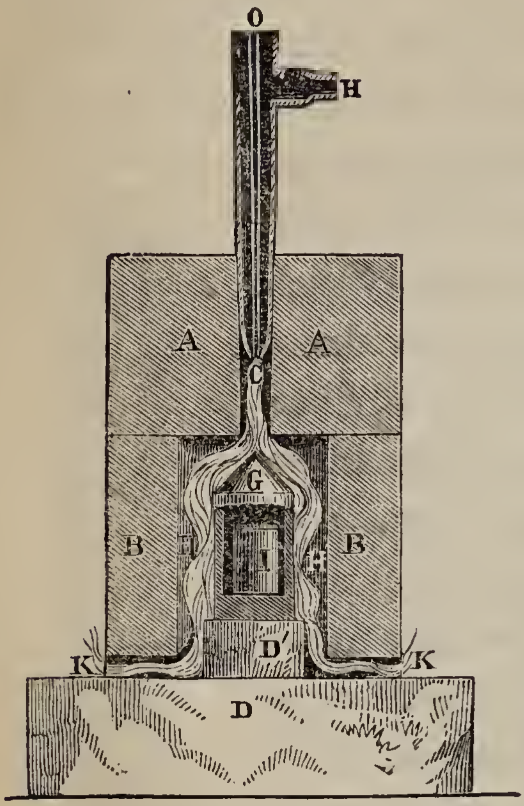
740. How is pure platinum prepared? 741. Describe Deville and Debray's method of preparing platinum.

of chalk-lime, figure 215, where the rest of the lead, (together with any gold, copper and osmium), is driven off in fumes; the remaining platinum is cast into any required form.

215



742. The Oxyhydrogen Furnace shown in section at figure 215, consists of three pieces of well burnt lime of slightly hydraulic quality which can readily be turned in a lathe. The cylinder A A is about $2\frac{1}{2}$ inches thick and is perforated with a slightly conical tube into which the tube of the oxyhydrogen blow-pipe is inserted, passing about half way through it; a second deeper cylinder of lime, B B, is hollowed into a chamber wide enough to admit the crucible and leave an interval of not more than a sixth of an inch clear around it. At K K are four apertures for the escape of the products of combustion. A crucible, I, with a conical cover, G, is enclosed in a crucible, H H, made of lime. The coke crucible standing upon a lime support, D, contains the substance to be melted and it is so placed that the apex of the cover is exactly under the blow-pipe jet at a distance from $\frac{3}{4}$ to $1\frac{1}{4}$ inch

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742. Describe the oxyhydrogen furnace for melting platinum.

from it. At the International Exhibition of 1862, Messrs. Johnson exhibited a mass of pure platinum (prepared by Deville's process in a furnace of this kind,) weighing 230 pounds and valued at 3840 pounds sterling, equal to about seventeen thousand dollars. It thus appears that the great problem of melting large masses of platinum, hitherto considered almost an impossibility, has been completely solved.

743. Platinum condenses Gases—The metal platinum has the remarkable property of condensing gases upon its surface, and thereby increasing their affinities. This effect is in proportion to the surface exposed. It may be prepared for this experiment by burning paper, previously moistened with a solution of this metal. Such an ash, by simple exposure to the air, condenses and retains a large quantity of oxygen within its pores. On holding it in a jet of hydrogen, the condensed oxygen immeately unites with the latter gas so energetically as to inflame it.

216

744. Platinum is employed for similar purposes, in the form of a sponge, and as a powder, called *platinum black.* A mixture of nitric oxide and hydrogen, passed through a tube containing heated platinum black, issues from the tube as ammonia and water. The hydrogen has entered into combination with both of the elements of the nitric oxide, producing two new compounds.

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743. Mention a remarkable effect of platinum on gases. 744. Give another illustration of this effect.

745. Other Uses of Platinum.—The most important use to which platinum is applied in the arts, is in the manufacture of chemical apparatus. Its extreme infusibility and resistance to acids, adapt it especially to this purpose. In the manufacture of oil of vitriol, for example, no other material excepting gold could well take the place of the platinum vessels in which concentration is effected. Platinum crucibles are also invaluable, as they may be exposed to the fire of a blast furnace without injury. Nothing less than the most intense heat of the oxyhydrogen blow-pipe, or Galvanic battery, is sufficient to fuse this metal.

Alloys.

746. Alloys are compounds of the metals with each other. Comparatively few of the metals possess such qualities as render them suitable to be employed alone by the manufacturer; zinc, iron, tin, copper, lead, mercury, silver, gold and platinum are all that are so used. Antimony, arsenic and bismuth are too brittle to be used alone but are very useful for hardening other metals. By combining two or more metals their properties are so altered that the compound is adapted to many valuable purposes for which neither metal could be used alone. Antimony is too brittle for type-metal, and lead is so soft it would soon be crushed under the press, but four parts lead and one of antimony give an

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745. Why is platinum superior to other metals for chemical apparatus?
746. What are alloys? How are the properties of metals affected by combination?

alloy that will sustain the requisite pressure without crushing or cracking. Brass, an alloy of copper and zinc, is harder and more easily wrought than copper and far more tenacious than zinc. The chemical properties of alloys are generally such as might have been anticipated from the nature of the components. Yet the alloy of two oxidizable metals is sometimes more readily oxidized than either of the components. The melting point of an alloy is generally lower than the mean of the metals which compose it. The ductility of metals is also generally impaired by combination with one another.

747. ALLOYS USED IN THE MANUFACTURES.—*Brass* is an alloy of copper with about one-half its weight of zinc, but the proportions are varied to suit different purposes: Lead and tin are sometimes added.

Muntz's Patent Sheathing Metal. A good substitute for copper—contains three-fifths copper and two-fifths zinc.

Speculum Metal contains about 6 parts of copper, 2 of tin and 1 part of arsenic. Lord Rosse employed for the speculum of his great telescope an alloy of about 682 parts copper to 318 parts of tin.

German Silver is an alloy of 100 parts copper, 60 of zinc and 40 of nickel. The white color is due to nickel. An alloy of 30 parts silver, 25 of nickel, and 55 of copper, forms a nearly perfect substitute for silver for all ornamental purposes.

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747. What alloys are in common use? What is their composition?

Bronze is copper containing ten per cent. of tin. Tempering produces upon bronze an effect directly opposite to that upon steel; and in order to render bronze malleable it must be heated to redness and quenched in water. The alloy which thus acquires the greatest tenacity contains 8 parts of copper to 1 part tin. This alloy is particularly suitable for medals. It suffers less than copper by friction and oxidation.

Bell metal is a kind of bronze containing copper 78, and tin 22 parts in 100.

Pewter is an alloy of tin with variable proportions of antimony or lead. Britannia ware, so called, is a sort of pewter.

Type-metal is an alloy of lead with about one-fourth its weight of antimony. By the use of tin, instead of lead, a better, but more expensive type-metal may be produced. Zinc, with a few per cent. of copper, lead, and tin, have also been recently employed. Type-metal is sufficiently fusible to allow of its being readily cast; it expands at the moment of solidification and copies the mold accurately. It is hard enough to bear the action of the press, and yet not so hard as to cut the paper.

Fine and coarse solders are alloys of tin and lead, the former being two-thirds and the latter one-fourth, tin. Hard solder is a variety of brass.

Newton's Fusible Metal, which has the remarkable property of melting in boiling water, is composed of 8 parts of bismuth, 5 of lead, and 3 of tin. An alloy of 2 parts bismuth with one of lead and one part tin melts at 201° Fahrenheit.

Wood's Fusible Metal consists of cadmium 1 part, tin 1, lead 2 and bismuth 4 parts. It melts at about 150° F. By varying the proportions the melting point may also be varied. Its fusing point may be lowered to any extent by the addition of mercury, which may be employed within certain limits without materially impairing the tenacity of the metal. Another alloy devised by Mr. Wood, containing cadmium 1 part, lead 6, and bismuth 7 parts, melts at 180° Fahrenheit. It takes less cadmium to reduce the melting point of an alloy a certain number of degrees than it requires of bismuth, besides that the cadmium does not impair the tenacity and malleability of the alloy, but increases its hardness and general strength.

Alloys of Aluminum. Aluminum forms several alloys of much value in the arts. An alloy of 1 part silver with 20 parts of aluminum works like silver, but is harder and takes a finer polish. One-twentieth part of aluminum gives to copper a beautiful gold color and hardness enough to scratch the standard alloy of gold used for coins, but the malleability of the alloy is much less than of copper. One-tenth of aluminum gives with copper a pale gold-colored alloy of great hardness and malleability, and capable of taking a polish like that of steel. One part of aluminum with 20 parts of pure silver gives an alloy almost as hard as silver coin containing one-tenth of copper, and thus permits us to harden silver without introducing a poisonous metal. Many of the above alloys are slightly varied in their character by the addition of other metals in small quantity.

CHAPTER III.

SALTS.

SOLUTION AND CRYSTALLIZATION.

748. Definition.—Under the general head of salts, are included all compounds of acids and bases, and beside these, the compounds of chlorine, bromine, iodine, sulphur, &c., with the metals. Sulphate of copper or blue vitriol is an example of the first class, and chloride of sodium, or common salt, of the latter.

749. Neutral, Acid and Basic Salts.—In general, salts containing an equivalent of base to an equivalent of acid are called neutral. The composition fixes the name, whether exactly neutral to the taste and in their action on vegetable colors, or not. Salts containing more acid in proportion are called super-salts or acid salts, and those containing more base, sub-salts or basic salts.

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748. What compounds are called salts? 749. What are neutral, acid, and basic salts?

750. There are two exceptions to the above rules. The first is that of certain classes of acids which have double and treble neutralizing power, and require therefore, the first two atoms and the latter three atoms of base, to make them neutral salts. Such acids are bibasic and tribasic, in contradistinction from the monobasic or ordinary acids. Phosphoric acid is one of the latter class of tribasic acids, and the neutral phosphates have therefore three atoms of base and are called tribasic phosphates. Phosphates containing more acid or base than their proportion are acid or basic accordingly. The second exception is that of salts or bases which contain more than one atom of oxygen to an atom of metal. In proportion as they contain more, they neutralize more acid. Alumina or oxide of aluminum, for example, contains three atoms of oxygen, (Al_2O_3). Its neutral sulphate, therefore, is a salt containing 3 atoms of acid as sulphate of alumina, ($Al_2O_3,3SO_3$). A salt of alumina containing more or less than this proportion, is acid or basic accordingly.

751. DOUBLE SALTS.—There are also double salts or compounds of salts with each other. They are generally of the same acid. Thus alum ($KO,SO_3,Al_2O_3,3SO_3 + 24\,HO$), is a double sulphate of potassa and alumina, and the bisulphate of potassa (§ 766) may be regarded as a double sulphate of potassa and water. Such double salts are not mere mixtures. They have their own

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750. What exceptions are mentioned? 751. What are double salts?

crystalline form, and each molecule of their crystals contains all the elements of both salts.

752. Binary Theory of Salts.—Sulphate of potassa, and other similar salts, are commonly regarded as ternary compounds. But many chemists are of the opinion that they are constituted after the plan of the binary salts, and their acids on the plan of a hydrogen acid. They would write sulphuric acid, SO_4H, instead of HO,SO_3, thus indicating that the hydrated acid is composed of the radical, SO_4, (a compound playing the part of an element,) with hydrogen. Sulphate of potassa would, according to this view, be written K, SO_4, instead of KO,SO_3. The acid and salt are thus represented as analogous in constitution to a hydracid and a binary salt; thus, $(SO_4)H$ corresponds with ClH, and (KSO_4) with KCl. The advantage of this view is that it makes but one great class of acids and one of salts, associating substances which are analogous in their properties. Hydrogen thus becomes characteristic of an acid.

This view also simplifies the subject of the production of salts from acids, making it to consist simply in the replacement of the hydrogen of the acid by a metal. Thus in the action of sulphuric acid (HO,SO_3) on zinc, sulphate of zinc (ZnO,SO_3) is formed by the simple replacement of the hydrogen of the acid by the metal zinc. As will be seen more clearly in the introduction to Organic Chemistry, it is no conclusive

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752. What is said of the binary theory of salts

objection against this view, that the radical SO_4 has not been isolated. There is the best reason for believing in the existence of many such hypothetical radicals. A similar objection has indeed been urged against the ordinary view, according to which SO_3 neutralizes potassa in the sulphate of this base. The objection lies in the fact that anhydrous sulphuric acid is not possessed of acid properties, and can therefore be scarcely regarded as an acid, in its anhydrous condition.

753. PREPARATION OF SALTS.—The salts of most acids may be produced by simply bringing the acid and oxide together. Sulphate of potassa is thus produced from sulphuric acid and potassa. Heat is sometimes required to bring about the combination. They may also be prepared from the carbonates. Thus, acetate of lime is produced by pouring strong vinegar on chalk, or carbonate of lime. Carbonic acid is in such cases expelled by the stronger acid which is employed. Other methods of preparing individual salts will be hereafter given.

754. SOLUTION.—The particles of all bodies are held together, as before explained, by the attraction of cohesion. But water has also an attraction for these particles. In the case of many substances, it overcomes the force of cohesion and distributes them throughout its own volume. Such a distribution, in which the solid form of the solid is entirely lost, is called *solution.* Different liquids are employed as sol-

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753. Mention some methods of preparing salts? 754. Explain solution.

vents for different substances. A solution is said to be *saturated* when no more of the solid will dissolve in it.

755. PRECIPITATION.—In solution, the particles of bodies have not lost their property of cohesive attraction. It is only overcome by a superior force. As soon as this is weakened they unite again to form a solid. The solvent power of alcohol for camphor, is thus diminished when water is added to the solution. As a consequence, the camphor immediately reassumes the solid form. This experiment is made by adding water to an ordinary solution of camphor. When a solid is thus reproduced from a liquid, it is called a *precipitate.*

217

One case of precipitation has been already mentioned. But it may be effected by various methods. All of these may be arranged under two heads; precipitation *by changing the character or quantity of the solvent*, and precipitation *by changing the substance dissolved.*

756. CHANGE OF SOLVENT.—The three cases in which precipitation is effected by changes in the solvent, are, *mixing*, *cooling*, and *evaporation*. The first has just been described. The second is illustrated in the production of alum crystals by cooling a hot solution. The third consists in dissolving a solid in some liquid and then boiling away the latter. The experiment may be tried

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755. Have the particles lost their cohesive attraction? how may they be precipitated Mention two general methods of precipitation. 756. Mention three cases of precipitation by change of solvents.

with a saturated solution of salt and water. As fast as the water is boiled away, the portion which has lost its solvent re-assumes the solid form.

757. Change of Substance dissolved.—The change in the substance dissolved, is effected in some cases by addition, and in others by subtraction. Carbonic acid blown through lime water precipitates it by addition. The precipitate is chalk or carbonate of lime. Potash added to a solution of sulphate of copper, precipitates it by substraction; the precipitate is oxide of copper, deprived of its acid by the potash.

758. Explanation.—The above cases of precipitation demand some further explanation. As fast as carbonic acid is blown into the lime water, in the first case, the new substance, chalk or carbonate of lime, is produced throughout the liquid. We may suppose that innumerable particles are first formed, before they unite to form a precipitate. But the cohesive attraction put forth by the particles of this new compound is so great that the opposing attraction of the water is overcome, they rush together, and assume the solid form of a precipitate. This did not happen in the case of lime alone, because the cohesive attraction between its particles is inferior to the opposing attraction of the water. The second case is to be similarly explained.

759. Relation of Cohesion and Affinity.—The chemical affinity of potassa for carbonic acid is evi-

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757. Describe two cases by change of substance. 758. State the cause of precipitation in the above cases. 759. What is said of the relation of cohesion and affinity?

dently greater than that of lime. The former base retains the acids so firmly that no degree of heat can effect it, while the latter gives up its acid with readiness, under the influence of a high temperature. Notwithstanding the superior affinity of potassa, lime will take from it its carbonic acid, if added to a solution of carbonate of potassa in water. The mixture being made, the particles in this and in all similar cases tend to re-arrange themselves in the solid form. They seem to do this without reference to their chemical affinities, in such a manner as best to resist the solvent action of the water or other liquid. Carbonate of lime resists such action better than carbonate of potassa. The former is therefore produced. The *cohesion* of carbonate of lime, using the term in the sense of capacity to resist the separating power of water, has therefore determined the production of this substance in opposition to ordinary chemical affinities.

760. The above case illustrates a general law. Two substances, which when united form an insoluble compound, generally unite and produce it, when they meet in solution. To illustrate by another example: phosphate of lime or bone ash is insoluble. Then we may be sure that phosphoric acid and lime, if brought together by mixing two solutions, will desert any substances with which they were before combined, and unite to form insoluble phosphate of lime. This rule is not without exceptions, but it enables the chemist to

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760. State and illustrate the general law.

determine beforehand innumerable cases of precipitation.

761. SOLUTION AND CHEMICAL COMBINATION.—Solution differs from chemical combination in the varying proportions in which it occurs according to temperature and in the absence of any change of chemical properties. Nitre, for example, dissolves in water at 100°, in nearly double the quantity which will dissolve at 70°. At the same time, it forms a solution to which it has imparted its own chemical properties unchanged.

762. Another important distinction is found in the following fact. While chemical combination is most active between bodies whose properties are most opposed, such as acids and bases, solution occurs most readily in the case of *similar* substances. The metals dissolve in mercury. Salts dissolve in water. Fats and resins dissolve in alcohol and ether, which, like themselves, contain much hydrogen.

763. CRYSTALLIZATION.—In passing from the liquid to the solid condition, the particles of most bodies assume a crystalline arrangement. Their mutual attraction is more than a mere force which draws and binds them together. It groups them in regular forms. The crystals thus produced are often too small to be separately seen. But even where this is the case, the crystalline structure is readily observed. Surfaces of zinc or cast iron exposed by recent fracture, are familiar examples.

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761. How does solution differ from chemical combination ? 762. State another important distinction. 763. What is said of crystalline arrangement ?

But where the circumstances are favorable for the formation of individual and separate crystals, the most beautiful and symmetrical forms are often the result.

218

764. Production of Crystals.—Most of the salts to be described in this chapter may be obtained in the form of crystals by evaporating or cooling their saturated solutions. The method by cooling has already been described in the chapter on Water. In obtaining crystals by evaporation, the solution is to be moderately heated in a saucer or other vessel.

765. Water of Crystallization.—The crystals formed by either method commonly contain water, which becomes part of the solid crystal, and is called water of crystallization, the amount of which often depends upon the method of forming the crystals. Salts containing water in a state of combination are called *hydrated* salts. Sulphate of magnesia (*epsom salts*) when crystallized by evaporation at common temperatures contains seven atoms of water to each atom of salt; if crystallized by evaporation at a high temperature the crystals contain six atoms of water, and if crystallized from solutions below 32° large crystals are obtained containing twelve atoms of water to one atom of the salt. Some crystalline salts contain no combined water, and are hence called *anhydrous* salts. If Epsom salt, sulphate of magnesia, is heated to 125° the salt retains only six equivalents of water;

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764. How may crystals be produced? 765. What is water of crystallization?

at a temperature of nearly 300° but one equivalent of water is retained, yet this one atom of water is retained even at a temperature of 400°. When common alum is heated it is dissolved in its own water of crystallization, which amounts to 45 per cent. of its own weight. When the water is all expelled an anhydrous insoluble powder remains.

766. Basic Water in Salts.—In some crystals a part of the water cannot be removed without entirely decomposing the salt. Water thus combined, forming an essential part of the salt, is called basic water. Ordinary sulphate of potash contains one equivalent of potash combined with one equivalent of sulphuric acid. Its composition is expressed by the formula KO,SO_3, the comma after KO (oxide of potassium) indicating that it is chemically united with the sulphuric acid represented by SO_3. There is another salt called the bisulphate of potash which contains two equivalents of sulphuric acid to one equivalent of potash, but it also contains one equivalent of water so closely combined with it that it cannot be removed without removing a part of the sulphuric acid. The formula for this salt is $KO,HO,2SO_3$. Here the water, HO, acts the part of a base and is hence called *basic water*, because one atom of potash, KO, and one atom of water, HO, neutralize two atoms of sulphuric acid expressed by the symbol $2SO_3$. Oxalic acid forms two salts with potash one of which is represented by the formula

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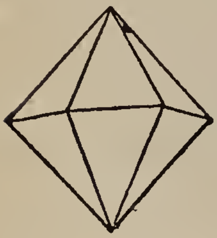
766. What is basic water?

($2KO,C_4O_6+2Aq$), and the other by the formula (KO,HO,C_4O_6+2Aq). In these formulas 2 Aq represents two atoms of water (*Aqua*) of crystallization. The symbol is preceded by the sign of addition, +, to show that the water is added to the salt but not chemically combined with it, but the atom of water represented in these formulas by HO preceded by a comma is considered as an essential part of the salt for it cannot be removed without removing at the same time a part of the acid. This atom of HO is called basic water while that which is represented by Aq is water of crystallization.

767. Variety of Crystals.—The forms of leaves and flowers are scarcely more various than those of crystals. The latter are, as it were, the flowers of the mineral world, as distinctly characterized in their peculiar beauty as the flowers that bloom in the air above them. Even where color fails, the eye of science distinguishes peculiar features which often enable it to determine the nature of a substance from the external crystalline form which it assumes.

219



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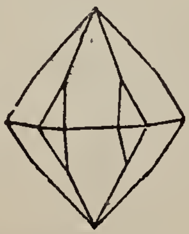

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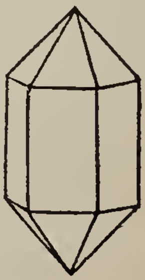

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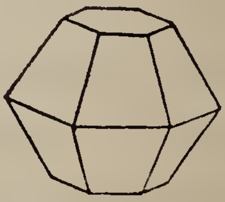

768. Forms of Crystals.—As every flower has its own distinctive form of leaves and petals, so every sub-

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767. How may the variety of crystals be illustrated? 768. What is said of the variety of forms in a single substance?

stance has its own form or set of forms from which it never essentially varies. Among these or its combinations, it is, as it were, left free to choose in every crystal which it builds. The mineral quartz, which caps its prismatic palace with a hexagonal pyramid, is an example. Its common form represented in figures 144 and 222 is a combination of the prism and double six-sided pyramid, which commence the series.

769. A form similar to the double six-sided pyramid, with faces corresponding to its twelve converging edges, belongs to the same set. Double pyramids similar to each of these, but of one-half or one-third their relative height, or differing from them by some other simple ratio, also belong to the same set of forms. Figure 221 represents a form composed of two of these pyramids. Figure 223 represents another form in which one of them is modified by two faces of a prism. To all of these and certain other intimately related forms, the imaginary privilege of selection and combination, above referred to, extends. But most substances, like quartz, as above described, affect some particular shape or combination in which they usually appear.

770. Modifications of Crystals.—Whatever the form or combination may be, it is susceptible of variation, in any degree, so long as its angles correspond to those of the perfect shape. Thus the mineral quartz, in its commonly occuring combination, is not restricted to a perfectly symmetrical shape, like that above pre-

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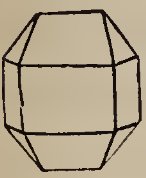
769. Describe some forms of a single set. 770. What modifications of the same form may occur?

sented. It may develop one surface and diminish the others to any extent. Forms such as are represented in the margin result. Different as they seem, it will be observed that they agree precisely with the perfect shape in the angles between the surfaces of the prism and pyramid, and the different surfaces of each. In this their identity as crystalline forms consists. It would thus seem that nature pays exclusive attention to the corners and angles in her various systems of crystalline architecture.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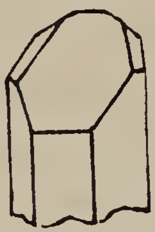
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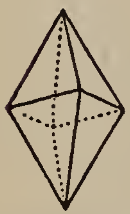
771. The least variation of the relative length of the vertical axis that is not by some simple ratio, constitutes a new and distinct form. This has its related forms as before, the whole making a new and distinct set, to which the choice of any substance that enters it is limited.


227

772. Systems of Crystal Forms.—It will be obvious to the student that the substitution of an octahedron, such as is represented in the accompanying figure, for the double six-sided pyramid, would be the starting point of an entirely distinct system of forms. Within its limits there might be innumerable sets as before. It would be, as it were, the type of a new order of crys-

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771. What constitutes a new set? 772. Define another system of crystalline forms.

talline architecture, susceptible of variations consistent with the general style.

773. A third system is characterized by inequality in three principal dimensions. The axes or lines connecting the solid angles in the octahedron, and joining the faces in the prism, are all unequal. As each axis may be indefinitely varied in this system, there is room within its limits for still greater variety than before. The fourth system differs from the third in an oblique position of some one of the unequal axes. The student will readily imagine certain oblique forms which it includes. The fifth system is characterized by an oblique position of three unequal axes.*

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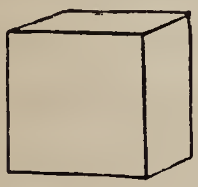

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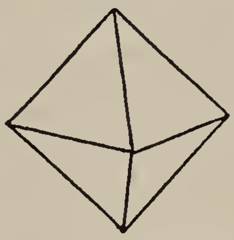

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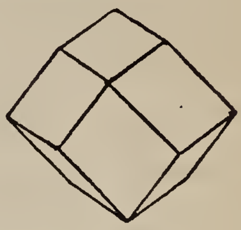

774. The regular system, which is properly the first, has all its axes equal and all its angles right angles.† The figures which precede this paragraph represent some of its simpler forms. Those which follow, are among its most interesting combinations. In figure 233 the student will be able to select three distinct kinds

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773. Define the third and fourth systems. 774. What are the characteristics of the regular system ?

The variations of length and inclination of axes which correspond to the different systems, may be beautifully illustrated to the eye by a wooden frame work movable at the center with threads connecting the arms.

† The first and sixth systems are made to change places in the above arrangement, for the convenience of illustration from the quartz crystal.

of surfaces. One of these sets, if enlarged to the exclusion of the others, would produce a cube, another a regular octahedron, and a third a dodecahedron; forms corresponding to those of figures 228, 229 and 230.

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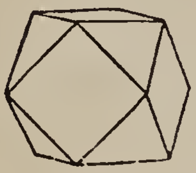

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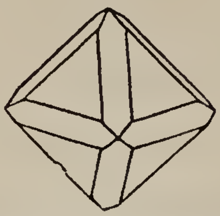

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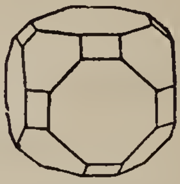

In view of its simplicity, the regular system may be regarded as a sort of primitive architecture, yielding, however, to no other system in the beauty of its forms. Under one or the other of these systems all forms of crystals are included. To each of them, with the exception of the regular system belong innumerable sets of forms according to the degree of inequality or inclination of the axes. Equality and rectangular position of the axes being characteristic of the first system, it is not susceptible of the sort of variation which is essential to produce different sets of figures. But in this, as in other systems, the modification of surfaces may occur to any extent.

775. As the architect is able, from some relic of a broken column, to build up in imagination the temple of which it formed a part; as the comparative anatomist knows how, from the fragment of a single bone to reconstruct in imagination the perfect animal which possessed it; so, from the merest point of a crystal, its complete form may often be readily inferred. In pro-

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775. Show how the form of a crystal may be inferred from its angles.

portion as a double pyramid is lengthened out, the angles above and below are rendered more acute. From an accurate admeasurement of this angle its whole shape may therefore be inferred. Such admeasurement of various angles is employed not alone as a means of inference of perfect from imperfect shapes, but as the simplest means of accurate description. For, as before stated, the dimensions of the corresponding angles of a crystal form its characteristic.

776. ISOMORPHISM.—Many substances which are alike in the number and arrangement of their atoms, although these atoms are different in kind, have the same crystalline form. This is the case with common alum and other alums to be hereafter mentioned. The similar arrangement of atoms will be best seen by inspecting the formulæ which represent them.

Common Alum $= KO,SO_3; Al_2 O_3,3SO_3; 24HO.$
Ammonia Alum $= NH_4O,SO_3; Al_2 O_3,3SO_3; 24HO.$
Soda Alum $= NaO,SO_3; Al_2O_3,3SO_3; 24HO.$

The potassium in common alum may be replaced, in whole or in part, by either soda, ammonia or lithia, and in the same manner the alumina may be replaced in whole or in part by the sesqui-oxide of iron, chromium or magnesium, and the crystalline form will be unchanged. All these compounds are therefore isomorphous.

The term isomorphism expresses their likeness in form. Besides this series there are many other isomorphous groups.

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776. Have different substances ever the same crystalline form?

777. It is to be regarded as probable, that the shape and size of the molecules thus similarly composed is exactly the same, and that it is for this reason that they may be used in building up crystals of the same form. The different alums will even unite when they crystallize in building up one and the same crystal. Substances which are thus similar in composition and crystallize in the same form, are called *isomorphous.* There are many cases of similar crystalline form in substances which are not thus related in other respects. Such bodies are not called isomorphous, notwithstanding their identity of crystalline form. Certain substances crystallize in forms belonging to two or even three different systems, according to the temperature, or other circumstances under which their crystallization occurs. Such substances are called *dimorphous* or *trimorphous*

Oxides.

778. The compounds of the metals with oxygen, with the exception of those which have decidedly acid properties, are called *oxides.* When a metal unites with oxygen in several different proportions, forming different oxides, these are distinguished as *protoxide*, *deutoxide* or *binoxide*, *tritoxide* or *teroxide :* terms signifying first, second, and third oxides. The highest oxide is also called *peroxide.* An oxide containing three atoms of oxygen to two atoms of metal, is called *a ses-*

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777. Give the probable reason. 778. Define an oxide. By what terms are different oxides distinguished ?

quioxide. The names of chlorides, sulphurets, &c., are similarly modified, to indicate the proportion of chlorine, sulphur, &c., which they respectively contain. Compounds of non-metallic substances with oxygen which do not possess acid properties, are also called oxides. There are, for example, oxides of nitrogen and phosphorus.

779. PROPERTIES OF OXIDES.—The lower oxides are generally strong bases, while the higher oxides exhibit basic or acid properties according to circumstances. Binoxide of tin, for example, described in a previous chapter, acts as a base in combining with sulphuric acid to form a sulphate, while, if fused with potassa, it acts as an acid and forms a stannate. On account of its acid property, the binoxide of tin is also called stannic acid. The name is derived from *Stannum*, which is the Latin word for Tin. In general oxides require for their complete neutralization as many atoms of acid as they contain atoms of oxygen. Protoxides require one equivalent of acid to neutralize them. Sesquioxides, although weaker bases, require three equivalents of acid to form with them neutral salts, but such compounds are unstable and are easily decomposed. Basic oxides are in general devoid of all metallic appearance and present in the highest degree the qualities of earthy matters. Oxides, when found crystallized, are usually harder, less fusible, and less volatile than the metals which they contain. Potassa, protoxide of potassium, requires for its fusion a temperature but little less than

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779. What is said of acid and basic properties in oxides?

that required for melting iron, although potassium as we have seen melts at a comparatively low temperature.

780. Formation of Oxides.—Oxides may be formed directly by the union of oxygen and metal, or, indirectly, by separating them from some salts which contain them. Thus oxide of copper may be produced by simply heating copper in the air; or, by precipitation from the nitrate, through the agency of potassa, or. thirdly, by simply heating the nitrate until all the acid is expelled. The oxides of tin and antimony are also directly produced, by the action of nitric acid on the metals.

781. Hydrates, or Hydrated Oxides.—Oxides commonly combine in the act of precipitation with a certain proportion of water. The compounds thus formed are called hydrated oxides, or simply *hydrates.* The water may, in most cases, be separated from them by heat, and the uncombined oxide thus obtained.

782. Conversion of Oxides.—When oxides are converted into chlorides, sulphurets, &c., by double decompositions, to be hereafter described, the chlorides, sulphurets, &c., correspond to the oxides from which they are formed. Thus, protoxide of iron yields protochloride, while sesquioxide yields sesquichloride.

783. The Alkalies.—The oxides of potassium and sodium are called *alkalies.* They are known as potassa and soda, and are commonly obtained as hydrates.

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780. How are oxides formed? Give examples. 781. What is a hydrated oxide? 782. What is said of the conversion of oxides? 783. Give some properties of the alkalies.

They are white infusible substances from which the water connot be expelled by heat. They are soluble in water, and are the strongest of all bases. From their destructive action on animal matter, they are called *caustic alkalies*, and are often distinguished by this term from the carbonates of potassa and soda. Ammonia oxide of ammonium, is called a volatile alkali.

Potassa. $KO=47$.

784. POTASSA is prepared from wood ashes. The ley obtained from these being evaporated to dryness, the mass which remains is the crude potash of commerce. This, when purified, becomes *pearlash.*

785. CAUSTIC POTASSA. *Hydrate of Potassa*, $KO,HO=56$.—Commercial potash and pearlash are both carbonates of potash, from which the carbonic acid must be removed, in order to produce potassa itself. This is done by a milk of slaked lime. A solution of potash in at least ten parts of hot water, or a hot ley, made directly from wood ashes, should be employed in the experiment. To this the milk of lime is added, little by little, the solution boiled up after each addition, and then allowed to settle. If, after settling, a portion of the clear liquid is found no longer to effervesce on the addition of an acid, it is sufficient evidence that all the carbonic acid has been removed by the lime, and the

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784. What is the source of potassa? 785. How is potassa prepared? Give a modification of the above method.

process is completed. This must be ascertained by trial. About half as much lime as potash will be required in the process. Caustic soda is similarly made from the carbonate of soda.

The boiling in the above process may be omitted, if the mixture be frequently shaken up during several days. This modification of the method is much more convenient for the production of caustic alkalies in small quantities. Solutions, useful for a variety of chemical purposes, are thus obtained, and should be preserved for use. They may be converted into solids by evaporation, and the solid thus obtained fused and run into moulds. The commercial caustic potassa, occuring in slender sticks of white or grey color, is thus produced. It contains one equivalent of water and is properly a hydrate of potassa.

234

235

786. Affinity of Potassa for Water.—Ordinary potassa, as before stated, is a hydrate. But its affinity for water is by no means yet satisfied in this form. If exposed in an open vessel, it rapidly attracts moisture from the air. It often dissolves, in the course of a few days, in the water thus obtained.

787. Decomposition by Potassa.—Potassa added to the solution of almost any salt occasions a precipitate. The potassa takes the acid and precipitates the insolu-

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786. How can the affinity of patassa for water be proved? 787. What is said of the decomposition of salts by potassa?

ble base. If the experiment is made with an ammonia salt, the base being volatile passes off into the air. Experiments may also be made with green, blue, and white vitriols, which are, respectively, sulphates of iron, copper and zinc.

788. CLEANSING PROPERTIES OF POTASSA.—If soiled rags are boiled with a dilute solution of potassa, they will be thoroughly cleansed by the process. The potassa unites with the acid of the grease contained in the cloth, and thus makes it soluble in water.

789. ACTION OF POTASSA ON ANIMAL MATTER.—Potassa is extremely destructive of animal matter. It readily dissolves the skin, as may be proved by rubbing a little between the fingers. If applied in sufficient quantity, it destroys the vitality of the flesh. It is often used for this purpose by surgeons.

790. EFFECT ON VEGETABLE COLORS. — Vegetable blues which have been previously reddened by acid, are restored to their original color by the action of potash and other alkalies. The blue pigment called *litmus* is the one most readily obtained. In preparation for the experiment, it is infused in hot water. The transformation from blue to red and *vice-versa* may be repeated as often as desired, by the alternate addition of acid and alkali. Paper soaked in the red and blue liquids forms the *test-paper* of the chemist. It is used to indicate the presence of smaller quantities of acid and

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788. Illustrate the cleansing properties of potassa. 789. What is the action of potassa on animal matter? 790. How does potassa affect vegetable matter?

alkali than could be recognized by the taste. An extract of purple cabbage leaves, or the leaf itself, may be used in the above experiment. In this case the change of color by alkalies is from red to green.

Soda. $NaO=31$.

791. Properties of Soda.—The properties of soda are very similar to those of potassa, as above described. Caustic soda, like caustic potassa, is a hydrate represented by the formula NaO,HO. Soda imparts a yellow color to flame and gives a bright yellow line in the spectroscope; potassa imparts to flame a beautiful violet color and gives a more diffused spectrum than soda, with a red line in the extreme red rays and a violet line in the extreme violet rays.

Oxide of Ammonium. $H_4NO=18$.

792. Formation.—When hydrated sulphuric acid combines with ammonia, the water which it contains is regarded as converting the ammonia into oxide of ammonium, with which the acid then combines. The action of other hydrated acids is the same. In naming the corresponding salts, the oxide of ammonium is called ammonia. Thus, the compound with sulphuric acid, is called sulphate of ammonia. It is to be borne in mind, that oxide of ammonium of such salts, con-

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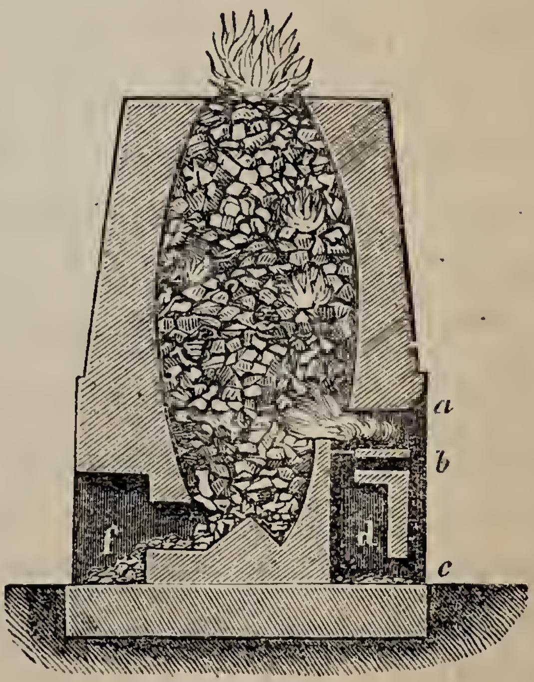
791. What of the properties of soda? 792. What is said of oxide of ammonium?

tains a molecule of water in addition to the constituents of ammoniacal gas. Nitrate of ammonia, for example, consists not simply of H_3N,NO_5, but it contains in addition an equivalent of water which cannot be expelled by heat without the entire decomposition of the salt. This nitrate is therefore looked upon as a nitrate of the oxide of ammonium and its formula is written H_4NO,NO_5.

Oxide of Calcium, or Lime. $CaO = 28$.

793. LIME.—Lime or oxide of calcium is best obtained by heating chalk, marble or limestone. These are all carbonates of lime. Under the influence of a high temperature the tendency of the carbonic acid to assume the gaseous form is so increased, that the chemical affinities of the base are overcome. The carbonic acid escapes, leaving the caustic lime behind. This is the process of the ordinary limekiln. Figure 236 shows the most approved form of limekiln. The doors for the fuel, the fire grate and ash pit are shown at *a*,*b*,*c*,*d*. The

236



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793. How is lime obtained?

lime is removed at *f* while a new supply of limestone is added from time to time at the top of the kiln. The superior strength of potassa and soda as bases, is illustrated by the fact that the carbonic acid cannot be removed from them through the agency of heat.

794. HYDRATE OF LIME; $CaO,HO=37$.—SLAKED LIME.—When water is added to lime, one equivalent immediately combines with it and forms a hydrate. The hydrate, like that of potassa, is dry, although it contains a large portion of combined water. As the water thus becomes solid in the compound, its latent heat is given off to the air or surrounding objects. It has been recently proposed to employ the heat thus produced for culinary operations. If the process of slaking is conducted under a tumbler, with a slight surplus of water, steam will be produced. On lifting the tumbler, it will become visible by its condensation into vapor. Anhydrous sulphate of copper slakes like lime and changes from white to green.

795. IGNITION BY LIME.—The heat thus produced is often sufficient to ignite gun-powder. It should be sprinkled on the mass and kept dry while the slaking proceeds. Warm water and well-burned lime should be employed in the experiment. Ships carrying lime are often set on fire by access of water to the lime, and buildings where it is stored are set on fire in the same manner.

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794. What is hydrate of lime? 795. How may gunpowder be ignited through the agency of lime?

796. Action of the Air.—If lime is exposed to the action of the air, it gradually combines with carbonic acid and water, and becomes converted into a mixture of hydrate and carbonate. It is then called air-slaked lime. By sufficiently long exposure the conversion into carbonate is complete.

797. Lime in Mortar.—Ordinary mortar is a mixture of sand and lime. It hardens not simply by drying, but by the absorption of carbonic acid from the air. A compound of hydrate and carbonate of lime, possessed of great hardness is thus produced. A gradual combination also takes place between the silica and the lime, which binds the two constituents still more firmly together.

798. Hydraulic Cement.—If, in the preparation of lime, a limestone is used which contains a certain proportion of clay, (clay is a silicate of alumina), a double silicate of alumina and lime is produced. The compound has not alone the property of combining with water, like ordinary lime, but of becoming extremely hard and insoluble in the process. Such a lime is called *hydraulic cement*, and is used for building under water. Silica, magnesia, and some other substances impart the same property to lime.

Alumina, Magnesia, &c.

799. Alumina, &c.—Alumina, ($Al_2O_3=51.5$), so named from the corresponding metal, is insoluble, and

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796. What is the action of the air on lime? 797. Why does mortar harden? 798. What is hydraulic cement? 799. What is alumina?

is called an *earth.* It is, like the peroxide of iron, a sesquioxide, containing three atoms of oxygen to two of metal. Natural alumina colored blue is called sapphire. Colored red it forms the Oriental ruby. The topaz and the emerald are also compounds containing the same oxide. Baryta, strontia, lime and magnesia, are regarded as standing midway between the earth alumina and the alkalies and are called *alkaline earths.* They are more or less soluble, and possess the general properties of the alkalies in a diminished degree. Magnesia is sometimes classed as an earth.

800. OTHER METALLIC OXIDES. — The remaining metallic oxides are powders of different colors. Most of them are insoluble. The more important have been already noticed in the Chapter on Metals. Their hydrates may be obtained by precipitating solutions of their salts with potassa, soda, or ammonia. The hydrate of the oxide of copper and peroxide of iron may serve as examples. The former is blue and the latter a reddish brown.

801. The hydrated oxides of nickel, cobalt, tin and copper, produced from solution of these metals by the addition of ammonia, are again re-dissolved in an excess of ammonia. That of copper dissolves with a beautiful blue color, which is conclusive evidence that the liquid with which the experiment is made contains copper in solution.

802. USES.—Oxide of magnesium or magnesia, and

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800. What are the properties of the other metallic oxides? 801. Which hydrated oxides dissolve in ammonia? 802. Give the uses of some of the oxides.

mercury, among others, are used in medicine, and white oxide of zinc, as a paint. Litharge or protoxide of lead is employed in making flint-glass and varnishes. Red lead is used as a paint. Oxide of bismuth is employed as a cosmetic.

803. Oxide of manganese is used to color glass purple and violet. Oxide of cobalt, to color it blue; oxides of copper, and chromium, to impart a green color to glass and porcelain; peroxide of iron, to give it a yellowish red, and protoxide, a bottle-green. Sub-oxide of copper gives to glass a beautiful ruby red. Silver and antimony are employed to produce different shades of yellow and orange. Violet and rose color are obtained by means of the *purple of Cassius*, a beautiful purple precipitate, containing tin and gold, and prepared by adding protochloride of tin to a gold solution.

804. Glass Staining.—The effect of oxides, above mentioned, in coloring glass, may be illustrated by fusing them into a borax bead. The bead is to be formed with the aid of the blow-pipe, in a loop of platinum wire. In the absence of such wire, the borax glass may be made upon the surface of a pipe bowl. Instead of employing the oxide, it is generally more convenient to moisten the bead with a very small quantity of a solution of the metal. In order to obtain good colors, the quantity of coloring material employed must be very small.

237

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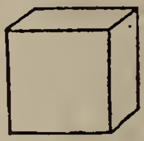
803. What color is produced in glass by the oxide of manganese, cobalt, copper, iron, &c., &c.? 804. How may these effects be illustrated?

805. For staining glass and porcelain superficially, a colored and easily fusible glass is first prepared with borax, or some analogous material. This being ground up and applied as a paint, is afterward baked into the surface. Several of the oxides mentioned in a preceding paragraph are thus employed.

Chlorides.

806. Description.—The chlorides are, for the most part, soluble salts, of colors corresponding to the solutions of the metals from which they are produced. Common salt, figure 238, may stand as a type of the class. Chloride of silver and subchloride of mercury or calomel are insoluble; the chloride of lead is but slightly soluble in water.

238



807. Preparation.—Chlorides may be made by the action of chlorine or hydrochloric acid on the metals. The combustion of antimony in chlorine gas, the solution of gold in *aqua regia*, and that of zinc in hydrochloric acid are examples. The chemical action in each of these cases has been explained in previous chapters. The solutions being evaporated, the chlorides are obtained in the solid form. The solution of zinc in hydrochloric acid is a case of *single elective affinity*: the metal elects or chooses the chlorine.

808. Chlorides may also be formed by the action of

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805. How are glass and porcelain stained superficially? 806. Describe some of the properties of chlorides. 807. How are chlorides made from metals? Give examples. 808. How are chlorides produced from oxides?

hydrochloric acid on oxides. Thus common salt or chloride of sodium may be made by mixing hydrochloric acid and soda. The hydrogen of the acid and the oxygen of the soda unite to form water, while the chlorine of the acid and the metal sodium unite to form the chloride. This is a case of double decomposition, resulting from *double elective affinity*. The chloride commonly corresponds to the oxide from which it is produced. Thus soda, which is a *protoxide*, yields common salt, which is a *protochloride*. Again, sesquioxide of iron, containing three atoms of oxygen to two of metal, yields sesquichloride of iron containing the same proportion of chlorine.

809. The insoluble chlorides may be obtained directly in a solid form by a similar double decomposition. Thus, chloride of sodium and oxide of silver in solution yield, when mixed, a precipitate of *chloride of silver;* newly-formed oxide of sodium or soda remains in solution. The latter unites with the acid originally employed to dissolve the oxide of silver. This is commonly nitric acid.

239

810. Chloride of Sodium. $NaCl=58.5$.—Common Salt.—Common salt is found in great abundance in Poland and other countries, as rock salt, which is regularly mined like coal. An extensive deposit of salt almost entirely pure, perfectly white and much of it in transparent crystals, has been recently discovered in

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809. How are the insoluble chlorides obtained directly in a solid form?
810. From what sources is common salt obtained?

Petite Anse Island near the mouth of the Mississippi River. Large transparent crystals of salt are found in the mines of Poland. Salt is also obtained by evaporating the water of the sea or salt springs, in the sun or by artificial heat. When the salt water is boiled down the salt separates in crystals, while the impurities remain in the small portion of liquid which is not evaporated. These consist principally of chloride of magnesium and other salts. Boiling water dissolves but about one-seventh part more salt than water at the temperature of 32° Fahrenheit.

811. When salt is to be made from water which contains it in very small proportion, it is a frequent practice in Europe, to pump the weak brine to the top of large heaps of brush, and allow it to trickle through them. The object of the method is to produce a large evaporating surface. The air, as it passes through the heaps, carries away a large part of the water and leaves the salt behind. The strong brine which is collected below is then boiled down, as before described. The annual produce of the salt springs at Syracuse, New York, is 9,000,000 bushels, and is constantly increasing.

812. Beautiful crystals of common salt may be obtained by gradually evaporating a saturated solution. This will be accomplished by keeping it for some time moderately warm on a stove or in the sun. The progressive development of crystals and their peculiar

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811. How is salt produced from very weak brine? 812. How may crystals of salt be obtained?

forms are represented in the figures. They are made of innumerable small cubes, which build themselves

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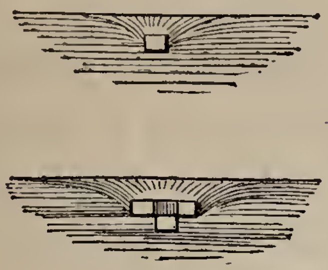

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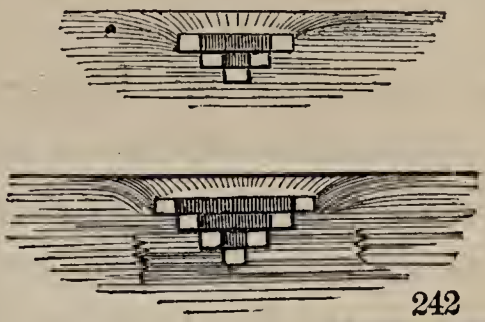

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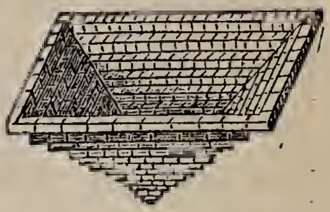

regularly upon the edges as the larger crystals sink little by little into the solution.

813. Uses of Common Salt.—The use of common salt in preserving the flesh of animals from decay, depends in part on the fact that it extracts from the flesh a large proportion of water. It thus, to a certain extent, dries them. This action will be immediately observed if a little salt is sprinkled upon flesh. It will speedily draw out the juices of the meat and itself disappear by dissolving in them. By what action salt preserves meat is not fully known.

814. Sea Water.—Every pound of sea water contains from one-half to five-eighths of an ounce of salt. The greater part of this is chloride of sodium or common salt. The water of the Dead Sea contains a much larger proportion, and is more than an eighth part heavier than pure water. Owing to its greater density,

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813. How does salt act to preserve flesh? 814. How much salt is contained in sea water? in the water of the Dead Sea?

a muscular man floats breast high in it without the least exertion. Fresh eggs, which sink in sea water, float in that of the Dead Sea with one-third of their length above the surface.

815. CHLORIDE OF LIME.—BLEACHING POWDER.—The commercial article of this name is prepared by passing chlorine gas over lime. It is a white powder with an odor similar to that of chlorine gas. Its value depends on the fact that the gas is thus brought into a solid form and made capable of transportation. The best samples of commercial chloride of lime contain 30 per cent. of chlorine. It may be released again by the simplest means, to be used as a bleaching and disaffecting agent. The addition of an acid, as has been seen in the chapter on Chlorine, is all that is necessary to effect this object. It occurs, indeed, spontaneously in the moistened powder, through the action of the carbonic acid of the air.

816. ILLUSTRATION.—To illustrate its bleaching power, a strip of calico may be soaked in a solution of the chloride, and then in acid water. Nascent chlorine is thus liberated in the fiber of the cloth, and is more effectual than if otherwise applied.

817. DISINFECTING PROPERTIES.—Chloride of lime is also used as a disinfectant. For this purpose it is placed in shallow dishes and moistened with water or dilute acid. The chlorine thus liberated at once destroys all noxious vapors.

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815. On what does the value of chloride of lime depend? 816. How may its properties be illustrated? 817.

818. FORM OF COMBINATION.—Chemists are not agreed in regard to the chemical action which occurs in the formation of chloride of lime. The mixture is, practically, chlorine and lime, for as soon as an acid is added, all of the original lime unites with the acid and chlorine is evolved.

819. CHLORIDE OF ALUMINUM. ($Al_2Cl_3=134.$)—This salt is of peculiar interest and importance, in view of its employment in the preparation of the metal aluminum. Alumina mixed with powdered charcoal is made into paste with starch or oil and divided into pellets, which are first charred in a covered crucible and then exposed to ignition in a current of dry chlorine. Carbon in a finely divided state is thus intimately mixed with alumina. The alumina is torn asunder as it were by the affinities which are thus brought into play. The carbon takes its oxygen and passes off with it as carbonic oxide, while the chlorine takes the metal and escapes with it as volatile chloride of aluminum which afterwards condenses in the cooler parts of the apparatus as a crystalline, somewhat translucent mass, or as an amorphous powder.

820. COLORED FLAMES.—A series of beautiful flame experiments may be made with the chlorides. The flame of alcohol assumes different colors according to the chloride employed. Chloride of sodium or common salt gives a yellow; chloride of potassium, violet;

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818. How are its elements combined? 819. How is chloride of aluminum prepared? 820. What is said of colored flames?

chloride of calcium, orange; chloride of barium, yellow; chloride of copper, blue. Instead of the chlorides, other soluble salts may be employed with the addition of a little hydrochloric acid. A beautiful green may be obtained from a copper coin moistened with strong nitric acid, with the use of alcohol as before. The colors of fireworks are similarly produced by the addition of the above and certain other salts.

245

821. Other Chlorides.—The other chlorides are not of sufficient general interest to be here particularly described. Corrosive sublimate, the uses of which are mentioned in the chapter on Mercury, is a chloride of this metal. Calomel is a subchloride of the same metal much used in medicine.

Iodides, Bromides and Fluorides.

822. The iodides and bromides are classes of salts analogous to the chlorides. Those of potassium used in medicine and in photography, are the most important.

823. Detection of $\frac{1}{1.000.000}$ Iodine.—A beautiful blue is prepared by adding a little chlorine water and starch paste to a solution of iodide of potassium. The chlorine sets iodine at liberty, which then combines with starch to form the blue compound. By this test iodine

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821. What is said of other chlorides? 822. What is said of the iodides and bromides? 823. How is the blue iodide of starch prepared?

can be detected in a liquid which contains but a millionth part of this element. By the substitution of bromide of potassium in the experiment, an orange color is produced.

824. TEST FOR CHLORINE AND IODINE.—The experiment may also be made by moistening a slip of paper with starch and iodide of potassium, and holding it in an atmosphere containing a little chlorine gas. An extremely small quantity of chlorine is thus indicated, and the prepared paper thus becomes a test for chlorine. Such paper is also used to show the presence of ozone in the air.

246

825. CHANGE OF COLOR BY HEAT.—By mixing solutions of iodide of potassium and corrosive sublimate or chloride of mercury, a beautiful scarlet iodide of mercury is produced. On heating the dried precipitate it becomes yellow. The experiment is best made with two watch glasses. The iodide is heated in the lower one and collects by sublimation, with change color, in the upper. The same experiment may be performed by dipping a sheet of paper in the solution. On warming the paper the iodide becomes yellow.

826. CHANGE OF COLOR BY TOUCH.—On touching the yellow incrustation with the point of a needle, it is immediately stained scarlet at the point of contact.

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824. How is this experiment employed as a test for chlorine? 825. What is said of the iodide of mercury? 826. What effect is produced by touching the yellow incrustation?

The color gradually spreads, as if it were a contagious disease, through the whole mass, until every particle has regained its original scarlet. This experiment furnishes a very remarkable instance of change of an important property without change of composition. As the change of color proceeds, the small scales of which the yellow iodide is composed break up into octahedrons. The yellow iodide upon the paper prepared as in the preceding paragraph, will also turn red on being rubbed. The change of color is regarded as a consequence of the re-arrangement of atoms, which produces the change of form.

Fluorides.

827. Fluor-spar.—The fluorides, with the exception of those of the alkalies, are for the most part white insoluble compounds. The only one of especial interest, is the beautiful mineral known as *fluor-spar*. This mineral is a fluoride of calcium. It is found of white, green, purple and rose color, crystallized in regular cubes or octahedrons. Hydrofluoric acid, which has the remarkable property of etching glass, as before described, is prepared from it.

247

Sulphurets.

828. The compounds of the metals with sulphur are called *sulphides* or *sulphurets*. They are of various

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827. What is said of fluor-spar? 828. Define a sulphuret?

colors, and, for the most part, insoluble. Iron pyrites and galena or sulphuret of lead, are examples. The figure represents a crystal of *magnetic pyrites*, which is one of the sulphurets of iron. The form belongs to the sixth or hexagonal system.

247

829. PREPARATION.—Most of the sulphurets may be produced by adding hydrosulphuric acid to solutions of the different metals or their salts. Sulphur and metal unite and precipitate, while the hydrogen and oxygen, previously combined with them, form water.

830 The sulphuret of zinc is white; that of arsenic, yellow; and that of antimony, orange. The remainder of the insoluble sulphurets are black. Solutions of white vitriol, arsenious acid, and tartar emetic may be used, as above directed, to produce sulphurets of zinc, arsenic and antimony. If the zinc precipitate should be colored, it is owing to the presence of iron in the salt, as impurity. Blue vitriol may be employed to produce black sulphuret of copper.

248

831. The sulphurets of ammonium, potassium and sodium cannot be precipitated by this process. Being soluble, they remain in the liquid. Solutions of the caustic alkalies are to be used in preparing them. The solutions of these sulphurets are useful, as they may, in many cases, be substituted with advantage for hydro-

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829. How are sulphurets generally prepared? 830. Mention the colors of some of the sulphurets. 831. What is said of the sulphurets of the alkalies?

sulphuric acid in precipitating sulphurets from solutions of other metals. Certain other sulphurets are soluble and do not precipitate, as will be seen from the table in the Appendix.

832. LIVER OF SULPHUR.—There are a number of sulphurets of potassium, containing each a different proportion of sulphur. That which contains five atoms of sulphur to one of metal is called, from its peculiar color, *liver of sulphur*. It is prepared by boiling flowers of sulphur in a strong solution of potash. It may also be made by fusion of the same materials. The protosulphuret can be made from the sulphate, by reduction with hot carbon. Certain other soluble sulphurets may be produced in the same manner.

833. MILK OF SULPHUR.—This form of sulphur, like that just mentioned, is used in medicine. It may be prepared from a solution of the liver of sulphur, by the addition of an acid. The latter combining with the potassa, the sulphur is precipitated in a state of the finest division, giving to the liquid the appearance of milk.

834. OTHER SULPHURETS.—The natural sulphurets have colors different from the similar compounds when produced, as above, by precipitation. Thus, the natural sulphuret of lead or *galena* has the color of the metal; that of mercury is red, and is called cinnabar; that of zinc, called *zinc blende*, and by miners *black jack*, is of different shades—brown, yellow and black. The pre-

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832. What is liver of sulphur? How is it prepared? 833. How is milk of sulphur prepared? 834. What is said of the other sulphurets?

cipitated sulphuret of mercury turns red by sublimation, and in this state forms the familiar pigment called *vermilion.* Sulphuret of iron, which is employed in making hydrosulphuric acid, may be prepared by holding a roll of sulphur against a rod of iron previously heated to whiteness. This may be readily done in any blacksmith's shop. The fused sulphuret falls in globules from the surface of the iron.

Sulphates.

835. The sulphates, with the exception of those of the alkaline earths, are, for the most part, soluble salts. They are similar in color to the solutions of the corresponding metals. The sulphates of the alkalies and of the alkaline earths are not decomposed when heated to redness, except sulphate of magnesia which loses part of its acid. The sulphates of zinc, cadmium, nickel, cobalt, copper and silver require an intense heat to decompose them. Other sulphates part with their acid when strongly heated. Sulphuric acid, called oil of vitriol, may be obtained by heating sulphate of iron, called green vitriol, § 413.

836. PREPARATION.—The soluble sulphates are produced either by the direct combination of sulphuric acid with the proper oxide, or by its action on the metals. The latter has been already particularly described in the section on Sulphuric acid. The insolu-

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835. What is said of the color and solubility of sulphates ? 836. How are the sulphates formed ?

ble sulphates, such as those of baryta and lead, may be obtained by precipitating a soluble salt of the base by means of some soluble sulphate, such as sulphate of soda. They are also sometimes formed in nature by the action of the air on sulphurets. In this action the metal is converted into oxide, and the sulphur into acid, which together form the sulphate. Green vitriol is sometimes thus formed in soils from sulphuret of iron or *fool's gold.*

837. SULPHATE OF LIME. ($CaO,SO_3=68$): GYPSUM (CaO,SO_3; $2HO=86$.)—This is a white, soft mineral occurring abundantly in nature. The figure represents a crystal of gypsum. The form belongs to the fourth system. The finer kinds are known as *alabaster.* When it occurs in flat transparent prisms it is called *selenite.* Sulphate of lime free from water of crystallization occurs in the mineral called *anhydrate*, crystallized in regular rectangular prisms, which are found in the salt rocks of the Tyrol, and in Upper Austria. Finely ground sulphate of lime is employed extensively as a fertilizer of the soil under the name of *plaster.* Plaster of Paris is produced by heating gypsum until its water is expelled. The plaster, when pulverized, has the property of *setting* with water, or, in other words, forming a hard coherent mass.

249

838. PLASTER CASTS.—Plaster casts are made by reducing burned or powdered gypsum to the consistence

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837. What is gypsum? 838. How are plaster casts produced?

of cream, with water, and then pouring it into moulds. A coin may be copied by pouring such a paste into a small paper box containing the coin. Two parts of ordinary ground gypsum, heated moderately until vapor ceases to escape, and then mixed with one part of water, form a good proportion. The heat should not be carried very far beyond that of boiling water, or the plaster refuses *to set.*

The hardening of the plaster takes place very rapidly. It is owing to the re-combination of the material with water. The water thus absorbed exists in a solid form in the compound, as in other salts.

839. ALUMINATED PLASTER.—Harder and better casts, more nearly resembling marble, are made by steeping the burned gypsum for six hours in strong alum water, and then re-heating it at a higher temperature. After being again pulverized, it may be used like ordinary plaster, but requires more time to harden.

840. SULPHATE OF SODA. (NaO,SO_3).—GLAUBER'S SALT.—This is a white salt forming crystals belonging to the third system, such as are represented in the figure. It is used to some extent in medicine, and in large quantities for the production of carbonate of soda. It is prepared by pouring oil of vitriol upon common salt. A double decomposition takes place between the salt and the water of the acid; hydrochloric acid is formed, which passes off, and soda, which re-

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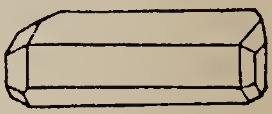

Why do plaster casts harden? 839. What is aluminated plaster? 840. Describe sulphate of soda, and its preparation.

mains combined with the sulphuric acid. It is to be understood that this reaction between water and common salt, takes place only when sulphuric acid is present. The method of making the experiment is given in the paragraph on the preparation of hydrochloric acid.

841. Sulphate of soda may be obtained in crystals by evaporation. Three forms of sulphate of soda may be obtained in crystals. The ordinary form contains 10 equivalents of water. Another form contains 7 equivalents of water and still another form contains no water. These crystals, like those of many other salts, lose their combined water on exposure to the air and become converted into a white powder. This change is called *efflorescence*, and the salt which experiences it is called efflorescent. In preparing the salt on a large scale, for conversion into carbonate of soda, great quantities of hydrochloric or muriatic acid are incidentally produced.

842. SULPHATE OF BARYTA. (BaO,SO_3)—The sulphate of baryta is a white insoluble substance, which may be obtained as a precipitate, by double decomposition of any soluble baryta salt with a soluble sulphate. It is a mineral of frequent occurrence, known as *heavy spar*. It is used for the adulteration of white lead, in which it may be easily detected as a residue, on dissolving the white lead in dilute nitric acid. The sulphate of lead is another of the few insoluble sulphates.

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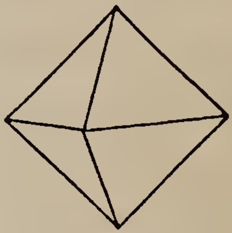
841. What is said of its crystals? 842. What is sulphate of baryta? How prepared? Uses?

843. Alum.—Ordinary alum is a double sulphate of alumina and potassa. (KO,SO_3; $Al_2O_3 3SO_3$; $24HO$). Solutions of the two salts, when mixed, combine to form the double salt. The sulphate of alumina required in the process may be obtained by dissolving alumina from common clay by sulphuric acid. Or it may be produced by exposing certain clays or slates which contain sulphuret of iron to the action of the air. Under these circumstances the sulphur becomes converted into sulphuric acid, which unites with both oxide of iron and alumina. From this mixture the protosulphate of iron is separated by crystallization, leaving a solution of sulphate of alumina to be used in the preparation of alum.

251



844. On heating alum in a crucible or pipe-bowl, it swells up into a light porous mass and is converted into *burnt alum*. At the same time it loses its water of crystallization, of which it contains twenty-four molecules to each molecule of the double sulphate. Common alum has a sweetish astringent taste; it is soluble in 18 parts of cold water and in less than its own weight of boiling water. It retains 4 equivalents of water even at a temperature of 248°. At 392° it loses all its water and at a red heat the salt is decomposed. Alum is much used as a mordant in dyeing and for tanning the lighter kinds of leather.

252

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843. Describe alum, and its preparation. 844. What is burnt alum?

845. OTHER ALUMS.—The name alum is applied to a number of salts having a composition analogous to the common alum already described. In one of these, sesquioxide of chromium, and in another, sesquioxide of iron, takes the place of the alumina or sesquioxide of aluminum. In a third kind of alum oxide of ammonium replaces the potassa. All of these alums contain the same number of molecules of water of crystallization. They have all the same crystalline form, and, if mixed in solution will crystallize together. They are, therefore, isomorphous salts. Their perfect analogy of composition will be best seen by the inspection of their formulæ, as follows:

Potash alum,	KO,SO_3;	$Al_2O_3, 3SO_3$;	$24HO$.
Ammonia alum,	H_4NO,SO_3;	$Al_2O_3,3SO_3$;	$24HO$.
Soda alum,	NaO,SO_3;	$Al_2O_3,3SO_3$;	$24HO$.
Iron alum,	KO,SO_3;	$Fe_2O_3,3SO_3$;	$24HO$.
Chrome alum,	KO,SO_3;	$Cr_2O_3,3SO_3$;	$24HO$.
Manganese alum,	KO,SO_3;	$Mn_2O_3,3SO_3$;	$24HO$.

846. PERSULPHATE OF IRON.—MONSEL'S SALT.—($Fe_2O_3,3SO_3$). To one equivalent of protosulphate of iron in solution, one half an equivalent of oil of vitriol is added, the solution is boiled and nitric acid is added in small quantities as long as any red fumes are given off. By evaporation on glass plates, at a moderate temperature, the persulphate of iron is obtained in yellowish brown deliquescent scales, which are used in surgery as the most valuable agent known for arresting hemorrhage.

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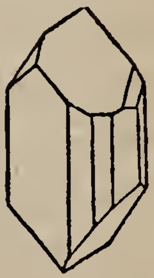
845. What is said of other alums? 846. What is said of persulphate of iron?

847. Other Sulphates.—Vitriols.—Several of the sulphates have received the common name of *vitriols.* Sulphates of zinc, copper, and iron are called respectively white, blue, and green vitriol. Green vitriol readily absorbs oxygen from the air, and becomes brown, from the accumulation of peroxide of iron upon its surface. A solution of it is changed to a yellowish-red color by the oxidizing action of either nitric acid or chlorine. A crystal of blue vitriol is represented in the figure. The form belongs to the fifth system.

253.



White anhydrous sulphate of copper slakes like lime with evolution of heat when water is applied, and at once changes to a beautiful green color. The sulphates of zinc and of copper are both powerful emetics and they are also both useful applications to inflamed and ulcerated surfaces.

Nitrates.

848. The nitrates are formed by the action of nitric acid on metals, as already explained, and also by the action of the acid on oxides previously formed. In the latter case, the metallic oxide takes the place of the water of hydration which always belongs to the acid. They are also produced by double decomposition. This latter method is illustrated below, in the preparation of nitrate of potassa from the nitrate of lime. The figure represents a crystal of saltpetre. The form belongs to the third system.

254

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847. What is said of vitriols? 848. How are nitrates formed?

849. Nitrate of Lime. (CaO,NO_5; $4HO=82+36=118$).—This salt is of considerable interest, from the fact that it is employed in the production of saltpetre or nitre. It is formed in the so called, *nitre beds*, by mixing together refuse animal matter with earth and lime. In the gradual putrefaction of the animal matter which follows, its nitrogen takes oxygen from the air, and is converted into nitric acid. The acid then combines with the lime to form the nitrate. The salt is afterward extracted by water. The formation of nitric acid, above mentioned, takes place only in the presence of alkaline substances. In their absence the nitrogen passes off, combined with hydrogen, as ammonia. Even in the presence of lime, there is reason to believe that ammonia is first formed, and its constituents afterwards converted into nitric acid and water.

850. Nitrate of Potassa.—Nitre or Saltpetre. ($KO,NO_5=101$.)—This salt is a constituent of certain soils, especially in warm climates. These soils always contain lime, and are said to be never entirely destitute of vegetable or animal matter. It is obvious, therefore, that nitrate of potassa may be formed in them, as the same salt of lime is formed in the nitre beds just described. A small proportion of nitric acid exists in the atmosphere, combined with ammonia. This, also, may be a source of part of the nitric acid of the nitrous soils. Again, it is probable that nitric acid is slowly formed from the atmosphere by the direct combination

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849. How is nitrate of lime produced? 850. Explain the formation of nitre.

of its elements in the porous soil. Nitre, on being highly heated, yields a third of its oxygen in the form of gas.

851. Nitre is obtained from nitrous soils by lixivation with water and subsequent crystallization. From nitrate of lime, it is produced by double decomposition with carbonate of potassa. Carbonate of lime precipitates, while nitrate of lime remains in solution. This may be afterward poured off, evaporated, and crystallized.

852. Uses of Nitre.—Nitre is extensively employed by the chemist and in the arts, as an oxidizing agent. A few grains of it introduced into a solution of green vitriol or sulphate of iron, to which some free sulphuric acid has been added, will immediately change its color. The sulphuric acid sets nitric acid at liberty, to which the oxidation and change of color are to be attributed. Nitre, when heated, yields part of its oxygen, as before stated. If heated with metals, it converts them into oxides. The principal use of nitre is in the manufacture of gun-powder.

853. Gun-powder.—Gun-powder is a mixture of nitre, charcoal, and sulphur. When ignited, the carbon burns instantaneously, by help of the oxygen of the nitre, thus producing a large volume of carbonic acid gas. To this gas, together with the nitrogen which is also set at liberty at the same moment, the force of the

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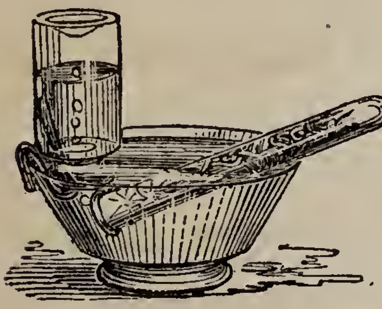
851. How is nitre obtained from nitrous soils? 852. Mention some of the uses of nitre. 853. Explain the action of the different constituents of gunpowder.

explosion is due. The sulphur at the same time combines with the potassium of the nitre, and remains with it as a sulphuret of potassium. Gunpowder $=C_3S+KO,NO_5$ become after ignition $=3CO+N+SK$. Three equivalents of carbon to one of nitre and one of sulphur expresses very nearly the composition of gunpowder. It varies, however, according to the uses for which it is intended, and the country in which it is manufactured. From the proportion, by equivalents, the relative weight of the constituents can readily be calculated.

854. COLLECTION OF THE GASES.—For the production and collection of the gases evolved in the combustion of gunpowder, the fuses of ordinary "*fire-crackers*" may be employed. Several of them are to be ignited at the same time in an ordinary test-tube. The mouth of the latter being then brought under a filled and inverted vial, the gases are collected as fast as they are evolved.

255



855. NITRATE OF AMMONIA. $(H_4NO,NO_5=80.)$—Nitrate of ammonia may be prepared from the carbonate by the addition of nitric acid, and subsequent evaporation. The nitric acid decomposes the carbonate of ammonia and the carbonic acid escapes as a gas while the nitric acid unites with the ammonia. This

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854. How are the gases collected? 855. How is nitrate of ammonia prepared and for what is it used?

salt is used for the preparation of laughing gas. See section 445.

856. NITRATE OF SILVER. ($AgO,NO_5=170.$)—Nitrate of silver or *lunar caustic* is employed in surgery, for cauterizing wounds. Nitrate of silver is also extensively used in photography. A solution of the salt in which the oxide has been precipitated by ammonia and re-dissolved by a slight excess, is extensively employed as an indelible ink. The black color comes from oxide of silver and finely divided metal precipitated in the cloth. It may be removed by soaking in a solution of common salt, and thus converting the silver of the mark into chloride of silver. This is soluble in ammonia, and may be afterward extracted by that agent. Nitrate of silver is also the basis of most dyes for the hair.

857. OTHER NITRATES.—Nitrate of soda ($NaO,NO_5=85$) is a white salt, found native in South America. It is used in the manufacture of nitric acid, and, to some extent, as a fertilizer of the soil. The remaining nitrates are soluble salts, of colors corresponding to the solutions of the metals, as already described. The uses of the nitrates of silver and bismuth have already been mentioned.

Carbonates.

858. CARBONATES.—The carbonates are, for the most part, white or light colored salts, of which chalk may

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856. Describe nitrate of silver. What are its uses? 857. Describe the other nitrates. 858. Describe the carbonates.

serve as an example. The carbonate of copper is found native, both as blue and green malachite. All of the carbonates, excepting those of the alkalies, may be decomposed by heat. The latter are soluble and retain their acid at the highest temperatures.

859 Preparation.—The insoluble carbonates may be produced by precipitating solutions of the metals or their salts by carbonic acid or solutions of the alkaline carbonates. In the latter case a double decomposition occurs with exchange of acids and bases.

860. Carbonate of Potassa. ($KO,CO_2=69$).—Potash.—The method of preparing potash and pearlash, from wood ashes, has already been considered in the paragraph on Potassa. *Saleratus* is a carbonate containing a large proportion of carbonic acid. Its use for "raising" bread and cake is familiar. The acid employed with it, sets the carbonic acid gas at liberty and thus puffs up the "sponge."

861. Carbonate of Soda. ($NaO,CO_2=53$.)—Soda.—Carbonate of soda is commonly known under the name of *soda.* It is a white soluble salt, familiar from its use in Seidlitz and soda powders. Its carbonic acid is the source of the effervescence in these preparations. The bicarbonate or supercarbonate of soda, $NaO,HO, 2CO_2$ is the form of soda in common use.

862. Carbonate of soda is prepared from the sulphate of soda. This salt being heated with charcoal is con-

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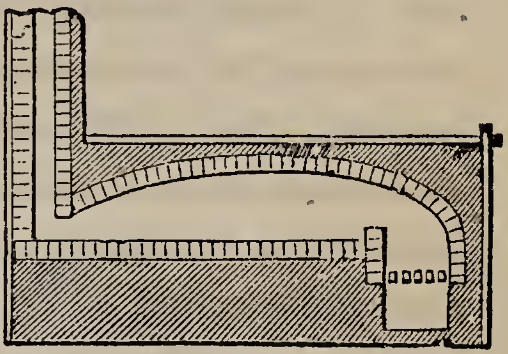
859. How are the insoluble carbonates prepared? 860. What is said of carbonate of potassa? 861. Describe carbonate of soda. 862. How is carbonate of soda prepared?

verted into sulphide of sodium. On heating the latter with carbonate of lime, a double decomposition occurs, and carbonate of soda is produced, with sulphide of calcium as an incidental product. Both parts of the process are combined in practice. Sulphate of soda, chalk and coal, are heated together in a reverberatory furnace, the carbonate of soda is then dissolved out from the fused mass, dried, purified, and subsequently crystallized. The sulphide of calcium would dissolve at the same time, and thus defeat the process, were it not rendered insoluble by combination with a certain quantity of lime.

256



863. Another method of manufacturing carbonate of soda, consists, essentially, in separating sulphur from the sulphate, by means of oxide of iron, and substituting carbon in its place. In this process also, the materials are heated with charcoal, in a reverberatory furnace, and the carbonate afterward extracted by water. The impure uncrystallized carbonate of soda, is known in commerce as *soda ash*, and is largely employed in the manufacture of hard soap and in other processes.

864. CARBONATE OF AMMONIA.—SAL VOLATILE.—The ordinary *sal volatile* of the shops, used as smelling salts, is a carbonate containing three equivalents of acid to two of base. ($2NH_4O,3CO_2+2Aq$). This is really

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863. Describe another method. 864. What is sal volatile?

a sesquicarbonate. It wastes away gradually in the air, and passes off in a gaseous form.

865. Preparation.—Sal volatile is prepared by heating together carbonate of lime and chloride of ammonium. Carbonate of ammonia immediately passes off, while chloride of calcium remains behind. The carbonate is led into a cold pipe or chamber, where it takes the solid form. The mixture of chalk and sal ammoniac is sometimes used as smelling salts. The production of sal volatile from the mixture is very gradual if heat is not applied.

257

866. The property from which the salt receives its name, may be illustrated, by holding in its vicinity a rod or roll of paper moistened with strong muriatic acid. A dense cloud of sal ammoniac is immediately produced in the air, from the union of the two vapors. The experiment is more striking, if the sal volatile is warmed in a cup or other vessel. This salt is sometimes used by bakers for making bread and cakes light and spongy.

867. Carbonate of Lime. ($CaO,CO_2=50$).—Carbonate of lime, in the form of chalk, marble and ordinary limestone, is a most abundant mineral. Whole mountain chains consist of the latter rock. The shells of shell-fish are principally carbonate of lime. There is good reason, indeed, to believe that all limestones have their origin in accumulations of such shells, which have

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865. How is sal volatile prepared? 866. How is it proved to be volatile? 867. What is said of carbonate of lime?

been consolidated in the course of ages. The figure represents a crystal of carbonate of lime or *calc spar.* The finest crystals of this mineral are obtained from Iceland, and are hence called Iceland spar.

258

868. Solubility in Carbonic Acid.—The solubility of carbonate of lime in carbonic acid is readily shown, by passing a current of the gas through water clouded with pulverized chalk or marble. Other mineral substances which form the food of plants are dissolved by the same means, and then find their way into the roots, to subserve the purposes of vegetable life.

259

869. Incrustations in Boilers.—Carbonate of lime dissolved in carbonated water is again precipitated on boiling the solution. This is owing to the escape of the acid. Incrustations in tea-kettles and steam-boilers, in limestone districts, owe their origin to the same cause. In some cases the crust is formed of gypsum or other earthy matters contained in the water. One method of avoiding this inconvenience in steam-boilers, is by the addition of a smaller boiler in which the water is first heated and its sediment deposited.

870. Stalactites.—The masses of carbonate of lime which hang like mineral icicles from the roofs of caverns, Figure 260, are called *stalactites.* The water that

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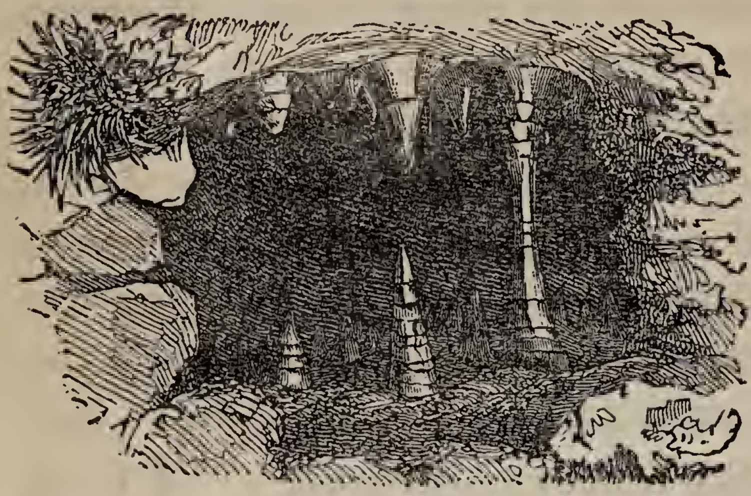
868. How is the solubility of carbonate of lime in carbonic acid shown? 869. What is said of incrustations in boilers? 870. What are stalactites?

penetrates the soil is the architect of these curious forms. Impregnated with carbonic acid derived from decaying vegetation, it takes up its load of carbonate of lime as it settles through the rock, and deposits it again on exposure to the air of the cavern, in various and often fantastic shapes. Another portion of water, dripping to the floor of the cavern, builds up similar forms, called *stalagmites*, from below.

260



871. Artificial Marble.—The surface of wood or stone may be marbled by covering it with successive coats of milk of lime, and allowing each in turn to dry before the next is applied. The surface is then smoothed and polished, and carbonic acid finally applied by which it is converted into marble. The milk of lime is simply a mixture of slaked lime and water, and may be so colored as to produce a variegated surface.

Phosphates.

872. Phosphates.—The phosphates, with the exception of those of the alkalies, are, for the most part, white insoluble salts. Ordinary phosphoric acid has

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871. How is artificial marble produced? 872. Describe the phosphates.

the property of combining with and neutralizing three equivalents of base, instead of one, as is the case with most other acids. It is therefore called a *tribasic* acid. The hydrated acid contains, also, three equivalents of water, and may be regarded as a salt in which the water acts the part of base. Arsenic acid is similar in this respect, as well as in the amount of oxygen which it contains and in the salts which it forms with bases. Two other kinds of phosphoric acid may be prepared from that above mentioned; the first combines with one, and the second with two equivalents of base. The phosphates which contain two equivalents of base to one of acid are called *pyrophosphates*, because the acid has been modified by the action of fire upon the tribasic phosphate of soda.

873. Preparation.—The phosphates of the alkalies may be produced by the action of phosphoric acid on the proper carbonates. The remaining phosphates may be precipitated by solution of phosphate of soda from solutions of the metals or their salts. As in other cases of precipitation, there is here a double decomposition with exchange of acids and bases.

874. Phosphate of Lime.—A tribasic phosphate of lime ($2CaO,HO,PO_5+3Aq$) occurs naturally crystallized in hexagonal prisms, which when colorless are called *apatite* and when green *moroxite*. These crystals contain, besides phosphate of lime, a variable quantity of fluoride

261

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873. How are the phosphates prepared? 874. In what mineral does phosphate of lime occur? What is bone-ash?

of calcium. The most important variety of phosphate of lime is that called bone ash, which is obtained by calcining bones, the phosphate of lime being the principal earthy ingredient of the animal skeleton.

875. SUPERPHOSPHATE OF LIME.—A mixture bearing this name, formed by the action of dilute sulphuric acid on burned bones, is extensively used as a fertilizer of the soil. The sulphuric acid, when added, appropriates part of the lime of the bones, forming with it gypsum; at the same time, it leaves the phosphoric acid which it displaces free to combine with another portion of phosphate of lime and thereby to render it soluble. The commercial article is a mixture of this soluble substance with the gypsum and animal charcoal produced in its formation. Other materials are often added, increasing or diminishing, according to their nature, its agricultural value. The basis of the manufacture is commonly the refuse bone black of sugar refineries.

876. OTHER PHOSPHATES.—The phosphate of soda is used in medicine, and by the chemist to produce other phosphates. The phosphate of silver is a beautiful yellow precipitate, obtained by precipitating salts of silver with phosphate of soda or any other salt containing phosphoric acid. Pyrophosphate of iron is also much used in medicine.

262

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875. Describe the preparation of superphosphate of lime. 876. What is said of other phosphates?

Silicates.

877. The silicates form an exceedingly large class of salts and are most abundant natural productions. All the forms of clay, feldspar, mica, hornblende, steatite or soapstone, and a large number of other common minerals, are silicates. Meerschaum, from which pipe-bowls are often manufactured, is a hydrous silicate of magnesia. Silicates are for the most part insoluble, and are variously colored. Mica and feldspar, two of the constituents of granite, may serve as examples. As components of this and other rocks the silicates make up a very large portion of the mass of the earth.

878. PREPARATION.—Most silicates may be artificially formed by fusing together quartz sand and the proper oxide. This is done in the manufacture of glass, to be hereafter described. Slags, which occur as a by-product in the reduction of metals from their ores, are artificial silicates. Silicates may also be formed by precipitating solutions of metals or their salts by the solution of an alkaline silicate. Most of the silicates are fusible at a high temperature, their fusibility increasing by mixture with each other. Those which contain readily fusible oxides melt at the lowest temperature, and in general the basic silicates fuse more readily than those which are neutral or contain an excess of acid.

879. CLAY.—All the varieties of clay are silicates or hydrated silicates of alumina; they are frequently

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877. What is said of silicates? 878. How are silicates prepared? 879. What is the composition of clay?

largely mixed with other substances. Clay results chiefly from the breaking down and disintegration of feldspathic rocks. Clay emits the peculiar odor known as argillaceous when breathed upon or slightly moistened. Its plastic qualities render it highly valuable.

880. Varieties of Clay.—*Kaolin*, the celebrated porcelain clay of China, is perfectly white and is nearly pure silicate of alumina. It is now found in several localities. The coarser varieties of clay usually contain oxide of iron, which gives them a yellow color when hydrated and red when anhydrous.

Pipe-clay is a white variety nearly free from iron. Some clays are colored blue by the presence of organic matter which is destroyed when heated.

Yellow Ochre and *Red Bole* are clays which derive their color from oxide of iron, which is present in large quantity.

Fuller's Earth is a porous silicate of alumina which has a strong adhesion to oily matters. When the proportion of carbonate of lime in a clay is considerable it constitutes what is known as a *marl*.

881. Soluble Glass.—Soluble glass is made by fusing sand with potassa or soda. Its production may be illustrated in a soda bead, by subsequently re-fusing it with addition of sand. As the silicic acid combines with the soda carbonic acid is expelled, as will be evident from an effervescence on the surface of the bead. The product when pure resembles ordinary glass, but

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880. Describe the different varieties of clay. 881. How is soluble glass made?

dissolves in boiling water without residue. Soluble glass is sometimes used as a sort of varnish for rendering wood or cloth fire-proof. Structures built of soft and friable stone may be preserved in a great measure from the action of the weather by a coating of this material. It has also been used to some extent as a substitute for starch or gum in stiffening fibrous substances. It is now used in the manufacture of certain kinds of soap. It is asserted that the compound obtained by the addition of twenty-five pounds of liquid soluble glass to a hundred pounds of pure soda soap has a greater cleansing power than common soap.

882. Glass.—Glass is a mixture of various silicates, with excess of silica, altogether destitute of crystalline structure, produced by fusing together the materials by a high and long-continued heat. The fused mass is in a plastic but never in a perfectly fluid condition. The nature and proportions of the ingredients vary according to the purpose for which the glass is to be used.

883. Window Glass.—Common window glass is a silicate of lime and soda. To form it, chalk, soda, quartz sand and old glass are fused together until the mass becomes fluid. The molten glass is then blown, by means of an iron tube, as soap bubbles are blown with a pipe. The first form of the bubble is that represented in the figure. The glass blower next contrives to lengthen out the bubble, as he blows it, to a larger size, and finally to blow out the end by a

263

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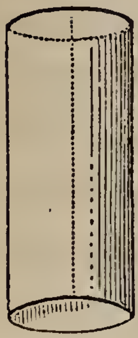
882. What is glass? 883. Describe the manufacture of window glass.

strong blast from his lungs. It is then trimmed with a pair of shears, and the other end cracked off by winding around it a thread of red hot glass. Such a thread is readily produced by dipping an iron rod into the pot of molten glass, and then withdrawing it. The bubble of glass is thus brought to the form of a cylinder, such as is represented in Figure 264. The cylinder is then cracked longitudinally, by letting a drop of water run down its length, and following it by a hot iron. It is subsequently reheated, opened, and flattened out into a sheet, which is then cut into panes of smaller size, if required.

264



884. Glass Tubes.—To make a glass tube, a bulb is first blown, such as is represented in Figure 263. An assistant then attaches his tube to the hot bulb at the opposite end, and moves backward. The glass is thus drawn out as if it were wax, and the cavity within it is elongated to a smooth and perfect bore.

885. Glass Bottles.—Bottles and a great variety of other objects of glass are made by the enlargement of similar bulbs within a mould of the required shape. Bottle glass is usually made of cheaper and less pure materials than window glass, and contains, in addition to the materials before mentioned, alumina and oxides of iron and manganese. It owes its green color to the protoxide of iron.

886. Plate Glass.—Plate glass, such as is used for

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884. How are glass tubes made? 885. How are glass bottles made? 886. What is plate glass?

large mirrors and shop fronts, is a soda and lime glass which is cast instead of being blown. It is poured out of the crucible in which it is melted, upon a cast-iron table and rolled into sheets, which, after careful annealing, are ground to a level surface and ultimately polished.

887. Crystal Glass.—This is the name given to a highly brilliant glass used for lenses for optical instruments, prisms, lusters and the finer qualities of cut glass ware. It is also called *flint glass* from the circumstance that the silica used in its manufacture was formerly derived from pulverized flints. It is composed of silicate of potash and silicate of lead. The large proportion of lead in flint-glass gives it a high refractive power and great brilliancy when cut, but renders it soft, easily fusible and liable to be acted on by many chemical agents. With the addition of borax, it is also employed for imitations of precious stones.

888. Bohemian Glass.—This celebrated glass is made mostly of silicates of potash and lime. Its hardness and infusibility give it a high value in laboratory analysis. The more fusible glass which is employed in the manufacture of beautiful Bohemian ornamental objects contains also silicate of alumina.

Crown Glass is composed of the same materials but in different proportions.

889. Colored Glass.—Glass is colored and stained by the addition of various metallic oxides. The pecu-

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887. What is crystal glass? 888. What is composition of Bohemian glass? 889. How is glass colored?

liar coloring effects of these substances have already been mentioned, in Section 803.

890. ENAMEL.—Enamel is an opaque glass, produced by the addition of some material which does not dissolve in the fused mass. Binoxide of tin is the material commonly employed. Various tints may be imparted to enamel, as to ordinary glass, by the addition of small quantities of metallic oxides. A thin surface of enamel is often baked on to a metallic surface, as in the case of watch dials and various objects of jewelry.

891. ANNEALING.—All glass to be valuable requires to be *annealed*, for when allowed to cool suddenly after fusion, it becomes exceedingly brittle and articles made from it are liable to fly to pieces upon the slightest touch of any substance hard enough to scratch its surface, even from a slight but sudden change of temperature, as when transferred from a cold to a warm room. This property is strikingly illustrated by what are called *Rupert's drops*, which are little pear-shaped masses of glass formed by dropping melted glass into cold water. These may be subjected, without breaking to considerable pressure but the instant the little end of the drop is broken off the whole mass crumbles into powder with a kind of explosion. This probably arises from the unequal tension of the layers of glass in consequence of the sudden cooling of the exterior whilst the interior remains dilated, or even red hot.

892. The following table will give an idea of the

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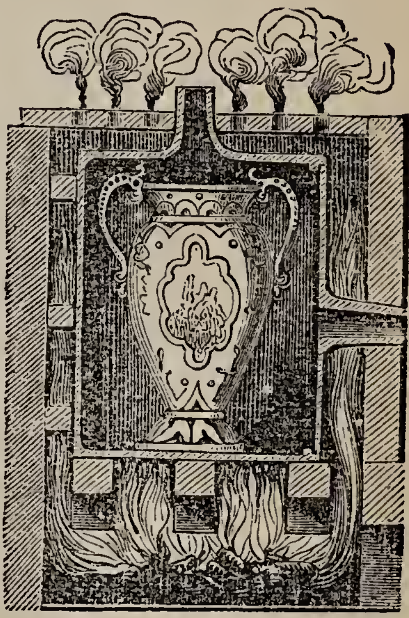
890. What is enamel? 891. How is glass annealed? 892. Describe the composition of the different kinds of glass.

relative proportions of the ingredients in the several kinds of glass mentioned above, viz.:—

	PLATE.	BOHEMIAN.	FLINT.	BOTTLE.	OPTICAL.
Silica,	78	69	52	59	43
Potassa,	2	12	14	2	12
Soda,	13	—	—	10	—
Lime.	5	9	—	20	1
Aluminum,	2	10	1	2	—
Oxide of Lead,	—	—	33	—	44
Oxide of Iron,	—	—	—	7	—
	100	100	100	100	100

893. EARTHENWARE.—Clay is the basis of all earthenware, from the finest porcelain to the coarsest brick. Being first fashioned by moulds or other means into the proper form, it is dried, baked, and subsequently glazed to render it impervious to water. In the manufacture of porcelain glazing is not essential. Sand and chalk are added to the original material, and the heat is carried so high as to bring the whole mass into a semi-vitreous condition. This is also the case in certain kinds of *stoneware*. Porcelain is, however, commonly glazed to add to its beauty.

265



894. GLAZING.—Earthenware after its first baking is porous, and therefore unfit for most uses for which it is intended. It is subsequently covered with a thin paste

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893. What is the basis of all earthenware? How is porcelain made?
894. Describe the process of glazing.

formed of the constituents of glass. Being then subjected a second time to the heat of the furnace, a thin glass or *glaze* is formed upon the surface. The glazing of certain wares is effected by exposure at a high temperature to vapors of common salt. A double decomposition ensues with the oxide of iron which the ware contains, by which soda is formed. This immediately fuses with the silica and other materials to form the glaze. The chloride of iron which is formed at the same time passes off as vapor. A paste of pounded feldspar and quartz, to which borax is sometimes added, is employed in glazing porcelain.

895. Porcelain Painting.—Metallic oxides form the basis of the pigments used in painting upon porcelain. The coloring effect of the different pigments is mentioned in the chapter on metallic oxides. Great improvements in the art of ornamenting porcelain have been recently effected by the discovery that the action of the oxygen in flame and of the products of incomplete combustion modify the shade given to pottery by metallic oxides, and produce with one and the same material very different colors. Thus, with the oxide of chromium in a reducing atmosphere a blue shade is obtained, while with an oxidizing atmosphere a green color is produced showing ruby red in the light. With the oxide of uranium, in an oxidizing atmosphere, a pure yellow is brought out, and hues varying from reddish brown to black in the reducing atmosphere. The patterns on ordinary earthenware are first printed

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895. What is said of porcelain painting?

on paper, and then transferred, by pressure, to the unglazed ware. The paper is afterwards removed by a wet sponge.

Borates.

896. Borax. $(NaO,2BO_3+10Aq.)$—Borax is the only important salt among the compounds of boracic acid. The salt contains two atoms of acid to one of base, and is therefore a biborate. It is a white soluble salt, which swells up when heated, in consequence of the escape of its water of crystallization.

266

897. Preparation.—Borax is found in solution in the water of certain shallow lakes in India. It remains as an incrustation in the beds of these lakes when they dry up in summer. It is also prepared by the action of a solution of boracic acid on carbonate of soda.

898. Borax Glass.—The light spongy mass which is produced on heating borax, may be melted down by greater heat and converted into borax glass. This glass has the property of dissolving metallic oxides, and receiving from them peculiar colors, as described in a former paragraph. The chemist often determines the metal which a salt or oxide contains, by the color which it thus imparts to glass. The method of making the experiment has already been given.

899. Soldering, Welding, etc.—Borax is employed

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896. What is borax ? 897. How is borax prepared ? 898. What is said of borax glass ? 899. Why is borax employed in soldering ?

in soldering metals, to keep the metallic surfaces clean. It does this by dissolving the coating of oxide which forms upon them, and forming with it a glass which is fluid at a high temperature, and easily pushed aside by the melted solder. Its use in welding iron depends on the same property. Iron, however rusty, may be soldered, or welded, by using as a flux the double chloride of zinc and ammonium which is formed by dissolving chloride of zinc in hydrochloric acid and adding sal-ammoniac. This cleans the surface of the iron and allows the two pieces of metal to come directly in contact with the solder or with each other. Borax is used, to some extent, in medicine. It is also a constituent of the glass called *jewelers' paste*, which is used in producing imitations of precious stones.

Chromates.

900. The chromates are prepared for use in the arts from the native chrome iron by fusing the ore with nitrate of potash; by this treatment the chromium absorbs oxygen and is converted into chromic acid, (CrO_3), which unites with the potash to form a yellow salt, the *chromate of potash* (KO,CrO_3.) By varying the process a red salt containing twice as much chromic acid as the first, the *bichromate of potash*, ($KO, 2CrO_3$) is produced. The bichromate of potash which crystallizes in beautiful red crystals is manufactured in immense quantities for use in the arts and is the source

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900. How are chromates prepared?

of several exceedingly valuable coloring materials and pigments.

901. Chrome Yellow. (PbO,CrO_3).—To prepare this pigment, a solution of the commercial bichromate of potassa is added to a solution of sugar of lead. A double decomposition ensues; the result of which is the production of a beautiful yellow precipitate, known as *chrome yellow*. The precipitate is a chromate of lead.

267

902. Chrome Orange. ($2PbO,CrO_3$).—Chrome yellow may be converted into *chrome orange*, by digestion with carbonate of potassa. Cloth dyed yellow by dipping it alternately into a solution of bichromate of potassa and sugar of lead, is instantaneously changed to orange by immersion in boiling milk of lime. This action of the lime, as well as that of carbonate of potassa, depends upon its abstracting a certain portion of the chromic acid, leaving thereby a chromate of lead of different composition and color.

903. Chrome Green. (Cr_2O_3).—On adding sulphuric acid and a few drops of alcohol to a solution of bichromate of potassa, the solution is immediately changed from red to green. The alcohol has taken oxygen from the chromic acid, and converted it into oxide, which remains in solution, as a soluble sulphate. Part of the sulphuric acid has at the same time combined with the

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901. How is chrome yellow prepared? 902. How is chrome yellow converted into chrome orange? 903. Describe the preparation of oxide of chromium.

potassa, to form sulphate of potassa. It is to the presence of the sulphate of chromium in solution that the color of the liquid is due. By adding an alkali to the solution, a green precipitate of the hydrated oxide is produced. This oxide forms a kind of "chrome green." Commercial chrome green is a mixture of Prussian blue and chrome yellow.

Manganates.

904. MANGANATE OF POTASH.—CHAMELON MINERAL. (KO,MnO_3)—By fusion with nitre, the black oxide of manganese may be still further oxidized, and converted into an acid. The new acid at the same time combines with the potassa of the nitre to form manganate of potassa. This salt has been called *chameleon mineral*, from the spontaneous change of color which takes place in its solutions.

905. PREPARATION.—The experiment may be made by filling a pipe-stem with a mixture of the materials, and thrusting it into burning coals. It may be made on a still smaller scale before the blow-pipe, using a broken pipe-bowl to support the materials. The compound dissolves in water, forming a green solution, which on standing is gradually changed to a beautiful red.

906. EXPLANATION.—The addition of a few drops of sulphuric acid, produces the above-mentioned change instantaneously. This acid combines with the potassa,

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904. What is chameleon mineral? 905. How is chameleon mineral prepared? 906. Explain the action of sulphuric acid upon it.

setting the manganic at liberty. One portion of manganic acid then appropriates part of the oxygen of the other part, and converts itself into permanganic acid, (HO,Mn_2O_7), which still remains combined with potassa, imparting the red color to the solution. The deoxydized portion of the acid precipitates, at the same time, as binoxide of manganese.

907. PERMANGANATE OF POTASH. (KO,Mn_2O_7).—By evaporating the red or purple solution, mentioned in the preceding paragraph, deep ruby-colored crystals of permanganate of potassa are obtained, which are soluble in 16 times their weight of water. The solution of this salt is now much employed in volumetric analysis. It readily parts with its oxygen to organic matter and deoxidizing bodies generally, by which it loses its color, and brown hydrated peroxide of manganese is deposited. A standard solution of permanganate has been employed for determining the amount of organic matter in air and water. A solution of this salt has been much used for the removal of foul effluvia in sick rooms. It is also applied for the same purpose to cancerous and other offensive ulcers.

Photography.

908. PHOTOGRAPHY is the art of producing pictures by the action of light. It depends upon the chemical changes which the salts of silver undergo when exposed to light. Solutions of gold and various other salts un-

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907. What is permanganate of potash? For what purposes is it used?
908. On what does the art of photography depend?

dergo chemical changes by the action of light, but none are so well adapted to the photographic art as the salts of silver which are almost exclusively employed for this purpose. All the salts of silver are more or less affected by light. In some instances they undergo a visible change, being rendered dark in proportion to the intensity of the light and the length of exposure. This is well seen in the white chloride of silver when in a humid state; and in the nitrate and ammonio-nitrate in contact with organic matter. The iodide and bromide of silver do not darken by exposure to light, but they undergo instantaneously a remarkable molecular change which renders them especially adapted for photography.

909. THE DAGUERREOTYPE may be regarded as a painting in mercury upon a silver surface. The employment of mercury is preceded by what may be called an invisible painting upon a delicate film of the iodide or bromide of silver upon the surface of the silver plate. This is accomplished, like the production of an image in a mirror, by mere presentation of the picture, or other object to be copied, before the prepared plate. The mercury, afterward used in the form of vapor, adheres to the plate, and forms its white amalgam, just in proportion to the lights and shades of the previous image thrown upon the plate.

910. THE DAGUERREOTYPE PROCESS.—In order to prepare the plate for what has above been called the

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909. Explain the daguerreotype. 910. Describe the process of taking daguerreotypes.

invisible painting, it is exposed to vapors of iodine, and thereby covered with a coating of iodide of silver.* A picture or face to be copied being presented before the prepared plate, the light which proceeds from it acts chemically upon the iodide of silver. It decomposes it, to a certain extent, and separates the iodine, thus opening the way for the mercurial vapor which is afterward to be employed. The light has this effect just in proportion to its intensity. That which proceeds from the lighter portions of the face, or dress, has most effect; that from the black portions, none at all, and that from the intermediate shades, an effect in exact proportion to their brightness. When the plate is afterward exposed to the action of the mercurial vapors, they find their way to the silver surface and paint it white, just in proportion as this chemical effect upon the iodine has been produced, and the way has been opened for their admission. The darker portions of the plate are pure silver. They appear dark in contrast with the white amalgam.†

911. Use of the Lens.—In taking daguerreotypes, a lens is placed between the object to be copied and the plate, in order that an image may be formed on the silver surface. Such an image is analogous to that

911. What is the object of the lens?

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* Bromide and chloride of iodine are employed to give additional sensitiveness to the plate. The iodide is thus made to contain a portion of bromide and chloride of silver.

† The art of taking portraits from the life by the Daguerreotype process, was invented by Dr. J. W. Draper, of the N. Y. University.

formed on the retina of the eye. The image is commonly made smaller than the object. Where this is the case, the rays are used in a concentrated condition, and their effect is proportionally increased.

912. Chemical Action of Light.—The chemical action of light, on which the production of daguerreotypes depends, is one of the most interesting and remarkable of chemical phenomena. The rays of the sun are so subtle that they pass through solid crystal and leave no trace of their passage. Yet with them comes a power that can overcome the strongest chemical affinities, and resolve the compounds which it has produced into their original elements. This power resides in what are called the *chemical*, *actinic*, or *tithonic* rays. These are mingled, under ordinary circumstances, with those of light, but are capable of separation by certain media.

913. Photographs.—Pictures produced through the agency of light, whether upon silver or paper, are, properly, photographs or *light pictures;* the name, however, is especially appropriated to pictures produced by the agency of light upon paper prepared for the purpose. The production of these pictures embraces two distinct processes. First the production of a *negative*, or a picture in which the dark parts of the object are light in the picture and the light parts dark,

268

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912. What is said of the chemical action of light? What rays possess this power? 913. What are photographs?

like the letters H, X, Y, in figure 268. Second, the production from the negative of a picture called a *positive* in which all the parts of the object possess their appropriate relations of light and shade. In these pictures the colors are seldom the same as in the real object.

914. Negative Pictures are prepared upon glass covered with a thin film of collodion. The collodion used for this purpose is prepared by adding to every ounce of plain collodion 3 grains of iodide of potassium, 2 grains of bromide of potassium and 6 grains of sal-ammoniac. The collodion thus prepared is poured over the surface of the glass and allowed to harden, when it is immersed in a bath of nitrate of silver. The silver bath contains 40 grains of nitrate of silver to an ounce of distilled water, and to this is added as much iodide of silver as the solution of nitrate will dissolve. The glass plate coated on one side with the prepared collodion is immersed for a few minutes in this silver bath when it is ready for use. The plate is then placed in the camera and the image of the object to be copied is thrown upon it as shown in figure 269, the light from all other sources except the object being carefully excluded. The camera consists of a rectangular wooden box as shown in the figure, to one face of which is attached a tube, bearing a lens, which forms the image. The opposite face of the box consists of a sliding drawer, holding a plate of ground glass, upon which the image is thrown, and by drawing it out, or sliding it in, the

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914. How are negative pictures produced?

picture may be rendered distinct upon the glass. When the image is clearly defined, the plate of glass is removed, and the collodion plate is introduced as above mentioned and exposed for a few seconds to the light of the image. The plate is then removed and in a dark room it is washed with a *developing fluid* which removes the salt of silver from the parts not acted on by the light and brings out the negative picture as above described. A common developing fluid is made by mixing 2 ounces of sulphate of iron, 6 drops sulphuric acid, 3 drachms acetic acid and half an ounce of alcohol with a quart of water. The distinctness of the picture is afterwards increased by immersing in the *toning bath;* consisting of 3 quarts of water, 1 pound hypo-sulphate of soda, 3½ ounces nitrate of silver changed into chloride and washed, and 5 grains chloride of gold. After these processes are completed the picture is permanently fixed upon the plate by means of transparent varnish.

915. AMBROTYPES are negative pictures placed upon a back ground of black varnish or other dark substance. They may be made upon glass and backed with black cement or upon plates of japanned iron or leather.

916. PHOTOGRAPHIC PRINTING; POSITIVE PICTURES.—Positive pictures are printed from negatives, with light and shade reversed, on sensitive paper exposed to sunlight covered by the negative picture. Sensitive paper is prepared by immersion in a solution of common salt, 80 grains of salt to a quart of water, and afterwards in

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915. What are ambrotypes? 916 How are positive pictures printed from negatives? How is the picture rendered permanent?

a solution of ammonio-nitrate of silver. It is then dried in the shade when it is ready for use. A suitable sensitizing solution may be prepared as follows: Dissolve an ounce and a quarter of nitrate of silver in a pint of distilled water, put three ounces of the solution in a separate bottle, and to the remainder add aqua ammonia chemically pure, drop by drop, until the silver is first deposited and then redissolved, pour in the three ounces which had been reserved when a slight deposit will again appear, filter the liquid and it is fit for use. Immerse paper of the finest quality two or three times in this fluid and place it between blotting paper to remove the superfluous liquid, dry the paper in the dark and it is ready for use. It is sufficient to sensitize one side of the paper only.

The negative plate is placed over the paper on the sensitive side and exposed for a few minutes to the direct rays of the sun. The positive picture is thus produced with light and shade in their natural relations. The chloride of silver on the paper is partially decomposed. A new substance, of darker color, is then produced; whether a lower chloride of different shade, or a mixture of metal and chloride, or a compound of oxide and chloride, is not very certainly known.

If nothing more were done to the picture thus produced, the whole surface of the paper would soon be blackened and the picture would disappear. The picture is fixed by washing the paper in a solution of hyposulphate of soda which removes the chloride of silver which has not been acted on by the light, while that portion which has been changed by light remains as the coloring matter of the permanent picture.

Note.—The details of all the processes described in sections 915 and 916 are considerably varied by different artists.

917. OTHER APPLICATIONS.—The contributions of photography to other sciences are numerous and of the greatest value. Thus, in astronomy, it has been employed for obtaining pictures of the moon, far exceeding in accuracy any which can be obtained by other means; also for recording the changing aspects of the sun during the progress of an eclipse. It has also proved a most valuable ally of the microscope, not alone by giving permanence to its magnified images, but in recording them with a precision and beauty altogether unattainable by the skill of the engraver. The means of most important advances in microscopic anatomy and physiology have thus been supplied. The meteorologist is also furnished by photography with the most valuable aid. A slip of paper, moved by clock-work behind a thermometer, and so placed as to receive the shadow of the mercury, may be made to record automatically successive changes of temperature, and thus take the place of tedious observation. The same device may be employed to record the fluctuatious of the barometer, the movements of the wind guage, and the variations of the magnetic needle.

918. ANASTATIC PRINTING.—This name is given to a process by which any kind of printed matter may itself be converted into a plate from which new copies may be printed. The paper containing printed matter or other designs is moistened with dilute nitric acid, but

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918. Describe briefly the process of anastatic printing?

the ink containing oil is not moistened. The paper is then laid upon a sheet of polished zinc and submitted to pressure by which a portion of the ink adheres to the zinc and protects the zinc from the action of the acid. When the acid in the paper touches the zinc it corrodes it and forms a surface to which ink will not adhere. The paper is then removed and the plate is washed with gum water which wets the corroded surface and leaves the inked surface untouched. The zinc plate is then used like an ordinary lithographic stone. When the inked roller is passed over it, the ink only adheres to the design, from which an impression may then be taken by the ordinary process.

919. Counterfeiting.—Bank notes may be counterfeited either by photography or by the anastatic process. Great apprehension has been felt lest they should render the use of paper money entirely insecure. An effectual means of protection against such counterfeiting has recently been devised.* Copying by the anastatic process, obviously depends upon the absence of oil from the back ground of the picture. The employment of an oil tint, instead of blank paper, for the back ground, is therefore a perfect security against it. Counterfeiting by the photographic process depends on the fact that the light which falls on a picture is intercepted by the dark letters. If they are printed in a transparent blue, the chemical rays are permitted to

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919. What is said of counterfeiting by the above process?

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* Seropyan's patent.

pass through the printed as well as the unprinted portions. A copy with the contrasts of the original picture is thereby rendered impossible. By printing with blue ink, on a back ground of some other color, both of the securities against counterfeiting above mentioned are combined. The green colors upon United States treasury notes are another device to prevent counterfeiting. Recent U. S. bonds have the denomination printed in a gilt device underneath the engraving which cannot be removed and cannot be copied by photography or by any other known process.

[illegible] are indispensable subject already, such [illegible] complicated and difficult to be [illegible]

PART IV.

ORGANIC CHEMISTRY.

CHAPTER I

GENERAL VIEWS

920. Definition.—Organic chemistry is that division of the science which treats of substances of *vegetable* and *animal* origin. Wood, starch, gums and resins; the juices, coloring matters, and fragrant principles of plants; the blood and flesh of animals; all come under its consideration. The process of germination, in which the plant first becomes a living thing; the processes of decay and putrefaction in which it returns to the earth and atmosphere, are also to be treated under this division of the subject. Most organic forms of matter experience peculiar changes, and are converted into new substances by natural or chemical means. The products of such transformations—with the exception of a few, such as water, carbonic acid and some other substances, which also exist ready formed in nature—belong to organic chemistry.

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920. Of what does organic chemistry treat?

921. Elements in Organic Bodies few.—Organic products differ remarkably from bodies which belong to the mineral or inorganic kingdom; and in many cases they may at once be distinguished by their external appearance. A striking peculiarity of their chemical character is the limited number of elements that enter into their composition. Some organic substances contain carbon and hydrogen only. A greater number are constituted of three elements, carbon, hydrogen and oxygen. Some contain in addition to these three, nitrogen; while a few have, besides these, a minute proportion of sulphur and phosphorus, with certain earthy and saline matters. The presence of carbon is so uniform in organic substances that generally an unknown body may be determined to be of organic origin by its becoming charred and blackened when heated without a full supply of air.

922. Variety of Organic Matter.—Though the number of elements entering into the composition of organic bodies is so limited, it may not be correctly inferred that the number of bodies is small. The reverse is true, for by a sort of fermentation the variety of distinct organic substances is almost without limit. By the arrangement of these different elements in different ways and in different proportions a host of organic forms is produced, presenting characters the most diverse and most variable. Sugar contains the same elements as vinegar. All the components of

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921. What are the elements of organic bodies? 922. What is said of the variety of organic matter?

strychnia are found in a crust of bread. Every color of every dye, every flavor of every sweet or bitter herb, every gum and every resin, is a distinct organic substance, though each of these may be made up of the same elements. In the animal body there is scarcely less variety. The number of substances that fall into the province of organic chemistry is thus immense.

923. MATERIALS OF ORGANIC GROWTH.—With the exception of the small proportion of mineral matter, which is derived from the earth, the materials out of which all animal and vegetable substances are formed are but few in number. In carbonic acid, water, and ammonia, and these derived partly from the air and partly from the earth, the plant finds the carbon, hydrogen, oxygen and nitrogen out of which it is constructed.

924. CONVERSION OF THE MATERIALS.—A vital principle slumbers within the seed, which in germination wakes into life. Calling to its aid the light and warmth of the sun, it weaves out of the scanty inorganic materials which have just been mentioned all the varied forms of vegetable matter. Among the materials one is a tasteless solid; the rest are tasteless gases. Yet sweet, sour and bitter flavors result from their combinations, with all the boundless variety of the organic world.

925. INSTABILITY OF ORGANIC PRODUCTS.—Another

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923. What are the materials of organic growth? 924. What causes the changes of organic materials ? 925. What is said of the stability of organic products?

peculiarity which characterizes organic products, though not so universal as that of the limited number of elements, is their instability. While a few remain permanent under ordinary circumstances, the larger number have a tendency to change, to decay, and to fall back to the materials out of which the plant constructed them. During this decay new compounds are produced adding still to the number of products which plants have formed during their growth. Chemical agents often assist in promoting changes, and the number of substances becomes yet more varied. The result of these changes is usually the production of substances of more simple composition, which are one step nearer the carbonic acid, water and ammonia from which they came and to which they will ultimately return.

926. Identity of Composition.—Attention has been called to the fact that organic substances have a remarkable identity of composition, the same elements in different proportions forming compounds of remarkably diverse character. Stranger than this, and at the first view incredible, is the fact that many organic substances, differing widely in properties, are precisely the same in their composition; not alone containing the same elements but containing them in precisely the same proportion. The sugar which sweet milk furnishes and the acid which exists in the sour, contain identically the same proportions of the same constituents. The oils of turpentine, lemon and pepper, so

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926. What is said of identity of composition?

different in their taste, contain an equal quantity of carbon and hydrogen, without the addition of any third substance to either to account for the difference. Chemical investigation has thus brought us to results as strange as the dream of the alchemist, who believed that lead might be converted into silver, and copper into gold. All such substances possessing the same composition with different properties are called *isomeric* bodies—a term signifying their similarity of composition.

927. ISOMERISM.—The examples instanced serve to show that mere identity of ultimate composition is not sufficient to produce identity of chemical character or properties. At a loss for any other way of accounting for such difference of properties we are compelled to believe that it is because of difference of atomic arrangement. We have seen in the case of iodide of mercury, mentioned in Section 826, that a mere touch will produce motion and re-arrangement of its atoms in smaller groups, and at the same time change the color of the compound from yellow to red. There are various forms of isomerism; in some cases we have no clue to the probable difference of molecular arrangement; in others there is every reason to suppose that the arrangement of the elementary atoms is on a totally different plan in the two or more bodies compared. Now the molecule of lactic acid, although containing the same relative proportion of all the constituents, is smaller than the molecule of sugar of milk. It con-

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927. What is meant by isomerism?

sists of six atoms of carbon, six of hydrogen, and six of oxygen, ($C_6H_6O_6$). The molecule of sugar of milk contains twenty-four of each ($C_{24}H_{24}O_{24}$) and can therefore furnish material to make four of acid as it does in the souring of milk. And we may suppose that the change from sweet to sour is owing to this subdivision of the molecules.

928. Different Forms of Isomerism.—In some cases the difference of properties of bodies which contain equal percentages of their constituents, may be simply explained upon the supposition that the state of condensation of those elements is different. Methyline, a gaseous body, is regarded as being made up of two atoms of carbon and two of hydrogen (C_2H_2); ethylene or olefiant gas of four of carbon and four of hydrogen (C_4H_4); and tetrylene or oil gas, of eight of carbon and eight of hydrogen (C_8H_8). The density of these bodies is proportioned to the number of atoms they are here represented to contain. Bodies supposed to be thus constituted are termed *polymeric.*

There are other cases of identical composition in which there is no difference whatever in the size of the molecule or the number of atoms which enter into its composition. This is the case with the oils of turpentine, lemon and pepper. The molecules of each are composed, not alone of the same proportion of the elements which enter into its composition, but there is reason to believe of the same number of atoms of each.

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928. What varieties of isomerism are mentioned?

Isomeric compounds of this kind, the equivalent numbers of which are identical, are said to be *metameric.* In these we are compelled to look for the difference which shall account for their peculiar property in a different arrangement of atoms inside of the molecules themselves. In illustration we may conceive of several bodies the composition of which is expressed by the formula $C_6H_5O_5$; and the atoms grouped somewhat as represented in the accompanying figures.

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929. CHANGE AND MULTIPLICATION OF COMPOUNDS.—Many organic substances when removed from the influence of the vital principle and exposed freely to the air, begin at once to change; begin to decay. The gradual decay of organic compounds is chiefly a process of spontaneous oxidation; for decay is in reality only a slow combustion. The body is attacked by the oxygen of the air, and burned, and destroyed, though so gradually as to produce no sensible elevation of temperature. Some substances which do not thus spontaneously change have the oxidizing action induced by contact with a body which is itself undergoing slow

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929. How are organic compounds multiplied?

oxidation. The action of heat exalts the attraction of oxygen for hydrogen and carbon, and we see the almost universal destruction of organic substances at a high temperature. In ordinary combustion but few compounds are obtained, the change being speedily effected and bodies, such as are found in the inorganic world, produced. But when the common process is interfered with by shutting off contact with the air, as in destructive distillation, a host of new products, varying according to the temperature and other attending circumstances, is the result. Some of the most important of these organic compounds will be noticed in succeeding paragraphs.

930. The chemist in examining the composition of organic bodies and tracing their relations to other compounds, calls to his assistance a variety of agents and by their aid produces metamorphoses, the different steps of which he can trace. Sometimes changes are effected by imitating nature and the method of *oxidation* is used. The organic body is brought in contact with some powerful oxidizing agent, such as nitric acid, chromic acid or a mixture of sulphuric acid and black oxide of manganese, under the influence of which, by a transfer of the oxygen, the desired change is accomplished. Sometimes the reverse process of *reduction* is adopted, at other times a method of displacement or *substitution*, by which the atoms or molecules of one body are made to take the place of those of a different kind

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930. How does the chemist examine organic bodies?

in another body, is used. From a compound a certain number of atoms of hydrogen may be removed and an equal number of atoms of another element may be substituted. Even compound substances, as the molecule of peroxide of nitrogen, (NO_4) may thus displace the atom of hydrogen.

931. SUBSTITUTION.—The study of the action of such substances as may replace others in combination has led to a knowledge of unlooked-for facts. Strange as it may appear, one element may take the place of another, and in many cases the character of the original body will be but slightly changed, even though the new substance introduced be wholly different in chemical character from the one that has been displaced. Hydrogen may be displaced by chlorine, a body as widely different from it as anything which nature affords. The mode of action consists in the removal of the hydrogen, or more rarely some other element of the organic substance, and the substitution of some element or compound, equivalent for equivalent, without destruction of the primitive constitution of the original compound. By such substitution ordinary hydrated acetic acid, ($HO,C_4H_3O_3$), may have its hydrogen displaced by chlorine, giving rise to trichloracetic acid, ($HO,C_4Cl_3O_3$), a stable substance of strong acid character, remarkably analogous to the acid from which it was formed. From this again, by withdrawing the chlorine and restoring the hydrogen, the original acetic acid is reproduced. In the

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931. What is said of substitution?

conversion of acetic acid into trichloracetic acid one element appears to have taken the place of another without disturbing the relative positions of the other constituents; as we may conceive a brick may be removed from an edifice whilst its place is supplied by a block of wood, or stone, or metal, without altering the form or symmetry of the structure.

932. TYPES.—The last example will serve as an illustration of the doctrine of chemical types and substitution, which certain chemists have endeavored to extend to all organic bodies. It has been asserted that the properties of these bodies depend solely upon arrangement without any reference to the nature of the elements combined. The fact is, that while there are many cases of such substitution without essential change of properties, it is always attended by more or less modification of the original substance. The properties of compounds are therefore to be regarded as depending neither upon the nature nor arrangement of atoms alone, but upon both causes combined. The *type* is the group which remains permanent while the individual atoms which compose it are changed.

933. COMPOUND RADICLES.—In organic chemistry radicles are represented by simple substances which enter into combination with oxygen, chlorine and that class of elements, forming a class of compounds. Thus sulphur is the radicle of sulphurous acid, (SO_2,) and sulphuric acid, (SO_3). Many organic bodies, although compounds, comport themselves as though they were *ele-*

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932. What are organic types? 933. What are compound radicles?

mentary substances. Some of these correspond in properties to metals, forming oxides, chlorides and salts, like true metals. Others resemble the metalloids. Each being organic, and like a metalloid, the root of a whole series of compounds is called an *organic radicle*, and as the organic substances above referred to are composed of different elements, they are called *compound radicles.*

934. Illustration.—A molecule of ordinary ether is composed of four atoms of carbon, five of hydrogen and one of oxygen, (C_4H_5O). But the carbon and hydrogen are grouped together forming a compound radicle called ethyl. (C_4H_5,) is combined with the oxygen to form ether or the oxide of ethyl. Alcohol, as illustrated in the figure, is the hydrated oxide of this radicle. Ethyl itself may be prepared indirectly from the oxide as potassium is obtained from potassa or oxide of potassium, although by a different process.

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935. Composition and Analogies of Compound Radicles.—Compound radicles, compound bodies which act like elements, may consist of two, three or more elements. They are often represented by symbols as in case of elements. Cyanogen, one of the simplest, as well as the earliest discovered, is composed of two atoms of carbon and one of nitrogen, ($C_2N = Cy.$) In its chemical properties it is analogous to chlorine. In

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934. How is this subject illustrated? 935. What is said of the composition and analogy of compound radicles?

kakodyl, which has the character of a metal, there are three elements and its composition is expressed by $C_4H_6As = Kd$. In the cyanide of kakodyl, ($C_4H_6As + C_2N = KdCy$), we have an instance of two compound radicles combining like elements. Ethyl, ($C_4H_5 = Et$) the organic radicle mentioned in a preceding paragraph, discharges functions in the compounds of which it is the root analogous to potassium in its salts. We may compare the composition of some of these bodies.

KO	EtO.	KO,HO	EtO,HO.
KCl	$EtCl$.	KO,SO_3	EtO,SO_3.
KI	EtI.	KO,NO_3	EtO,NO_3.
KS	EtS.	KO,NO_5	EtO,NO_5.

936. Radicles not Isolated.—The larger part of the organic radicles have not yet been isolated. They are only known in their compounds, yet the probability of their existence is so great that most chemists do not hesitate to give them names and places among chemical bodies. Absolute demonstration is needed in the form of complete isolation, that the true classification of groups may be assured, and the progress of the study of organic chemistry facilitated, which has been so greatly accelerated by the discovery of those already known.

937. Substitution Compounds.—It was stated in a previous paragraph that there are many cases of substitution of elements for each other without material change of properties. Certain cases of substitution of

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936. What is said of radicles not isolated? 937. What are substitution compounds?

compound radicles for the elements remain to be noticed. Theoretically considered they are among the most important discoveries which have for years been made in organic chemistry. Ammonia, as the student is already informed, is a volatile base whose molecules consist of one atom of nitrogen and three atoms of hydrogen, (NH_3). For one of these atoms of hydrogen a molecule of the radical ethyl (C_4H_5) may be substituted without very materially affecting its properties. The new ammonia thus formed is like the first, a volatile base resembling the first so nearly in odor that it must have been repeatedly mistaken for it when accidentally produced. It is, however, a liquid at ordinary temperatures. This body has received the name of *ethylamine* or *ethylia*, and its composition expressed by the formula, ($NH_2\,(C_4H_5)$). Diethylia ($NH(C_4H_5)_2$) is another body produced by the substitution of two molecules of ethyl for two atoms of hydrogen. Triethylia ($N(C_4H_5)_3$) is a third in which all the original atoms of hydrogen have been displaced. By a similar substitution of hydrogen in ammonia by the radicle methyl, another series is produced. Other radicles yield other series. Substitutions may even exist in the substituting radicles. All these bodies retain the type of ammonia, and all of them have basic properties. Many of them are strikingly similar to ammonia in odor and other properties.

938. HOMOLOGOUS SERIES.—Certain of the compound radicles sustain to each other a curious numerical rela-

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938. What are homologous series?

tion. They form a series in arithmetical progression differing from each other in composition by a common difference. In the series to which ethyl belongs, the common difference is two atoms of carbon and two of hydrogen, (C_2H_2). Methyl, the radicle of wood-spirit begins the list with two atoms of carbon and three of hydrogen, (C_2H_3). Ethyl follows—its composition being expressed by the addition of the common difference to the last—($C_2H_3+C_2H_2=C_4H_5$). High in the series is melissyl, with a composition expressed by $C_{60}H_{61}$. Each of these radicles has, like ethyl, its own oxide or ether, its hydrated oxide or alcohol; also its aldehyde and its acid. A series of radicles—ethers, alcohols, aldehydes and acids, each in arithmetical progression, is thus produced. Such series are called *homologous*. The composition of a few of the lower numbers of some of the most common groups is expressed below.

RADICLES.	ETHERS.	ALCOHOLS.	ALDEHYDES.	ACIDS.
C_2H_3	C_2H_3O	$C_2H_4O_2$	$C_2H_2O_2$	$C_2H_2O_4$
C_4H_5	C_4H_5O	$C_4H_6O_2$	$C_4H_4O_2$	$C_4H_4O_4$
C_6H_7	C_6H_7O	$C_6H_8O_2$	$C_6H_6O_2$	$C_6H_6O_4$
C_8H_9	C_8H_9O	$C_8H_{10}O_2$	$C_8H_8O_2$	$C_8H_8O_4$
$C_{10}H_{11}$	$C_{10}H_{11}O$	$C_{10}H_{12}O_2$	$C_{10}H_{10}O_2$	$C_{10}H_{10}O_4$

939. There are numerous gaps in most of the series, but the law of their progression has been so well established that no doubt can exist as to the probable production of the missing numbers; and as many of the gaps have been filled since the existence of these homolo-

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939. Are homologous series always complete?

gous series was first pointed out, it may be expected that before long these series will be complete.

940. PROGRESSION OF PROPERTIES.—The properties of the various members belonging to the homologous series gradually change as we ascend in the series. The most characteristic alteration is the diminution of volatility. The lower members of the alcohol series are highly volatile liquids; the later are solids at ordinary temperatures. The extreme terms of the series of acids compared, show a similar difference; formic acid being a volatile liquid which requires cooling below 32° in order to render it solid, whilst mellissic acid requires a temperature of 192° for its fusion. This change is gradual: for each increment of C_2H_2 the boiling temperature of the homologous acids rises on an average about 36°F. The density of the vapors increases by a similar law. It is thus possible to predict with accuracy the boiling point and density of vapors in members of the series which have not yet been discovered.

Crystalloid and Colloid Forms of Matter.

941. DIFFUSIBILITY OF CRYSTALLOID SUBSTANCES.—We have already seen (Section 763), that most inorganic substances, in passing from the fluid to the solid state, have a tendency to assume definite and regular forms called crystals. It is further to be noticed that when crystalline substances enter into solution in water or

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940. What is said of the progression of properties? 941. What is said of the diffusibility of crystalloid substances?

watery fluids they are rapidly diffused through the mass of water with which they are mingled; but the rapidity of diffusion varies considerably for different substances. When this class of substances are in a state of solution, they pass readily through membranes or porous partitions which water can penetrate. This power of passing in solution through membranes is called osmose, and it differs greatly in amount for different substances, and varies with the nature of the membrane itself. Thus if a bladder is filled with alcohol and immersed in water, the alcohol will pass through the bladder into the water and be mingled with it, at the same time some of the water will pass into the bladder, but more slowly than the alcohol flows out. If, however, the alcohol is confined in a sac made of the lining membrane of the gizzard of a chicken, the water will flow in faster than the alcohol will pass out.

Crystalline substances in a state of solution are held by the solvent with a certain degree of force which diminishes the volatility of the fluid. The solution is generally free from viscosity and is always sapid. The chemical reactions of such substances are energetic and quickly effected.

942. Colloid Substances.—In the organic kingdom we find many substances of a gelatinous form, which have little if any tendency to crystallize, and which on being separated from water assume a vitreous structure. These substances, which may be typified by animal gelatine, have received the name of *colloids*. While

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942. What are the properties of colloid substances?

the crystalline form is the more common among inorganic bodies, the colloid is the more common form of organic matter; yet some organic bodies have the crystalline and some inorganic bodies the colloid form. The planes and angles of the crystal, with its hardness and brittleness, are replaced in the colloid by rounded outlines with more or less softness and toughness of texture. Water of crystallization is represented by water of gelatination. Colloids are held in solution by a feeble power, and they have little effect on the volatility of the solvent. The solution of colloids has always a certain degree of viscosity or gumminess when concentrated. They appear to be insipid, or wholly tasteless, unless when they undergo decomposition upon the palate and give rise to sapid crystalloids. Their solid hydrates are gelatinous bodies. They are united to water with a force of low intensity; and such is the character of the combinations in general between a colloid and a crystalloid, even although the latter may be a powerful reagent in its own class, such as an acid or an alkali. In their chemical reactions, the crystalloidal appears as the energetic form and the colloidal the inert form of matter. Among the colloids rank hydrated silicic acid (§ 508) and a number of soluble hydrated metallic peroxides, of which little has hitherto been known; also starch, the vegetable gums, dextrin, tannin, albumen, and vegetable and animal extractive matters.

943. Colloids the Basis of Organization.—The

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943. How are colloids related to organization?

peculiar structure and chemical indifference of colloids appear to adapt them to act as the basis of organic bodies of which they become the plastic elements. Although chemically inert in the ordinary sense, colloids possess a comparative activity of their own arising out of their physical properties. The rigidity of the crystalline structure shuts out external impressions, but the softness of the gelatinous colloid partakes of fluidity, and enables the colloid to become a medium for liquid diffusion, like water itself. The same penetrability appears to take the form of a capacity for cementation in such colloids as can exist at a high temperature. Hence a wide sensibility of colloids to external agents. Another eminent characteristic of colloids is their mutability. Their existence is a continued metastasis. A colloid may be compared in this respect to water while existing liquid at a temperature below its freezing point, or to a supersaturated saline solution. The solution of the hydrated silicic acid, for instance, is easily obtained in a state of purity, (§ 508), but cannot be preserved. It may remain fluid for days or weeks in a sealed tube, but it is sure to gelatinize at last. Nor does the change appear to stop at that point; for the mineral forms of silicic acid deposited from water, such as flint, are found to have passed, during the geological ages of their existence from the vitreous or colloidal into the crystalline condition. The colloidal is in fact a dynamical form of matter; the crystalloidal being a statical condition. The colloidal form of matter may be looked upon as the probable primary source of the force appearing in the phenomena of vitality.

944. SEPARATION OF COLLOID AND CRYSTALLOID SUBSTANCES.—The unequal diffusion and transfusibility of colloid and crystalloid substances affords the ready method of separating them from each other. An instrument called a dializer is employed for this purpose, consisting of a hoop of gutta percha, or other firm material, over which is stretched a diaphragm of animal membrane, a film of gelatinous starch, hydrated gelatin, albumen, or, what is better than anything else, paper metamorphosed by sulphuric acid, known as *vegetable parchment*, (§ 959). The dializer when thus constructed looks like a small sieve. Place in the dializer a mixed solution of gum and sugar to the depth of half an inch and float the instrument upon a considerable quantity of water in a basin. In twenty-four hours three-fourths of the sugar will pass through the septum into the water, so free from gum as to be scarcely affected by subacetate of lead, and to crystallize on evaporation of the external water by the heat of a water-bath. Many interesting applications of this principle are made in chemical analysis, especially where organic substances are concerned. Defibrinated blood, milk and other organic fluids mixed with arsenious acid are retained in the dializer while the greater part of the arsenious acid passes out into the water almost entirely free from organic matter. This principle enables us to understand why animal and vegetable juices are re-

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944. How may colloid and crystalloid substances be separated ?

tained in their own proper tissues while nutrient fluids are absorbed and pass into the circulation.

945. Explanation.—In all these cases the septum of the dializer is a colloid substance softened with water so united with it as to form a hydrate. The crystalloid substance readily diffuses into the combined water of the colloid septum, and is taken away by the free water on the other side; but the colloid substance in the dializer has but a very feeble power of uniting with the combined water of the septum, and hence it is almost wholly retained in the dializer.

Note.—We are indebted to Prof. Graham (*Chemical News, London*, 1861,) for this view of the comparative properties of crystalloid and colloid substances.

CHAPTER II.

VEGETABLE CHEMISTRY.

946. Germination.—Before the processes of transformation of the materials of the earth and atmosphere into the innumerable products of the vegetable world can commence, a rudimental plant must be developed from the seed. The seed itself contains the materials for its production. These are principally starch, and

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945. How are these phenomena explained? 946. What is said of germination and the changes which attend it?

gluten,* or the other substances analogous to each, which are hereafter described. The first stage in the process is the absorption of moisture and oxygen from the air, and the consequent production of *diastase.*† This substance has the remarkable property of converting starch into sugar, and rendering soluble all of the remaining gluten of the seed. By the appropriation of these materials, which have been stored up for it in the seed, the germ is developed into a perfect plant. It lets down its roots into the soil in search of mineral food, and lifts its leaves into the atmosphere, from which it is to derive its principal nourishment. At this point the true vegetative process commences.

274

947. The Lowest Form of Organization is a Cell.—Just how the plant transforms inert inorganic substances into organized and living structures we shall probably never know. Examinations and inquiries have established the fact that the lowest primary form of organization we can detect is a *cell*, a little spherical or oval sac consisting of an external membrane enclosing fluid, gelatinous or semisolid contents. When many cells are collected together pressure or other causes

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[*] Gluten is the stringy substance which remains on removing the starch from dough by long continued kneading. It is further described in a subsequent paragraph.

[†] Diastase is an oxidized gluten which is always produced from gluten in germination.

947. Describe the vegetable cell.

change the primary form so that they assume angular cylindrical or fusiform outlines corresponding with the positions they occupy or the functions they are to perform. The embryo of the seed from which the plant is developed in germination had in its earliest stages the form of a single cell, Figure 278. From such a simple cell, increasing by enlargement and subdivision, the whole embryo as seen in the seed before germination is produced. The single enlarged cell divides by the formation of a cross partition into two cells, Figure 279, one of them into two more, Figure 280, and the process being continued by the formation of partitions in two directions, Figure 281, a collection of cells is formed all essentially like the first. By a continuation of this process the embryo is completed as it is seen in the seed. The stem, root, and leaves of the plant or tree

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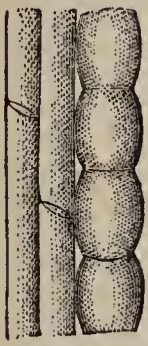

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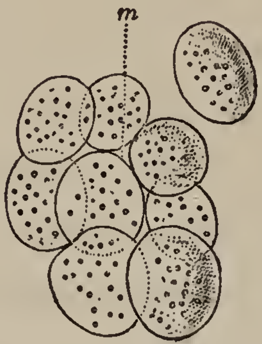

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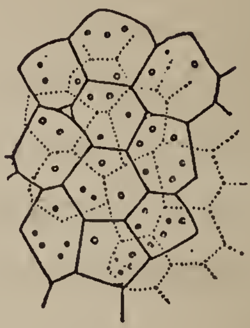

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are made up by the accumulation of a multitude of cells.

948. Vegetable Nutrition.—Every leaf is a net to catch the fertilizing constituents of the air and appropriate them to the uses of the plant. It drinks them in through its countless pores, while the root supplies the remaining material and sends it upward in the rising sap. All of these materials meet in the leaf, which is the laboratory in which their conversion into vegetable matter is to be accomplished. The light and heat of the sun co-operate with the vital forces of the plant in the transformation which succeeds.

949. Whatever proportion of carbonic acid and water may be employed as the raw material, it is obvious, by comparison of their composition with that of vegetable substances, as hereafter given, that the oxygen is furnished in larger quantity than is required. Water alone yields a sufficient supply of this element, and more than enough for most substances that are to be formed. As the process of transformation proceeds, this gas is therefore constantly thrown off into the air. It is the refuse of the manufacture. Inasmuch as the evolution takes place from the leaf and other green parts of the plant, it is reasonable to suppose that this is the point where the process of transformation is principally conducted. The gum, sugar, or other materials produced, are dissolved in the descending sap, and transformed into other products, in the course of their circulation.

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948. What is the office of leaves of plants? 949. What gas is evolved from plants?

950. The agency of the leaves of plants in absorbing and decomposing carbonic acid, may be illustrated by the simple means represented in the figure. A glass funnel being filled with leaves and slightly carbonated water, is exposed to the sun. Oxygen gas is gradually evolved from the absorption and decomposition of the carbonic acid, and collects in the tube of the funnel. The oxygen may be tested by the usual means. The inversion of the funnel without loss of its contents, is easily effected, by covering it with a saucer and turning it in a pail of water.

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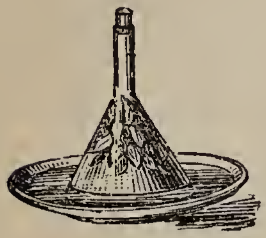

951. For certain transformations of material in plants, the evidence is entirely conclusive. The sugar beet and turnip are sweetest in the earlier stages of their growth. Later in the year they become hard and fibrous. This change is undoubtedly owing to the conversion of the sugar contained in the sap into woody fiber. In the ripening of grain, the sweet and milky juice of the young plant is converted into starch. Both hay and grain which are harvested too late, are deteriorated by the conversion of a portion of their starch and sugar into wood. In the ripening of fruits a portion of their acid is converted into sugar, as is evident from their change of flavor.

952. Office of the Root.—The agency of the roots

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950. How may the evolution of oxygen by leaves be proved by experiment? 951. What transformations occur in plants? 952. How is the action of the roots illustrated by experiment?

in supplying the plant with its mineral food, may be illustrated by the apparatus represented in the figure. In preparation for the experiment, a glass funnel is tightly covered with a piece of bladder, and then filled with a solution of sugar or salt. A tube is then fitted, air tight, to its extremity. A glass vial, from which the bottom has been removed, may be substituted for the funnel in this experiment. On placing the apparatus, thus arranged, in a vessel of water, the latter penetrates the animal membrane, and adds itself to the contents of the funnel. The flow of the water is called *endosmose*, and is made appreciable to the eye by the rise of liquid in the tube. An *exosmose*, or flow of a small portion of the contents of the funnel outward, takes place at the same time.

283

953. Motion of Fluids in Plants.—The delicate cells of which the extremities of rootlets are composed, are filled with water holding in solution gum, sugar, and other organic compounds, most of which are in the colloid state. Hence the soluble salts contained in the hygroscopic water adhering to the rootlets or adjacent soil pass inwards almost as freely as into pure water, and pass in the same manner from cell to cell until they are transformed into the colloid substances required to build up the tissues of the plant. It is a mistake to

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953. How is this principle applied to explain the motion of fluids in plants?

suppose the rootlets of common plants to be flooded with water. In such a condition of the soil most plants would die. In a soil adapted for the healthy growth of plants the particles of soil and the roots of plants are merely moistened with hygroscopic water, which affords soluble salts to the roots but is not adapted to carry away the juices of the plant if they could flow outward. Hence the illustration given above is applicable to the action in the roots of plants only so far as to explain the inward flow, *endosmose*, of materials to nourish the plant. The action above described occurs, more or less, in all the organs of plants through the walls of the minute cells of which they are composed. The transpiration of water from the leaves induces a flow of the sap upwards and the constant organization of materials by the growth of all parts of the plant creates a tendency for the nutrient material to pass to all parts of the plant where it is wanted. The relation of the plant and soil is further considered in a subsequent chapter.

954. CONSTITUENTS OF PLANTS.—Among the more important of vegetable substances, are wood, starch, sugar and gluten. Woody fiber forms the mass of the plant; starch and gluten collect in the seed; while sugar and gum exist principally in the sap and fruit, or exude from the bark.

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954. Mention some of the more important vegetable substances.

Wood.

955. Woody Fiber.—The term *cellulose* or *cellulin* is applied to the substance of woody fiber. It is composed of $C_{12}H_{10}O_{10}$, or $C_{24}H_{20}O_{20}$. The varieties of woody matter differ in color, texture and induration; but when freed from various foreign matters, they leave a white translucent residue. Certain piths, linen, cotton, filtering paper, and some other allied substances, are nearly pure cellulose. It is composed of carbon, hydrogen and oxygen. Its molecule contains twelve atoms of carbon, to ten of hydrogen and ten of oxygen. It constitutes the solid mass of all vegetable organs, whether hard and firm, like the fiber of the oak; soft, like the pulp of fruits; or fibrous, like cotton and flax. In one or the other of its varieties it thus serves us for shelter, clothing and food. It forms in plants the cells in which the vegetable juices are contained, and the veins or pores through which they circulate; and has thence received its name of *cellulose.* In wood, these cells are often lined or filled with a substance of nearly similar composition, to which the name of *lignin* has been given. Other matters passing through the plant are gradually deposited with cellulose in the older cells, so that an analysis of old cells gives results slightly different from young cells from which the formula for cellulose is obtained.

956. Action of Re-agents.—Cellulose is insoluble

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955. Mention different forms of woody fiber—and its composition.
956. What is said of the action of re-agents upon woody fiber?

in water, alcohol, ether and oils. It is acted upon by acids and alkalies, the action differing according to the degree of concentration of the re-agent. A large number of interesting compounds are thus produced, some of which are to be described. Vegetable cellular tissue, in its succulent form, is easily digestible, but when it has become incrusted by true woody matter, it is no longer digestible, or in a condition to serve as nutriment to the higher orders of animals.

957. EFFECT OF SULPHURIC ACID ON WOOD.—Sulphuric acid chars or blackens wood by abstracting a portion of the oxygen and hydrogen which it contains. The carbon is then left in excess, with its characteristic color. This action of sulphuric acid is a consequence of its strong affinity for water, the elements of which it appropriates from most organic substances. When pure cellulose is acted on by the cold acid a magma is formed which becomes blue on the addition of free iodine. If it is much diluted and boiled it is converted first into dextrin and subsequently into glucose. Linen rags may be made to furnish more than their own weight of this latter substance.

958. WOOD CONVERTED INTO SUGAR.—Wood may be converted into sugar, by causing it to combine, chemically, with four additional molecules of water. This addition gives it the precise composition and properties of grape sugar, and, in fact, converts it into that substance. Poplar wood is found best suited for the pur-

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957. What is the effect of sulphuric acid on wood? 958. How may wood be converted into sugar?

pose, and can be made to yield four-fifths its weight. To effect the conversion, the wood is first reduced to saw-dust, then moistened with somewhat more than its own weight of oil of vitriol, and left to stand for twelve hours. Being subsequently pounded in a mortar, the nearly dry material becomes liquid. It is then boiled with addition of water, and the transformation is completed. It only remains to remove the sulphuric acid, and evaporate the syrup. The former object is effected by the addition of chalk and subsequent filtration, and the latter, as usual, by boiling.

959. Vegetable Parchment.—By the action of sulphuric acid upon paper, a useful material known as *vegetable parchment* is obtained. It is prepared by plunging unsized paper for a few moments at a temperature of 60° into a mixture of oil of vitriol with half its bulk of water. The proportions are important; if the acid is weaker, the fiber is converted into gum, if stronger it is corroded. The paper must be quickly withdrawn and washed, first with water, then with a weak solution of ammonia, and lastly with water again. In this process the outer surface of the fibers appear to have become converted into a glutinous substance by which the fibers are cemented together, and the pores filled up. It is now tough, translucent, nearly impermeable to water, takes ink well, forming a useful substitute for ordinary parchment. It is put to some important uses in the arts. It may be substituted for

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959. How is vegetable parchment prepared?

bladder as a septum in electrolytic operations with great advantage.

960. Effect of Nitric Acid.—Nitric acid gradually consumes wood and other organic matter, as effectually as if they were burned by fire. The final products of its action are also the same as those of ordinary combustion. This action is accompanied with the evolution of orange fumes, as when the same acid acts on metals. The first effect of nitric acid is to stain wood yellow; for which purpose it is sometimes employed. By varying the strength and temperature of the acid a variety of compounds are obtained.

961. Pyroxylin or Gun Cotton.—This remarkable substance is prepared by dipping clean carded cotton into a mixture of equal measures of oil of vitriol and nitric acid. Small portions of the cotton are immersed completely in the cooled mixture of the acids, permitted to remain ten or twenty minutes, then withdrawn, the excess of acid pressed out and plunged into a large volume of cold water. The cotton is washed until the last trace of acid disappears, and cautiously dried at a temperature not exceeding 212°. During this operation scarcely a change of form occurs, but a remarkable chemical alteration takes place, and the fiber acquires entirely new properties. A certain number of atoms of hydrogen are abstracted and an equal number of equivalents of peroxide of nitrogen (NO_4) supply their place. It is more harsh and brittle than

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960. What is the effect of nitric acid on wood? 961. How is gun-cotton prepared?

before, and highly electric. It has gained weight and is remarkably combustible. Clean paper, tow, linen, sawdust, and other forms of cellulose yield similar compounds.

962. USE OF PYROXYLIN.—Pyroxylin is not likely, for several reasons, to supersede gunpowder for use in fire-arms. It takes fire at about 400°, which is about 200° below the temperature required for the ignition of gunpowder, and is much more liable to produce accidental explosions. In the open air, when inflamed it flashes off without smoke, smell or residue; within the gun-barrel the extreme suddeness of its explosion produces great strain, and is apt to burst the barrel. Its explosive force depends, like that of gunpowder, on a sudden combustion throughout its whole substance, and consequent evolution of a large volume of mixed gases and vapor. Of these, carbonic acid, nitrogen and aqueous vapor are the principal. In certain cases it may be used to advantage. In mining operations it may be driven into borings above the head of the miner, and on explosion produces less fume. In addition it has the advantage of leaving no train by leakage from the vessels in which it is stored. It may be exposed to damp air and even to prolonged immersion in water without injury if subsequently dried. Weight for weight its explosive force is three or four times that of the best musket powder. Pyroxylic paper is remarkable for the intensity of its electricity when slightly rubbed.

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962. What are the uses of pyroxylin?

963. Collodion.—The solution of pyroxylin in a mixture of alcohol and ether, is known under the name of *collodion.* When this solution is exposed to the air for a few moments in the form of a thin layer, the solvent evaporates, leaving the pyroxylin in a transparent film. Spread over excoriated surfaces an artificial cuticle is produced by which they are protected from the action of the air. For medical purposes the properly prepared cotton is dissolved in a mixture of ninety parts of ether and ten parts of alcohol. Collodion has its most extensive application in the art of photography. Impregnated with the sensitive salt, which is acted upon by light and diffused over a glass plate, it forms a surface admirably fitted for the reception of photographic impressions. Photographic collodion requires for its successful preparation attention to numerous minute precautions which cannot be given in detail here.

964. Effect of Alkalies on Cellulose.—Weak alkaline liquids have but slight action on cellulose, but concentrated solutions of the alkalies hasten the decomposition of organic substances generally when in contact with them. Advantage is taken of this action of the caustic alkalies for the production of materials demanded in the arts, particularly in the formation of oxalic acid. Oxalic acid is an organic acid, found in the juices of plants, but which may be obtained also by artificial means. One of the cheapest and most pro-

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963. What is collodion? For what is it used? 964. What effect do alkalies produce upon cellulose?

ductive processes consists in treating sawdust with a mingled solution of caustic potassa and caustic soda. The mixture is carefully heated at the proper temperature for some hours, in cast iron pans, and the result is a residue containing a large quantity of the mixed oxalates of potassa and soda. From these salts the oxalic acid may be separated and obtained in large crystals. Sawdust by this treatment yields half its weight of oxalic acid.

965. Action of other Re-agents.—A solution of chlorine acts but very slowly upon cellulose. Concentrated hydrochloric acid dissolves cellulose and deposits it on immediate dilution with water. A solution of oxide of copper in ammonia dissolves it in most of its forms, and deposits it, unaltered in composition, on acidulation with an acid.

966. Decay of Woody Fiber.—Wood in a moist state exposed to the air gradually undergoes decomposition. The rapidity of the destructive process depends much upon the texture of the wood, and the quantity and quality of the foreign matters associated with it; some promoting and others retarding decay. Decomposition goes forward most rapidly in the young spongy sap wood, since this admits the air more freely, and contains a proportionally larger amount of albuminous substances than the older portions. A species of fermentation is occasioned by the nitrogenized constituents; oxygen is absorbed, carbonic acid and water is

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965. Mention the action of other reagents. 966. What is said of the decay of woody fiber?

exhaled, and the wood crumbles down into a brownish mould called *humus*, *ulmin* and *gein*, substances rich in carbon, which element has been more slowly consumed than the other constituents. When there has been an abundant supply of moisture, and deficient access of air, the mass has a different composition and a different aspect; water has combined with the wood and it remains white as seen in stumps and the interior of some trees.

967. PREVENTIVES OF DECAY.—When wood is kept dry, or when submerged in water, it is little prone to change. In mummy cases, in the piles of bridges, and in submerged forests, wood has remained for centuries in a good condition. To prevent the action of air and moisture and the attacks of vegetables and insects is a matter of high importance. The tendency of wood to decay may be checked by imbuing it with certain oils, tars, oxides and salts. Alum, sulphate and pyrolignate of iron, sulphate of copper, corrosive sublimate, and chloride of zinc are some of the substances which have been thus applied. Wood, sail cloth, cordage, etc., have been pretty effectually preserved by steeping them for a given time in crude kreasote. By coating wood with a layer of resin, tar, or paint impervious to air and moisture, preservation is to a great extent accomplished. The superficial charring of piles and posts which are to be placed in the earth has been resorted to for a long time as a means of preservation. Railroad ties have

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967. How may the decay of wood be prevented?

been treated in this way. Casks designed to contain water for the use of mariners are charred in the interior. The most effectual method consists in directing a jet of inflammable gas against the structure to be preserved, by which the wood is burned to the required depth.

968. EFFECT OF HEAT UPON WOODY FIBER.—Wood heated with free access of air, takes fire, as every one knows, and is consumed. The greater portion of the mass escapes as carbonic acid and water, while a minute quantity of earthy material, ash, is left. If, however, the wood is shut off from contact with the air and submitted to destructive distillation, a variety of products is the result. There is a re-arrangement of the atoms of the wood itself without the help of oxygen or other elements. Some of the most interesting of these compounds are noticed below.

969. WOOD SPIRIT. ($C_2H_4O_2$).—In destructive distillation the products are gases, liquids, and a solid, carbon or charcoal. The wood is heated in iron retorts, connected with a proper condensing apparatus, and the inflammable gaseous products conducted into the furnace so as to serve as fuel. The liquid which is condensed contains a variety of substances, water forming a large part; among these is wood spirit or amylic alcohol. This when separated is in many respects like the common vinous alcohol, being a limpid, colorless, inflammable liquid, of a penetrating spirituous odor, and a disagreeable burning taste. It may for most purposes

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968. What is the effect of heat upon woody fiber? 969. What is wood spirit?

replace common alcohol, and having great solvent power is of considerable value in the arts.

970. WOOD VINEGAR. ($HO,C_4H_3O_3$).—Wood vinegar, or pyroligneous acid, has the same composition as acetic acid obtained from oxidation of dilute alcohol. It is largely used in dyeing, in the form in which it appears in market; it is colored dark by tarry matters, and has a smoky smell. When separated from impurities it is a clear, colorless liquid, having a sharp pleasant acid taste.

971. KREASOTE.—Kreasote appears to be the principal source of the peculiar odor and preservative qualities of wood smoke. When pure it is a colorless, somewhat oily liquid, of high refractive power, of a penetrating smoky odor, and a burning taste. It is but slightly soluble in water, not readily inflamed, and burns with a smoky flame. It is an irritant poison when undiluted, but when largely diluted, it has been found effectual in checking vomiting, and as an application in tooth-ache for the destruction of the nerve. It is the most powerful antiseptic known. A solution of it containing not more than one part in a hundred, preserves meat from putrefaction. The preservative effect of smoke, as well as of crude pyroligneous acid, is owing to the presence of a small amount of this substance. Kreasote consists of carbon, hydrogen and oxygen, but its exact composition is yet uncertain. The formula $C_{16}H_{10}O_2$ has been assigned to it.

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970. What is wood vinegar? 971. For what is kreasote used?

972. WOOD TAR.—Wood tar is a mixture of various oils and volatile crystalline solids composed principally of carbon and hydrogen. There are several varieties of tar. The kind so largely employed in the arts, as in ship-building, is obtained by subjecting to a rude process of distillation the roots and wood of the resinous pine; another variety of tar results from the destructive distillation of hard wood. *Coal tar* is a product resulting from the destructive distillation of coal. Wood tar is insoluble in water but soluble in alcohol, and is extremely rich in carbon, which gives it in part its black color. Tar from pine wood, when distilled, yields principally impure oil of turpentine, leaving a black resinous mass which constitutes ordinary *pitch*. Tar from hard wood, when distilled, gives a large number of interesting products. One of those, kreasote, has already been described, others are to be noticed.

973. COMPOUNDS OBTAINED FROM WOOD TAR.—*Eupion* is a very light oil of a peculiar greasy character, very inflammable and burns with a bright flame. The formula C_5H_6 has been assigned to it.

Kapnomor is a colorless oil of high boiling point and rather lighter than water. It has an odor of ginger, and a taste at first feeble, but afterwards becoming connected with an insupportable sense of suffocation. Its composition is thought to be $C_{20}H_{11}O_2$.

Picamar is a viscid, colorless, oily liquid, of greater

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972. What substances are contained in wood tar? 973. What valuable compounds are obtained from wood tar?

density than water, having a feeble odor but intensely bitter taste.

Pittacal is a solid compound of deep blue color.

Cedriret is also a solid and may be readily crystallized.

974. PARAFFIN.—Paraffin is perhaps the most interesting substance found among the solid constituents of hard wood tar. It likewise occurs among the products of distillation of peat, and in several mineral tars and some kinds of petroleum. At ordinary temperatures paraffin is a hard white crystalline solid, without taste or odor, and resembling spermaceti both to the touch and appearance. It melts at about 111°, and may be distilled over at a higher heat unchanged. Paraffin is insoluble in water. It burns with a bright smokeless flame; candles made of it burn like those made from the finest wax. It resists the action of acids, alkalies, chlorine and potassium, and it is called *paraffin* (from *parum affinis*) on account of its inertness or want of affinity. It is composed wholly of carbon and hydrogen.

975. SUBSTANCES RESULTING FROM NATURAL CHANGES OF WOODY FIBER.—*Peat.* The vegetable origin of this substance is at once evident on inspection. It is mainly the product of the slow decay of certain species of marsh plants under water. Peat bogs were in the first instance marshes, which have become filled up by the annual growth and decay of surface vegetation. The

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974. What is the appearance and use of paraffin? 975. What other substances are produced from woody fiber.

process of accumulation is comparatively rapid. The different layers vary greatly, those near the surface consisting of the partially decayed stems of mosses and roots, while the deeper layers exhibit little or no traces of vegetable structure, and in some instances are found converted into a true bituminous coal. In some countries it is extensively used as fuel. By distillation it yields many valuable products.

976. Coal and other Combustible Minerals.—Coal and many of its allied products are obviously of vegetable origin; but the circumstances under which they have formed and deposited in their present localities, are not well understood.

Lignite generally retains its woody structure to a considerable extent. It has a brown color, and sometimes resembles indurated peat. When heated it exhales a bituminous odor and burns with a bright flame.

The formation of *bituminous coal* is a consequence of the decay of vast accumulations of vegetable matter which has been buried in the earth during previous ages of its existence. Of this there are many varieties, Cannel, Newcastle and Breckenridge being among the most valuable. Bituminous coal burns with a bright luminous flame, and has a high value as a fuel and a source of illuminating gas. Where bituminous coal has been subjected to great heat, more carbon and hydrogen are expelled, and anthracite coal remains. A similar change takes place when bituminous coal is

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976. What is said of coal, lignite, bituminous coal and coke?

heated by artificial means, the resulting solid mass taking the name of *coke*.

977. Transition from Woody Tissue to Anthracite Coal.—There is no sharp line of demarkation between woody tissue and the hardest anthracite. From the highest to the lowest layer in the peat bog there is a gradual transition, the upper being made up of slightly changed vegetable fiber, the lower passing sometimes into true bituminous coal. Specimens of bituminous coal may be found which have less and less volatile matter, approaching gradually the character of anthracite. If comparison be made of the composition of these different substances, starting with woody tissue, which consists of carbon, hydrogen and oxygen, it will be seen that the proportion of oxygen diminishes rapidly, and that of hydrogen more slowly as it passes towards anthracite, in which form it consists of nearly pure carbon. Besides the carbon however, there are small quantities of oxygen, hydrogen, nitrogen, sulphur, and various mineral matters, constituting the incombustible residue or ash which is chiefly silicious matter with carbonate of lime and oxide of iron.

978. Bitumen, Asphaltum.—Asphaltum, or *mineral pitch*, occurs on the shores of the Dead Sea, in Barbadoes and Trinadad, and in several other localities. In many instances it is the product of the action of an elevated temperature upon vegetable bodies. Pure asphaltum is black or dark brown, has a slight bitumi-

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977. What is said of the transition from woody fiber to anthracite coal? 978. Where is bitumen obtained? How is it used?

nous odor, a resinous fracture; it softens when heated and burns with a smoky flame. Sometimes bitumen forms irregular deposits which impregnate the strata around; sometimes it occurs in regular beds similar to the deposits of true coal. Bitumen, of various degrees of purity and from various sources, is used in combination with chalk, sand, lime, etc., as a material for pavements and cements. The finer kinds of asphaltum are employed in the formation of a species of black varnish or enamel for leather.

979. MINERAL OILS.—Inflammable oily bodies, issuing often in large quantities from fissures in connection with coal strata, and in other localities, have been known from early historical time. There is reason to suppose that they owe their origin to the action of internal heat upon beds of bituminous rock strata. These are called *naphtha* or *petroleum*, according to their character. The term naphtha is given to the thinner and purer varieties of rock oil, the darker and more viscid liquids bear the name of petroleum.

980. NAPHTHA.—The finest specimens of naphtha are obtained at Amiano, in Northern Italy. It occurs also at other places in Italy, in the regions bordering the northwest side of the Caspian Sea and in various other localities. When pure, it is a light, colorless, inflammable and very volatile liquid. It has great solvent powers, dissolving readily caoutchouc, camphor, fatty and resinous bodies generally; and when hot, also

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979. What is said of mineral oils? 980. What is naphtha? How used?

sulphur and phosphorus. The entire absence of oxygen from its composition, adapts it perfectly to the preservation of the metals potassium and sodium in their metallic condition.

981. Petroleum. This term, as stated, is applied to the darker and more viscid rock oils. The oil varies considerably color and in thickness, some being very fluid and comparatively light in color, others quite viscid and nearly black. Its specific gravity is from 0.83 to 0.89. The Burmese petroleum has long been celebrated. The discovery of immense quantities of petroleum in Pennsylvania and other parts of the United States, and in Canada, is of vast economic importance. This occurring just as the ordinary sources of artificial illumination were diminishing, or were cut off, heightened the value of the discovery.

982. Composition, Purification and Use.—The oil consists of carbon and hydrogen, and is a mixture of several oils having different densities and different degrees of volatility. The purification is effected chiefly by distillation and alternate washings with an acid and an alkali. By these different processes the greater part of the color and offensive odor is removed, and the lightest and heaviest oils are separated from those of medium density. These medium oils are those that may be properly used in ordinary illumination. The lighter are too volatile for common lamps, forming as they do with the air a dangerous explosive compound. They replace to a great extent turpentine in the prep-

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981. Where is petroleum obtained? 982. How is petroleum purified?

aration of varnishes and in painting. The heavier oils are of value as lubricators.

983. Distillation of Coal.—When the distillation of bituminous coal is effected in vessels from which the air is excluded, there result many products. A large amount of volatile matter is expelled partly in the form of uncondensible gases, and partly in the form of vapors, which, when reduced to the ordinary temperature of the air, constitute liquids or solids, whilst a large proportion of the materials remains behind in the form of coke. Among the gaseous products, the most important are marsh gas, olefiant gas, hydrogen, carbonic acid, carbonic oxide, sulphuretted hydrogen and ammonia. These gaseous products, after purification, may be used as illuminating gas. The liquid portions contain water and various hydrocarbons which form *coal naphtha*, besides a quantity of viscous matter known as *coal tar*.

984. Coal Oils.—If the heat of the distillation be less than that applied in the manufacture of illuminating gas, a smaller quantity of permanent gaseous matter is formed, and a proportionally larger amount of condensible oils. By the distillation of rich bituminous coals at a comparatively low temperature, the illuminating coal oils at first sold as *kerosene* are produced. They are hydrocarbons, and in most respects correspond to the natural oils described in the section on petroleum.

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983. What is said of the distillation of coal? 984. What is coal oil?

985. Coal Tar and its Derivations.—Coal tar as produced in the gas factories, is a very complex substance; it is always alkaline from the presence of ammonia; it contains aniline and numerous other bases, as well as phenic and acetic acids. When distilled fetid ammoniacal compounds pass over and a light oil, *coal naphtha*, succeeded by small portions of a heavier oil containing a little *paraffin*. In the latter stages of the operation *naphthalin* is abundant in the distillate, and the oil becomes semi-solid as it cools. The black residue in the retort solidifies on cooling and forms a kind of *pitch* or asphaltum, which is used in the preparation of a coarse black varnish. The coal naphtha, like the natural naphtha, is found to be a complex substance giving by careful distillation the following products—1, an oil of alliaceous odor; 2, benzole ($C_{12}H_6$); 3, toluole $C_{14}H_8$); 4, cumole ($C_{18}H_{12}$) and cymole ($C_{20}H_{14}$). The naphtha is therefore a mixture of several definite hydrocarbons, among which *benzole* is the most important.

986. Benzole. ($C_{12}H_6$).—This is a very limpid, colorless liquid, of a peculiar and rather agreeable odor. If exposed to a cold of 32° it solidifies in transparent crystals, grouped like fern leaves, or in masses resembling camphor, which melt at 40°. It is an excellent solvent of caoutchouc and gutta-percha, and on evaporation leaves them with their peculiar physical character unaltered. Benzole dissolves wax, camphor, and fatty

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985. Describe coal tar and its derivatives. 986. What is benzole?

bodies with facility. Its solvent power for fats and oils enables it to be used with advantage for removing grease stains from articles of silk and woolen, and it is sold for this purpose under the name of *benzine*.

987. NITROBENZOLE. ($C_{12}H_5NO_4$). If benzole is added, in small portions at a time, to warm fuming nitric acid, it is dissolved, and on cooling is separated in the form of a yellow oil, which is termed *nitro benzole.* This oil has a very sweet taste and an odor so nearly resembling bitter almonds, that it has nearly superseded the latter in the preparation of perfumery and the scenting of soaps. By adding to nitro benzole a mixture of equal parts of alcohol and hydrochloric acid, and introducing a few fragments of zinc, a volatile artificial base of much interest, *aniline*, is produced.

988. ANILINE. ($C_{12}H_7N$).—This base is a limpid liquid of an agreeable vinous odor, and an aromatic burning taste; is very acrid and poisonous. It combines with acids forming salts, most of which crystallize readily. Aniline may be prepared from various sources and by a variety of reactions, but is chiefly obtained by action of reagents on substances procured from coal tar. It has its chief commercial interest from the fact that it is the source of many of the magnificent colors which have recently appeared. By the action of various oxides and salts upon aniline, a variety of colors are produced. A piece of wood dipped in a solution of any of its salts gradually acquires an intense yellow color.

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987. How is nitro-benzole obtained? 988. What is aniline?

The beautiful purple known as *mauve*, and the rich crimson termed *magenta*, are aniline products. A splendid blue and a variety of other tints have their source in aniline.

989. NAPHTHALIN. ($C_{20}H_8$).—This substance comes over late in the distillation of coal tar. It is a solid at ordinary temperatures, which when pure forms large colorless crystalline plates. It has a faint, peculiar odor, is unctuous to the touch and evaporates slowly at the common temperature of the air. From it many interesting chemical compounds have been prepared.

990. PHENIC ACID. ($HO,C_{12}H_5O$). This substance, also termed *carbolic acid*, is one of the constituents of coal tar. When pure, phenic acid forms long colorless crystals, which melt at 95°, and in the presence of a minute trace of moisture go into solution. When in solution it greatly resembles kreasote, in many particulars, having the smoky odor, burning taste and antiseptic properties of this body; indeed, much of the commercial kreasote consists of phenic or carbolic acid. It is valuable as a disinfectant.

991. PICRIC ACID. ($HO,C_{12}H_2(NO\ )_3O$).—Picric acid, often called *carbazotic acid*, is a solid crystalline body of an intensely bitter taste. It is prepared by the action of nitric acid on a number of substances, among which are aniline and the oil of tar. It and its salts are used for coloring, giving to silk a beautiful yellow color. Its coloring power is so great, that the

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989. Describe napthalin. 990. What is phenic acid? 991. What is picric acid?

aqueous solution may be diluted with several hundred times its bulk of water without losing its yellow color.

But a small portion of the different compounds obtained directly or indirectly from coal tar—a substance not long since regarded as worthless—have been here described. The source of these was originally in the form of vegetable tissue.

Starch.

992. STARCH. ($C_{12}H_{10}O_{10}$).—This, the lowest form of organized vegetable material, is found widely distributed in the vegetable kingdom, being almost universally present in plants of higher organization, accumulating abundantly in the cellular tissue of certain parts of the organism. As usually seen, it is in the form of a white glistening powder, or in columnar masses, which, when pressed between the fingers, emit a peculiar sound, and produce a feeling of elasticity. Under the microscope it is seen to consist of small grains, usually rounded or spheroidal, rarely angular, differing in size and shape according to the character and age of the plant from which it is extracted. It is mostly in the form of starch that the plant stores up elaborated material which is to be used either in its own future growth, or in the propagation of its kind. Man uses this stored material for food, which he finds most abundantly in grains and other seeds, in the tubers of

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992. Where is starch obtained?

the potato plant, in many fruits, and in the pith of certain trees.

993. STARCH GRAINS.—The grains of starch have a size varying from about $\frac{1}{260}$ of an inch to less than $\frac{1}{3000}$ of an inch in diameter. Under the microscope, they generally exhibit a series of concentric rings, which are supposed to have been formed by a deposition of successive layers of starchy matter within an external envelop, and a point, *hilum*, may generally be observed upon some part of the grains, which has been regarded as the spot where they adhered to the cell containing them. Examined by polarized light, potato starch, and some other kinds, present the appearance of a black cross, the centre of which corresponds to the hilum. In wheat starch, this cross is not easily observed. By this characteristic, as well as by the size and shape of the grains, mixtures and adulterations of various starches may be easily detected by the microscope.

994. VARIETIES OF STARCH.—The starch of commerce is usually obtained from potatoes or wheat. A large amount of a fine quality, and extensively used for cooking, is obtained from maize. Rice also furnishes a certain quantity. The grains of rice starch are angular. Other varieties are found to some extent in the market. *Sago* is a starch from the pith of the sago palm, and which is usually granulated. *Tapioca* is the starch of the *jatropha manihot*, which is pressed through a colander and dried, giving granular, irregu-

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993. What are starch grains? 994. What are the varieties of starch?

lar masses. *Arrow root* is the starch of the root of the *maranta arundinacea*, and of one or two other tropical plants.

995. Starch from Potatoes.—Starch is prepared from rasped potatoes by washing them on a seive. The water becomes milky, as it passes through, from the fine starch grains which it carries with it. These are allowed to settle, and being collected and dried, are brought into commerce as potato starch. A cotton-cloth may be substituted for the seive in this experiment.

284

Figure 284 will convey an idea of the appearance of the granules of potato starch magnified 400 diameters.

996. Starch from Wheat.—If wheat flour is moistened with water and exposed to the air, it enters into a putrefaction which destroys, in the course of a few days, the other constituents and leaves the starch unaffected. The residue being then washed and dried, the manufacture is completed.

997. Properties of Starch.—Starch is insoluble in cold water, as its method of preparation would indicate;

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995. How is starch prepared from potatoes? 996. How is starch made from wheat? 997. What are the properties of starch?

but is rapidly disintegrated by hot water. When heated with water, the granules swell, burst, and allow their contents to be mingled with the water, producing a nearly transparent glutinous mass, in which form it is used for stiffening various fabrics and articles of wearing apparel. The swollen appearance which potatoes, rice, and most other vegetables assume when boiled is due to a distention of their starch granules through an absorption of water at the boiling temperature. Starch is insoluble in alcohol and in ether. Iodine may be used as a test for starch, as described under the head of iodides.

385

998. Conversion of Starch into Sugar.—Starch, like woody fiber, may be converted into sugar through the agency of sulphuric acid. A dilute acid containing only $\frac{1}{50}$ of its volume of oil of vitriol, is brought to the boiling point, and the starch then added by degrees while the boiling continues. Long boiling is required to effect a complete conversion. An infusion of brewer's malt has the same effect as the dilute acid. The sulphuric acid is then to be removed, and the syrup concentrated as before described. The sugar in this case also is grape, and not cane sugar. Such sugar is manufactured largely in Europe for adulterating cane sugar. In England its manufacture is prohibited by law.

999. Conversion of Starch into Gum.—By keep-

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998. How is starch converted into sugar? 999. How is starch transformed into gum?

ing the liquid near to the boiling point, without actual boiling, the gum called *dextrine*, is obtained in the above process, instead of sugar. It may also be prepared by roasting starch, carefully, with constant stirring, until it acquires a brownish yellow color. This gum is used largely in calico printing, for thickening colors. It is also used in making the so-called "fig-paste" and certain other kinds of confectionery. The composition of starch and gum is precisely the same.

Gum.

1000. GUM. ($C_{12}H_{10}O_{10}$).—This term is generally applied to designate certain vegetable substances which possess the same elementary composition as starch; they are not organized like starch, nor are they crystallizable like sugar; they either readily dissolve in water or swell up into a viscid mass when moistened; and they are tasteless and insoluble in alcohol and in ether. Gum is found in the juices of most plants, and in some it exists so abundantly that it exudes from the bark of the plant, when wounded, as a viscid liquid which subsequently hardens into globular or tear-like masses. Familiar illustration of this may be noticed on peach and cherry trees. Gum is an essential constituent of the cereals, and of most seeds, and is abundant in many vegetables.

1001. VARIETIES OF GUM.—The most important gums

1000. What is gum? Where found? 1001. What are the varieties of gum?

of commerce are gum-arabic, gum-senegal and gum-tragacanth. Gum-arabic is the product of a species of *acacia*, which grows abundantly in Africa and Arabia; gum-senegal, the product of a similar tree, has its name from Senegal, in Africa, the district from which it was originally exported. These gums are freely soluble in water; the solution yielded by gum-senegal being somewhat thicker than that formed by gum-arabic. The pure gummy substance contained in them may be precipitated from its solution in water by alcohol, and is termed *arabin*. Gum-tragacanth is the product of a shrub found extensively in Asia Minor and Persia, and is composed mainly of a substance termed *bassorin*. It swells very much in water and forms a thick adhesive paste, but can hardly be said to dissolve in it.

1002. ALLIED SUBSTANCES.—Many seeds, such as linseed, quince seed, and certain roots, such as those of the marshmallow, furnish a large quantity of material closely resembling gum-tragacanth. The term *mucilage* is often applied to them.

1003. VEGETABLE JELLY.—This principle, like starch and gum, extensively pervades the vegetable kingdom, being the body which gives to the juice of many succulent fruits and roots the property of gelatinizing. In composition it is allied to gum. Many algæ, fuci, and lichens, abound in a gelatinizing principle, and are extensively used as food.

1002. What substances resemble gum? 1003. What is vegetable jelly?

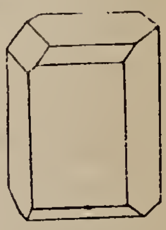
Sugar.

1004. Varieties of Sugar.—Several varieties of sugar are known; chief among vegetable sugars are cane sugar, or sucrose, and grape sugar, or glucose. Milk owes its sweetness to an animal sugar, called milk sugar, or lactose. All these sugars agree in having a sweet taste; in having the atoms of hydrogen and oxygen present in proportion to form water, and in being susceptible of vinous fermentation.

1005. Cane Sugar. ($C_{12}H_{11}O_{11}$).—This, the most important variety of sugar, is chiefly obtained from the sugar cane; but the sugar maple and the beet root furnish a considerable quantity, as well as the date and cocoa-palms. It is contained in carrots and turnips, in the pumpkin, the chestnut, the stalks of maize, the ripe sorghum, and in a large number of tropical fruits; indeed, it is present in small quatities in the sap of most plants, and in all fruits and vegetables which are not acid to the taste.

1006. Cane Sugar differs in its composition from starch, wood and gum, in containing a single additional molecule of water, while grape sugar contains four. It would seem from this composition, that it would be more easily produced by artificial means from starch and similar substances. But this is not the fact. No modification of the process above described, has

286



1004. What are the properties of sugar? 1005. What are the peculiarities of cane sugar? 1006. What is said of cane sugar?

as yet been devised by which starch and wood can be induced to take one additional atom of water, instead of four. Such a process would be a discovery of the greatest importance, as it would enable us to convert our potatoe and grain fields at will into sugar plantations, and make us independent of foreign supplies. The figure represents a crystal of cane sugar. The form belongs to the fourth system.

1007. The general Character of Cane Sugar and its ordinary varieties are well known. It has a specific gravity of about 1.6. It dissolves in one-third its weight of cold water, producing the thick viscid liquid known as syrup. Under favorable circumstances it crystallizes, as shown in figure 286. Ordinary loaf sugar consists of a congeries of minute transparent crystals. When two pieces of loaf sugar are rubbed together in the dark, a pale violet phosphorescent light is emitted. At a temperature of about 320° cane sugar undergoes fusion, and on cooling forms a transparent amber colored solid. If the application of heat to melted sugar be continued, and it be gradually raised to 400°, or a little more, each molecule ($C_{12}H_{11}O_{11}$) of sugar loses two molecules of water, and a brown, nearly tasteless, mass remains, known as *caramel*, ($C_{12}H_9O_9$). If caramel be heated beyond 420°, the compound is entirely decomposed, leaving a porous, brilliant mass of charcoal.

1008. Production.—In manufacturing sugar from

1007. What are the characteristics of cane sugar? 1008. How is cane sugar produced?

the cane, the juice is first pressed out between heavy iron rollers, then clarified, and finally boiled down until it will crystalize on cooling. The granular crystals form the raw sugar; the drainings, molasses. Lime is the principal agent in clarification. Its first effect is to neutralize the acid of the juice, which, as before seen, would gradually convert the cane sugar into grape sugar, and thus injure its quality. It also precipitates, with other impurities, the gluten, which, as will be hereafter seen, tends to produce more acid. The methods of producing sugar from the beet and maple are essentially the same. The final purification of sugar by bone black has already been described.

1009. Molasses.—A large portion of sugar is ordinarily lost in the form of molasses, from which it cannot be made to separate by crystallization. This is owing to the presence of impurities not separated by clarification which interfere with the process in a way not perfectly understood. A method has recently been contrived of avoiding the loss, and thus largely increasing the product of the beet and cane. Baryta added to the syrup combines with the sugar, and takes it to the bottom of the vessel as a solid compound of sugar and baryta, while the impurities remain behind. This precipitate is then removed and diffused in water. Carbonic acid being added, combines with the baryta, and leaves the sugar to form a pure and crystallizable syrup. Another method of increasing the product of

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1009. How may molasses be converted into sugar?

sugar has been described in the section on sulphurous acid.

1010. GRAPE SUGAR. ($C_{12}H_{14}O_{14}$.) This variety of sugar abounds in grapes, figs, plums, and some other fruits; and constitutes the hard, granular, sweet masses found on these fruits in their dried state. As noticed in paragraph 998, it is also obtained by action of reagents on starch; on this account it is termed *starch sugar.* It results too from the natural process of germination in which the starch of the seed under the influence of *diastase*, or decomposing nitrogenous matter, assimilates the elements of four molecules of water. The sweet taste of a sprouting grain of wheat or other cereal, affords a familiar illustration of this change. In France the production of this kind of sugar from starch is extensively carried on as a commercial manufacture. Potato starch and sago are principally used.

1011. GRAPE SUGAR DIFFERS FROM CANE SUGAR, in being less soluble in water and more soluble in alcohol. The former is less valuable than the latter, its sweetening power being as two of grape sugar to five of cane sugar. Sucrose crystallizes easily in prisms, but glucose crystallizes with difficulty in warty concretions composed of hard transparent cubes.

1012. GLUCOSE, OR GRAPE SUGAR, IN THE ANIMAL SYSTEM.—It makes its appearance in excessive quantities in the blood and urine in a disease termed *diabetes.*

1010. What is grape sugar? 1011. How does grape sugar differ from cane sugar? 1012. Under what circumstances is sugar found in the animal system?

It has been shown to be rapidly produced from one of the normal constituents of the liver. It has also been found, that by irritating with a needle the fourth ventricle of the brain of a dog or rabbit, grape sugar is developed in the blood after a few minutes.

Alcohol. ($C_4H_6O_2$).

1013. Source and Properties.—Alcohol is the product of the fermentation of sugar. It is a colorless, volatile, inflammable liquid, burning with a pale bluish flame, having an agreeable well-known spirituous odor, and an acrid burning taste. When pure it has at 60° a specific gravity of 0.7938, boils at 173°; it has never been frozen, though at a temperature of 166° below zero it becomes viscid.

1014. Production from Sugar.—By the addition of brewers' yeast or some similar ferment to sugar, it is gradually converted into alcohol. Two molecules of water are separated in the process. One-third of the carbon and two-thirds of the oxygen which remain, pass off as carbonic acid gas, while alcohol is left. The yeast enters into no combination, and furnishes no material in the process. It acts merely by its presence to effect the decomposition, as will be hereafter explained.

1015. In this process of conversion, each molecule of sugar makes two of alcohol and four of the acid. The

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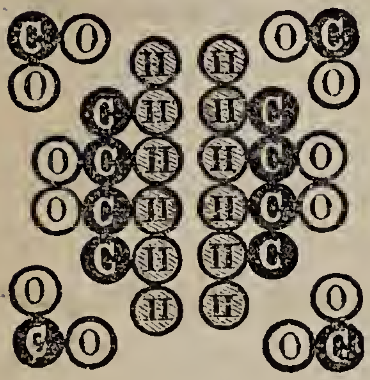
1013. What are the sources of alcohol? 1014. How is alcohol produced from sugar? 1015. Explain the diagram.

figure represents a molecule of grape sugar after the removal of two molecules of water. An arbitrary arrangement is given to the atoms for convenience of illustration. On striking off enough carbon and oxygen from the corners to make the required amount of carbonic acid, the residue may be supposed to fall apart into two molecules of alcohol. Alcohol is also produced from cane sugar by fermentation. The first stage in the process is its conversion, by yeast, into grape sugar. The latter is then changed into alcohol and carbonic acid, as above described.

287



1016. Composition.—The composition of alcohol appears sufficiently from the middle groups of the preceding figure. According to the theory of compound radicals it is a hydrated oxide of ethyl. The principal group of the annexed cut, represents a molecule of the radical; the remaining circles stand for the oxygen and water with which it is combined in alcohol.

288

1017. Production from Potatoes and Grain.—Where molasses or solution of sugar is the material used, alcohol is produced as already shown. But when potatoes and grain are employed as the material, a previous process is necessary by which the starch is

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1016. What is the composition of alcohol? 1017. How is alcohol made from potatoes?

converted into sugar. This consists in the addition of bruised malt to the mashed potatoes or grain. The *diastase* of the malt has the effect of gradually transforming starch into sugar by its presence, as yeast converts sugar into alcohol. The mixture being kept at a temperature of about 140°, in a few hours the transformation is complete. The starchy mixture has become sweet, and receives the name of *wort.* Brewers' yeast and water being then added to the wort, the conversion into alcohol commences. This is afterward separated from the water and refuse fiber of the potato or grain by the process of distillation, described in a subsequent paragraph.

1018. PRODUCTION FROM ILLUMINATING GAS.—Alcohol may also be produced from heavy carburetted hydrogen, one of the constituents of ordinary illuminating gas. This is one of the most remarkable results of modern science. Most of the processes of organic chemistry consist in taking apart the complex molecules of organic matter and reducing them to a simpler form, as was illustrated in the production of alcohol and carbonic acid from sugar. Nature, for the most part, jealously withholds from man the power so to direct her forces as to *build up* and produce more complex organic substances by the combination of those of simpler nature. This takes place as a general rule only under the influence of the vital forces of vegetable and animal existence, as when the plant produces sugar from the elements of the atmosphere.

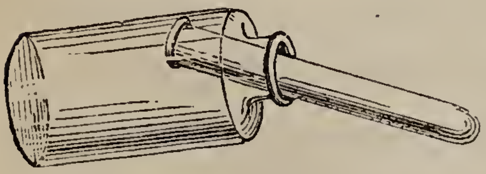
1018. What is said of the production of alcohol from olefiant gas?

1019. By reference to the central group of the figure, which represents a molecule of heavy carburetted hydrogen, it will be seen that all that is necessary to effect its conversion into alcohol, is the addition of two molecules of water. By long agitation of the gas with strong sulphuric acid, the transference of part of the water which it holds combined is effected. On subsequent dilution and distillation, alcohol is obtained from the mixture. Carbonate of potassa is added in the process of distillation, to diminish the proportion of water which would otherwise pass off with the alcohol. After repeated distillation strong alcohol is thus obtained.

289

1020. Distillation of Alcohol.—The process of distillation may be illustrated with the simple apparatus represented in the figure. On heating wine, cider or beer in the test-tube, its alcohol, which is more volatile than the water with which it is mingled, will be expelled as vapor and re-condensed as a colorless liquid. The cooler the vial is kept the more perfect is the condensation. For laboratory operations the most convenient arrangement is a retort and condenser, as exhibited in figure 291.

290



1021. Manufacturing Process.—The apparatus commonly employed in the distillation of alcohol, consists

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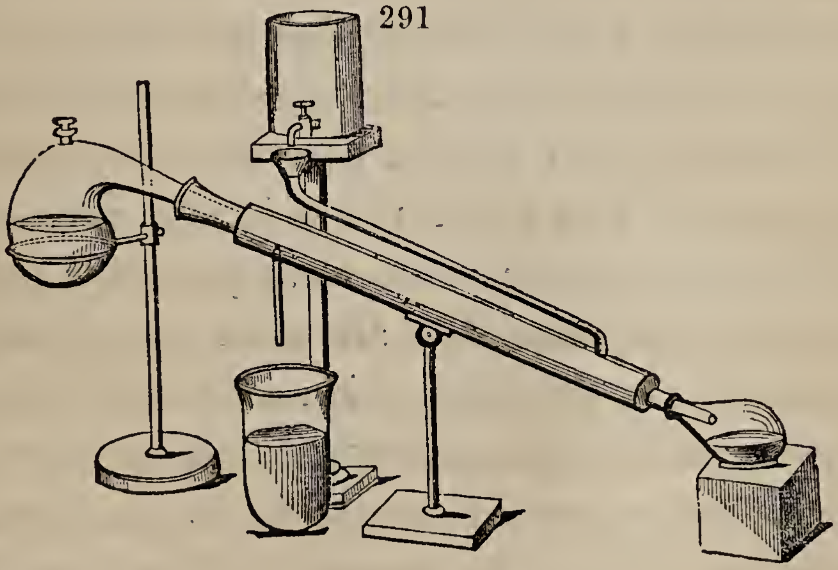
1019. Explain its production. 1020. What is said of the process of distillation? 1021. How is alcohol distilled on a large scale?

of a large copper vessel in which the fermented wort is heated, and a long tube called the *worm*, in which the vapors are condensed. The worm is made to wind in a spiral, through a tub of cold water, that the condensation may be more completely effected. The spirit pours out at the lower end of the worm, where it emerges from the tub. It may be strengthened by repeated distillation. *Liebig's Condensor*, shown in Fig. 291, is used for distillation in the laboratory. In order to obtain it entirely free from water, a highly rectified spirit is mixed with lime, or chloride of calcium, and redistilled. These substances have such affinity for water, that they prevent its escape as vapor, while they in no wise effect the distillation of the alcohol. By this means pure alcohol, or absolute alcohol, is obtained.

291



1022. Uses of Alcohol.—Ordinary spirits of wine is a dilute alcohol containing but about seventy per cent. of absolute alcohol. The strongest alcohol known in

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1022. What is spirits of wine? Mention some uses of alcohol.

commerce contains about 93 per cent. of alcohol and the balance water. Sometimes absolute alcohol is demanded for the chemist's use. Proof spirit is a mixture of equal parts of water and alcohol. The taste and odor of alcohol, its combustible character and action as a stimulus, are well known. It furnishes a cleanly fuel to the chemist and emits during its combustion a high temperature. It is a solvent of great value, dissolving readily resins, essential oils, iodine and a large number of bodies not soluble in water. It is largely used in medicine. Its solvent power renders it valuable in the preparation of medicinal extracts; cologne and other perfumed liquids are produced through its agency.

1023. Spirituous Liquors.—Spirituous liquors contain alcohol in large but varying proportions. They differ in their flavor according to the material from which they are produced. Brandy is distilled from wine, rum from fermented molasses, gin from a mixture of fermented rye and barley with juniper berries, and whiskey from malt liquors. The latter name is also given, in this country, to the liquor made from potatoes, corn, and rye. In Europe, the latter are more commonly called brandies. Some whiskeys which are characterized by a smoky flavor, had this communicated to them in the original manufacture by the smoke in the close apartments where they were prepared. This peculiarity is now conferred by the addition of a minute quantity of kreasote.

1023. What is the source of the different spirituous liquors?

1024. Wines.—Wines are produced by the fermentation of the juice of the grape. On exposure to the air, the gluten of the juice becomes a ferment, and causes the conversion of the sugar into alcohol. The addition of yeast is therefore unnecessary. This is also true of the juice of the apple, pear, and other fruits from which fermented liquors are similarly produced. The different kinds of wine owe their peculiarities chiefly to the variety of grape, the method of manufacture, and the climate in which the grape is grown. The same variety of grape in different climates produces a wine having a different flavor. Even vineyards in the same locality yield wines peculiar to themselves.

1026. Champagne.—Champagne and other sparkling wines owe their peculiarity to the presence of carbonic acid in large proportion. This is secured by allowing the last stages of fermentation to proceed in firmly corked bottles, so that all the gas which is evolved is retained. Or an ordinary wine is first produced by the usual process, and sugar and yeast are then added, to excite a new fermentation in the bottled liquid.

1026. Alcohol in Wines.—Wines differ in the amount of alcohol which they contain; from five per cent., in the weakest champagne, to twenty-five, in the strongest sherry. Those of southern climates are strongest, because the grapes of those regions contain more sugar to undergo conversion into alcohol. Most wines also contain more or less acid and unfermented sugar.

1024. How are wines produced? 1025. How is champagne made? 1026. What is said of the proportion of alcohol in wines?

1027. Flavor of Wines.—The wine flavor which belongs to all wines, is owing to the presence, in extremely small portion, of an ethereal liquid called *œnanthic ether.* This substance does not exist ready formed in the grape, but is produced in the re-arrangement of atoms which takes place in fermentation. Its vinous odor, when separated from the wine, is most intense. It is prepared in Europe from grain spirit or cheap wines, and is used in this and other countries for producing imitations of wines of higher price. Potato whiskey is commonly the basis of these manufactured wines. Beside the general vinous flavor, different wines, like flowers, have an aroma or bouquet peculiar to themselves. These are owing to other and different flavoring substances, present in still smaller proportion than the œnanthic ether.

1028. Tartar.—The improvement which age gives to wine is owing largely, not wholly, to the production of aromatic ethers as stated above. All wines are acid chiefly from the presence of the acid tartrate of potassa. During fermentation the bitartrate of potassa becomes less soluble, by reason of the production of alcohol and the acidity of the wine diminishes while its strength increases. This is deposited in the cask or bottle and is known as crude tartar or argol. It is from this circumstance that grape juice alone is fit for making good wine; when that of gooseberries or currants is used as a substitute, the malic and citric acids which those fruits contain cannot be thus withdrawn. Tartar consists of

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1027. What is said of the flavors of wines? 1028. What acid is found in wine?

acid, tartrate of potassa, with a little tartrate of lime and coloring matter, and is the source of the tartaric acid of commerce.

1029. BEER AND ALE.—Beer is the fermented extract of malted grain. The *malt* is prepared by softening barley in water, and then allowing it to sprout or germinate. Diastase, which is formed in the process of germination, converts the starch of the grain into sugar, and thus prepares it for the subsequent process of fermentation. Yeast and hops are added to the extract of malt, which is called the *wort*, to bring about fermentation and help to give the product flavor. Ale is a similar malt liquor of different color. Porter is a darker variety of beer, made from malt which has been browned by roasting.

1030. The juices of fruits containing sugar, when fermented, produce an alcoholic liquor strong in alcohol in proportion to the sugar present. Cider is from the juice of the apple, perry from the pear; and nearly every fruit may be made to yield its own peculiar liquor. Even savage nations evince a knowledge of this fact. The nations of the islands of the Pacific when first visited, not only knew how to prepare an intoxicating liquor from the juice of the cocoanut but were accustomed to rectify it by a rude process of distillation.

1031. CONVERSION OF ALCOHOL INTO ETHER.—Alcohol is converted into ether by heating with oil of vitriol. To illustrate its preparation, equal volumes of strong

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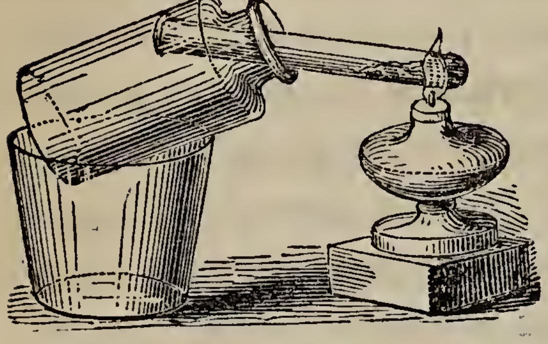
1029. How are malt liquors prepared? 1030. What juices of fruits will produce alcohol? 1031. How is alcohol converted into ether?

alcohol and oil of vitriol may be thoroughly mixed in a test-tube, and the vapors condensed in a cool vial, as represented in the figure. A little sand may be added to the mixture with advantage. The vial should be kept cool by means of paper repeatedly moistened during the process. The space between the tube and the neck of the vial should also be loosely closed with wet paper.

292



1032. Explanation.—Alcohol is, as above stated, the hydrate of the oxide of ethyl. Sulphuric acid combines with the oxide itself, on heating, forming a bisulphate, and at a little higher temperature, yields it up again, as gaseous ether or oxide of ethyl. The change in the alcohol consists, simply, in the loss of an atom of water. The whole figure represents a molecule of alcohol; the lower portion one of ether.

293

1033. Production of Ethyl.—The radical ethyl cannot, like many metals, be directly produced from its oxide. Heat, or other means, applied to accomplish this object, destroys the radical itself. But the end may be reached by a circuitous process.

294

1032. Explain the above re-action. 1031. How is the radical ethyl procured.

This consists in first producing from the oxide, an iodide of ethyl, and then removing the iodine by a metal. A colorless gas, of the composition indicated by the hydrogen and carbon atoms of the figure, is thus evolved.

1034. Conversion of Alcohol into Olefiant Gas.—The production of olefiant gas from alcohol has been described in Section 584. The subject is again introduced for the purpose of illustrating the change, by reference to the atomic composition of the two substances. Representing the atom of alcohol as before, it is converted by the removal of two atoms of oxygen, and two of hydrogen, into olefiant gas. The composition of this gas is indicated by the central group of the annexed figure. The abstraction of oxygen and hydrogen is effected through the agency of the sulphuric acid used in the process. It will be observed that the radical ethyl, which has remained permanent in the changes before described, is here destroyed by the abstraction of a part of its hydrogen.

295

1035. Conversion of Alcohol into Aldehyde.—Aldehyde ($C_4H_4O_2$) is a clear colorless liquid of a peculiar ethereal odor, produced by the action of the air or oxygen on alcohol. It is the product of a partial, slow combustion, or *eremecausis* of the alcohol, and forms the middle point in the conversion of alcohol into vinegar. It is for this reason that it is here introduced.

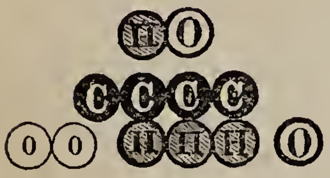
296

1034. How is alcohol converted into olefiant gas? 1035. What is aldehyde?

1036. The two atoms of hydrogen which are burned out in the process, are indicated in the figure by smaller inscribed letters. By the removal, the radical ethyl is converted into the radical acetyl. Aldehyde is therefore a hydrated oxide of acetyl. The characteristic odor of the substance is often perceived in the process for making vinegar. It may also be produced by depressing a wire gauze upon an alcohol flame, and thereby making the combustion incomplete.

1037. Conversion of Alcohol into Vinegar.—If dilute alcohol is exposed to the air, it is converted, by oxidation, into acetic acid. Part of its hydrogen having been burned out to form aldehyde, the oxygen acts further to oxidize the aldehyde which has been produced. The composition of each molecule is such as is represented in the preceding figure. It will be observed that the oxygen added is just sufficient to supply the place of the hydrogen removed in the formation of aldehyde. The latter substance being a hydrate of the protoxide of acetyl, acetic acid is a hydrated teroxide of the same radical. The presence of yeast or some other similar ferment, is essential in the production of vinegar as well as in that of alcohol.

297



1038. Process of Manufacture.—A few years since, vinegar was exclusively produced by the souring of wine or cider. At present, large quantities are made

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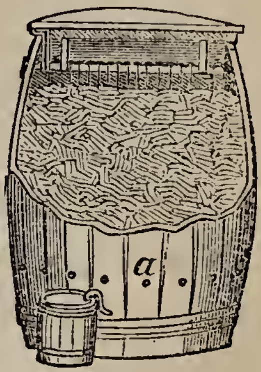
1036. How is alcohol converted into aldehyde? 1037. Explain the conversion of alcohol into vinegar. 1038. Describe the process.

from alcohol, by diluting it with water, adding a little yeast, and then exposing it to the action of the air. This is best accomplished by allowing the diluted alcohol to trickle through shavings packed in well ventilated casks, as shown in figure 298. A few passages through the cask suffice to convert the liquid into vinegar. The addition of yeast is unnecessary in producing vinegar from cider or wine, as these liquids contain a substance which acts as a ferment. The vapor of alcohol may be readily converted into acetic acid by contact with platinum black. The property of platinum to produce oxidation in similar cases has been already explained.

298



1039. Chloroform. (C_2HCl_3).—Chloroform is best obtained by distilling pure alcohol with water and bleaching powder. Its molecule consists of two atoms of carbon, and one of hydrogen, combined with three of chlorine. The carbon and hydrogen atoms are regarded as more intimately combined to form the radical formyl. Chloroform is therefore a terchloride of this radical. It is a colorless and volatile liquid, of a peculiar, sweetish smell. The inhalation of its vapor produces insensibility to pain, and is much employed in surgical operations for this purpose. Ether has the same effect in a less degree. A mixture of the two is more commonly employed in this country.

1039. How is chloroform prepared? Mention its properties.

1040. FUSEL OIL.—Fusel oil is a peculiar kind of alcohol, of extremely nauseous odor and poisonous properties, which accompanies ordinary alcohol in its production from potatoes and grain. It may be separated by filtration through charcoal. But this process of purification is often neglected, and the fusel oil left to add its poison to the deleterious effects of the alcohol itself. It is this doubly poisonous alcohol which forms the basis of numerous manufactured liquors, wines and cordials. Fusel oil is the hydrated oxide of *amyl*, or amylic alcohol. This radical contains ten atoms of carbon to eleven of hydrogen. It is the last of the series of alcohols mentioned in Section 938.

1041. OTHER ALCOHOLS.—As indicated in the last paragraph, the term alcohol is used to designate other bodies than the ordinary vinous alcohol. The greater number of these have too little general interest to be introduced here. Besides the amylic alcohol mentioned above, pyroxylic spirit, or methylic alcohol, is best known.

1042. METHYLIC ALCOHOL. ($C_2H_4O_2$).—This alcohol is found among the products obtained by the destructive distillation of wood at a high temperature. It has many of the properties of ordinary alcohol, and in mechanical and manufacturing processes it may be substituted for it. In Great Britain it is largely used with the ordinary alcohol for the same manufacturing pur-

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1040. What is fusel oil? Mention its properties. 1041. What is said of other alcohols? 1042. How is methylic alcohol obtained, and how is it used?

poses. It is wholly unfit for use as a stimulating drink. *Pyroxylic spirit* is the hydrated oxide of methyl.

1043. Ethers.—In chemistry the term ether has a wide signification. When unqualified by any other term it is understood to have reference to compounds described in a preceding paragraph as the oxide of ethyl. All the alcohols are made up on the same plan and are generally described as the hydrated oxide of some particular radicle. Each oxide of a radicle is an ether, so there are as many ethers of this kind as there are different alcohols. And acids combine with these ethers forming compound ethers, so that the number of ethers becomes immense. A few of the most interesting of these compounds will be noticed under the subject of artificial essences.

Organic Acids.

1044. A large number of acids of organic origin are known. About two hundred distinct acid compounds, products of the vegetable kingdom, have already been obtained. They are mostly composed of carbon, hydrogen and oxygen, with the latter element generally in excess. They are for the most part solid and colorless, and many are crystalline. Some exist in the juices of plants and may be separated by simple processes. Tartaric and tannic acids are instances of this class, others are the result of natural decomposition or are the products of art. Acetic and pyroxyllic acids furnish

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1043. What are ethers? 1044. What is said of the number and source of organic acids?

examples in this connection. Others again exist in vegetable structures, and also may be produced by artificial means. Oxalic and benzoic acids are instances of this kind. When existing in plants they are not usually free but are combined with potassa, soda or lime, forming salts with these bases.

1045. ACETIC ACID. ($HO,C_4H_3O_3$).—The production of this acid from alcohol has already been described. It is also a result of the destructive distillation of hard wood. An impure acid from this source, known as *pyroligneous* acid, is largely used in the arts. Ordinary vinegar is a dilute acetic acid. It cannot be concentrated by evaporation, as the acid is volatile as well as the water which dilutes it. To obtain the strong acid recourse is had to the salts of acetic acid from which it is prepared by the method used for nitric and muriatic acids. It mixes with water at low temperatures in all proportions, and is commonly seen in its dissolved state. The pure acid may be obtained as a solid, but is a liquid at ordinary temperatures, and has a powerful and peculiar odor. It is entirely volatile and the vapor combustible.

1046. VINEGAR.—The dilute acetic acid used for domestic purposes varies in quality according to the source whence it is obtained. Cider, wine and beer furnish vinegar by the change which the alcohol they contain undergoes, this alcohol by oxidation becoming acetic acid. Saccharine liquids also produce vinegar by the

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1045. How is acetic acid obtained? 1046. What acid is contained in vinegar?

sugar which they contain being converted into alcohol, and this alcohol ultimately into acetic acid. Common vinegar usually contains from three to five per cent. of acetic acid, with a small amount of nitrogenous and coloring matters. Acetic acid dissolves many organic substances, such as gluten, gelatin, gum, resins, the white of eggs, etc., hence the use of vinegar in moderate quantities promotes digestion.

1047. DETERIORATION OF VINEGAR.—Vinegar often becomes the home of animal and vegetable life. It is apt to be infested with *flies*, (*Musca cellarus*), and by animalcules, commonly termed *eels* (*Vibriones aceti*). These may be destroyed by heating the liquid. When vinegar is exposed to the air it gradually becomes turbid or *mothery*, losing its acidity and depositing a gelatinous *conferva*, the vinegar plant. The vinegar becomes weak as this growth increases, the acetic acid being assimilated by the plant. The popular idea that this gelatinous mass, termed the *mother of vinegar*, promotes the process of change and adds strength to vinegar, is correct only in this, that it holds vinegar like a sponge, and when placed in an alcoholic or saccharine liquid it induces acetous fermentation from the vinegar that is present. A crumb of bread soaked in vinegar would be equally serviceable.

1048. ACETATES.—The salts formed by the union of acetic acid with bases are numerous, and many of them of much importance in the arts. *Acetate of lead* is

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1047. How does vinegar deteriorate? 1048. Mention some of the acetates.

perhaps as well known as any of this class of salts. When oxide of lead is dissolved in excess of acetic acid and the filtered liquid is evaporated, prismatic crystals are obtained having the composition $PbO,C_4H_3O_3+3HO$. This salt is popularly known as *sugar of lead.* A solution of the tribasic acetate ($3PbO,C_4H_3O_3$) is known in pharmacy as *Goulard's Extract of Lead.* It is applied as a cooling lotion to sprains and bruises. *Acetate of Ammonia* has long been used in medicine under the name of *Spirit of Mindererus. Acetate of Potassa,* a very deliquescent salt is of great value in medicine. *Acetate of Soda* is largely manufactured as a source of acetic acid. *Acetates of Alumina* are extensively used as mordants by calico printers. *Peracetate of Iron* is used by dyers and calico printers. *Acetates of Copper* are valuable as pigments and constitute the varieties of *verdigris.*

1049. OXALIC ACID. (HO,C_2O_3).—This acid, one of the earliest isolated by chemists, is found ready formed in the juice of the varieties of sorrel and rhubarb, in several other plants and in some fruits; in these it is generally combined with potassa or lime. Certain lichens, growing upon calcareous rocks, contain half their weight of oxalate of lime. In combination with iron, it is found as a mineral. It is also produced by the action of reagents on a variety of organic matter.

1050. CHARACTER AND USES.—The ordinary crystals of oxalic acid (HO,C_2O_3+2HO) are transparent, four sided prisms, not unlike epsom salt in appearance, for

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1049. How is oxalic acid found? 1050. For what is it used?

which it is sometimes mistaken. They are intensely sour, dissolve readily in cold water, and more largely in hot water. Unlike other vegetable acids, oxalic acid is a powerful poison; a dose of it having destroyed life in ten minutes. The antidote is chalk or magnesia suspended in water. The crystals, when heated, volatilize without combustion and without leaving any carbonaceous residue. It is extensively employed in calico printing and dyeing, and to some extent in bleaching and cleansing straw goods. In chemical analysis it is used as a test for detecting the presence of lime.

1051. ARTIFICIAL PRODUCTION.—The natural sources of oxalic acid do not supply the demand and recourse is had to its artificial production. Its formation from woody fiber was noticed in Paragraph 964. One manufacturing establishment in Manchester, England, produces nine tons of oxalic acid weekly from sawdust. Oxalic acid is manufactured in large quantities for commerce by the action of nitric acid on sugar, starch and dextrin. Instead of adding the nitric acid directly to the sugar or other organic compound, a mixture of saltpeter and oil of vitriol is used, and the nitric acid is evolved from the saltpeter by the action of the sulphuric acid during the process of manufacture. The result is the production of oxalic acid and sulphate of potassa. These may be readily separated.

1052. OXALATES. *Oxalate of Ammonia* is a valuable reagent in chemical analysis, being used much more

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1051. How is oxalic acid manufactured? 1052. Mention some of the oxalates.

frequently than oxalic acid itself in the detection and separation of lime. *Oxalates of Potassa* are common salts. The binoxalate, known as the *salt of sorrel*, is obtained from the juice of wood-sorrel to which it gives its sour taste. It is sometimes used for the removal of ink-stains and iron-rust from linen. *Oxalate of Lime* is the white solid formed whenever a solution of oxalic acid or an oxalate is added to a soluble salt of lime. It exists also in many plants and often accumulates in the cells and occasionally floats in the juices in the form of minute crystals, known as *raphides*. This salt exists occasionally in the human urine and forms stony concretions, called *mulberry calculi*. The other salts of oxalic acid are not of general interest.

1053. TARTARIC ACID. ($2HO,C_8H_4O_{10}$).—This acid is found free, but more frequently in combination in many vegetables. It is the acid of the tamarind, the pine apple and several other fruits, but exists most abundantly in the juice of the grape, which is its principal source. It exists here as the acid or bitartrate of potassa. It is occasionally met with in combination with lime, forming the tartrate of lime. It may be separated from its combinations and obtained as a colorless solid.

1054. CHARACTER AND USES.—Tartaric acid forms translucent or transparent crystals, often of a large size, which are very sour. When highly heated the acid fuses and burns, evolving a peculiar odor and leaving a slight residue of carbon. Mixed with bicarbonate of

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1053. How is tartaric acid obtained? **1054.** For what is tartaric acid used?

soda, tartaric acid forms a compound used as an effervescing draught. It is used to some extent in domestic cooking. But by far the greatest application is in calico printing, for which purpose large quantities are consumed. In the laboratory it is used as a test for potassa and to prevent the precipitation of certain oxides. It is also used in the separation of the newly discovered metals cæsium and rubidium.

1055. Tartrates.—There is a large number of salts of tartaric acid, most of which may be obtained in a crystalline condition. The most common of these are those used in medicine. *Tartrate of potassa* ($2KO,C_8H_4O_{10}$) is an artificial crystalline salt, readily soluble in water and has a saline and bitter taste. *Bitartrate of potassa* or *acid tartrate* is the salt that exists in the juice of the grape. On fermentation of the juice it is deposited in the wine casks as a white or red crystalline incrustation, called *argol* or *crude tartar*. Pipe-clay added in small proportion to the solution of the crude tartar in boiling water absorbs the coloring matter and takes it to the bottom as a sediment. The purified crystals afterwards appear upon the surface of the liquor, and upon the sides and bottom of the boiler, which are popularly known as *cream of tartar*, a term which was originally applied to the partially crystallized surface mass. *Tartrate of potassa and soda* ($KO,NaO,C_8H_4O_{10} + 8HO$) is known under the name of *Rochelle salts*. *Tartrate of potassa and antimony* ($KO,SbO_3,C_8H_4O_{10} +$

1055. Mention some of the tartrates and their uses.

HO) is the *tartar emetic* or *tartarized antimony* of pharmacy.

1056. Citric Acid. ($3HO,C_{12}H_5O_{11}$).—This acid is found abundantly in the juice of lemons and limes, from which it is prepared for commerce. It exists also in many other fruits, as the orange and cranberry, and in connection with another acid, malic, in our small fruits, as the currant, gooseberry, etc. Citric acid forms colorless, prismatic crystals, which have an agreeably acid taste, and are very readily soluble in water. Citric acid is used in the preparation of acid drinks and in pharmacy as a substitute for lemon-juice. Like tartaric acid it is used in calico-printing. The citrates of potassa, soda, ammonia, iron and magnesia, are of value in medicine.

1057. Malic Acid. ($2HO,C_8H_4O_8$),—This acid was first obtained from the juice of the apple, but is now known to be extensively diffused through the vegetable kingdom. It is present in most acidulous fruits, and is often accompanied by citric acid. It is now chiefly extracted from the unripe berries of the mountain ash. Malic acid is obtained in crystals with difficulty and when in solution, unless quite pure, is liable to undergo decomposition.

1058. Tannic Acid. ($C_{54}H_{22}O_{34}$).—Tannin, or tannic acid, exists in nut-galls and in the bark and leaves of many trees. It is the principle which imparts to them

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1056. Where is citric acid found? For what is it used? 1057. Where is malic acid procured? 1058. Mention the source and properties of tannic acid.

their astringent taste, and gives to the tan liquor the property of converting hides into leather. When separated from the other substances with which it is combined in nature, it is a yellowish, gummy mass. It is soluble in water, and possesses the property of precipitating glue or gelatin, and many metallic oxides.

1059. Writing Ink.—Common writing ink is prepared from nut-galls and proto-sulphate of iron. When first made, it is principally a tannate of the protoxide of iron, and forms a very pale solution. Before it is fit for use, it must be exposed for a time to the air, and thereby converted, partially, into tannate of the peroxide. This is a bluish black precipitate, and imparts to it the requisite color. It is essential to the permanence of ink, that the change should take place, in part, in the fiber of the paper itself. Too long exposure should, therefore, be avoided in the manufacture. The pale ink thus produced, which blackens further in using, is much more permanent than a thicker, darker ink, produced when this caution is not observed.

299

1060. Six parts of nut-galls to four of copperas, are found to be the best proportions for producing a permanent ink. The galls are to be boiled with water, the decoction strained, and mixed with copperas solution. Gum and cloves are added, the former to keep the coloring matter of the ink from settling, and the latter to prevent its moulding. After a ripening of a month or

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1059. What is the coloring matter of writing ink? 1060. Give the process of its preparation.

more the liquid is strained. The coloring matter of ink is immediately produced in a solution of copperas, as a bulky precipitate, by the addition of tincture of galls and a little nitric acid.

1061. GALLIC ACID. ($C_{14}H_6O_{10}$).—This acid is found in small quantities in connection with tannic acid in nut-galls, in sumach, and in a large number of astringent vegetables. It may be obtained from tannic acid; this latter acid, when dry, remains unchanged, but when moist, or in solution, it absorbs oxygen and passes into gallic acid. Gallic acid is white and crystalline, soluble in water and alcohol. Like tannic acid, when heated in the air, it melts and burns like a resin. With the salts of the peroxide of iron it produces a blue-black precipitate; it does not precipitate gelatin.

1062. PYROGALLIC ACID. ($C_{12}H_6O_6$).—This substance is manufactured in large quantities for the purposes of photography. It is obtained by sublimation of gallic acid which, when at a temperature between 410° and 420°, is volatilized and converted into carbonic and pyrogallic acids. The pyrogallic acid thus produced forms brilliant crystalline plates, is freely soluble, very feebly acid, and of an astringent, bitter taste. An alkaline solution of this acid absorbs oxygen gas very readily, and is used in chemical analysis for the purpose of determining the amount of oxygen in a mixture of gases where this element is present. But its most extensive application is in photographic operations, for the pur-

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1061. What are the properties of gallic acid? **1062.** How is pyrogallic acid obtained? For what purpose is it used?

pose of developing the latent image upon the collodion film containing the silver salt, after it has been exposed to the action of light.

1063. Cyanogen. (NC_2 or Cy).—Before proceeding with the description of hydrocyanic, or prussic acid, the production of cyanogen, which enters into its composition, will be briefly considered. Cyanogen is a colorless gas, with a peculiar odor resembling that of peach pits. It is nearly twice as heavy as atmospheric air. It burns with a beautiful purple flame. Cyanogen is a compound radical, possessed of important analogies to chlorine and the other electro-negative elements. Its molecule contains one atom of nitrogen and two of carbon.

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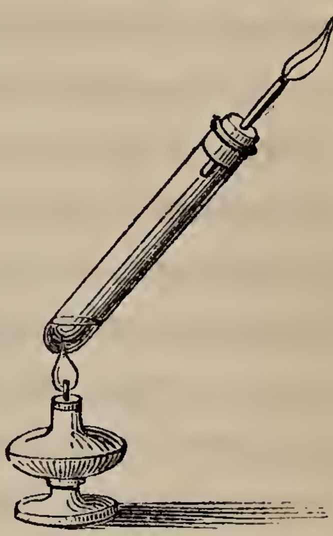

1064. Production.—Cyanogen may be expelled from the cyanide of mercury by the agency of heat. This metal retains cyanogen as it does oxygen, but feebly. A method more commonly employed is to produce and decompose the cyanide of mercury at the same moment. This is effected by mixing chloride of mercury; to furnish the metal, with the double cyanide of iron and potassium, which furnishes the cyanogen. The other elements unite to form chlorides of iron and potassium, while the cyanide of mercury is decomposed as fast as

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1063. Mention the composition and properties of cyanogen. 1064. How is cyanogen prepared?

it is formed. The double cyanide of iron and potassium, above referred to, is the commercial *yellow prussiate of potash.* Two parts of this salt are to be heated with one of chloride of mercury, in the above process. The prussiate cannot be used alone for the production of cyanogen, on account of the firm retention of this radical by the highly electro-positive metals which enter into the composition of the salt.

1065. Cyanide of Potassium. (KCy).—Cyanide of potassium is a white substance, resembling porcelain in appearance, and quite soluble in water and alcohol. It is largely employed in preparing solutions of the precious metals, for galvanic gilding and silvering. It is produced on a large scale, by fusing together carbonate of potash and refuse animal matter. The latter furnishes the carbon and nitrogen required for the production of cyanogen, while the carbonic acid and oxygen of the salt, are principally evolved as oxide of carbon. The cyanide of potassium is best extracted from this residue by alcohol, which leaves the other material undissolved.

1066. Prussiate of Potash. ($K_2FeCy_3=K_2Fcy$).—Cyanide of iron is always incidentally formed from the iron of the vessel in the above process. If water is added to the fused mass, both cyanides dissolve; although the latter, when alone, is entirely insoluble. From the solution, the double cyanide of potassium and iron, mentioned in a preceding paragraph, is ob-

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1065. How is cyanide of potassium prepared? Mention its uses.
1066. How is yellow prussiate of potash prepared? Mention its uses.

tained, by evaporation, in splendid yellow crystals. It is known in commerce as yellow prussiate of potash, and is largely used in the arts for the production of *prussian blue* (Fe_4Fcy_3), and cyanide of potassium. Prussian blue is obtained by adding its solution to a salt of the peroxide of iron. As any solution of iron is readily peroxydized by the addition of a little nitric acid, the yellow prussiate may be employed as a test for this metal.

1067. FERROCYANIDES.—The yellow prussiate of potash, produced as above described, is not properly a double cyanide of iron and potassium. There is reason to believe that the cyanogen is more intimately combined with the iron than such a name would imply. It seems to have lost its ordinary properties in the compound. Neither the alkalies or sulphide of ammonium, which usually precipitate iron from its solutions, have any power to precipitate it from this salt. The three molecules of cyanogen, which enter into its composition, seem to have hidden and absorbed it. They have formed with it, indeed, a new compound radical, called *ferrocyanogen*, ($FeCy_3 = Fcy$). The double salt above mentioned is therefore more properly a ferrocyanide of potassium. Ferrocyanogen, like all other compound radicals, conducts itself, under ordinary circumstances, as an elementary substance.

1068. FERRICYANOGEN.—On the removal of one atom of potassium from two molecules of the prussiate of

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1067. What is said of ferrocyanogen? 1068. What is ferricyanogen?

potash, a coalescence of the ferrocyanogen of the two molecules seems to be the result, and a new compound radical is formed. This radical is called *ferricyanogen*, ($Fe_2Cy_6=Fdcy$). It combines with the three remaining atoms of potassium, to form ferricyanide of potassium, (K_3Fdcy).

1069. Prussic Acid. (HCy).—Hydrocyanic acid is made from cyanide of potassium, by the same method employed for producing hydrochloric acid from common salt. The ferrocyanide of potassium is more commonly employed in the process. Prussic acid is intensely poisonous. A drop or two of the concentrated liquid, placed upon the tongue of a dog, produces immediate death. On account of its extremely dangerous properties, the preparation of the acid should never be attempted except by a professional chemist. The odor of the acid is somewhat similar to that of cyanogen, and may be frequently detected in the vicinity of establishments where galvanic gilding is conducted. Ferrocyanogen and ferricyanogen, like simple cyanogen, have their hydrogen acids and series of salts. The acid of the former is bibasic, and that of the latter tribasic, as already shown by the composition of their potassium compounds

Organic Bases.

1070. Alkaloids.—Morphine and strychnine, the former a useful medicine, and the latter, the most dread-

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1069. Give the properties of prussic acid and its mode of preparation.
1070. Give the names of some of the alkaloids. Why are they so called?

ful of poisons, are examples of the alkaloids. They are white crystalline bodies but slightly soluble in water. Most of them contain the four organic elements, and they possess a positive chemical character of great activity. They are called alkaloids from their resemblance, in certain properties, to the alkalies of inorganic chemistry. Their action upon vegetable colors is the same; like the alkalies, they also form salts with both organic and inorganic acids. They are, in fact, true alkalies. Their alkaline property does not, however, seem to depend on the oxygen which they contain. Some of them, indeed, do not contain this element. It is highly probable that certain of the alkaloids belong to the class of compound ammonias mentioned in the first Chapter of Organic Chemistry.

1071. Their action on the human body does not depend upon their alkaline character, but on the other and peculiar properties belonging to each. The salts of the alkaloids are generally preferred in medicine, in view of their ready solubility. In large doses they are all poisonous. The tincture of nut-galls is employed as an antidote, because of the property of the tannic acid which it contains, to form with most of the alkaloids insoluble precipitates.

1072. OCCURRENCE.—*Morphine* is contained in opium, *quinine* is extracted from Peruvian bark, and *strychnine* from the *nux vomica.* The latter is also the poison of the celebrated *upas.* *Theine* and *nicotine* are other

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1071. What is their action on the human body? Their antidote?
1072. What is the source of the alkaloids?

alkaloids, the former of which is found in tea and coffee, and the latter in tobacco. Theine may be obtained, as a sublimate of silky crystals, by moderately heating tea in an iron pot covered with a paper cone.

1073. Preparation.—Most of the alkaloids may be extracted from the material which contains them by means of acidulated water. A salt of the alkaloid is thus obtained in solution. From this salt the alkaloid may be precipitated, like oxide of iron or any other base, by ammonia. Nicotine is a most energetic poison, falling scarcely below prussic acid in its destructive properties.

Essential Oils and Resins.

1074. Volatile or Essential Oils.—Oils of turpentine and lemon, and otto of roses, are examples of essential oils. They are almost as various as plants themselves, and may be regarded as the odorous principle of plants. They are mostly characterized by a strong aromatic odor and a pungent burning taste. Dropped on paper they give a stain, but this disappears after a little time; they volatilize, hence the distinctive name *volatile* oils. They dissolve in alcohol, forming a class of substances known as *essences*, whence comes the name *essential* oils. They have not the greasy feel of fatty oils, nor do they form soaps with alkalies. By oxidation they are converted into resins.

1073. How are the alkaloids extracted? 1074. What are the properties of essential oils?

1075. Occurrence.—The essential oil is not generally diffused uniformly through the plant, but is found most largely in some particular part. The rose, violet, and a large number of plants, yield an essential oil from the petals of the flower; mint and thyme from the leaves and stalk; cedar and pine from the wood; vanilla and caraway from the seed; cinnamon from the bark; and ginger from the root. Sometimes different oils are found in different parts of the same plant; thus with regard to the orange tree, the leaves, flower and fruit each yield a distinct oil.

1076. Preparation.—The oil is generally obtained by distilling portions of the plant with water. The volatile oil passes over with the steam and floats upon the condensed liquid in the receiver. Oil of turpentine is thus made from the common turpentine or pitch, as it is sometimes called, which exudes from the pine; ordinary *rosin* remains behind. In some cases the oil is pressed from the part of the plant containing it, as from orange and lemon peel. The delicate perfume of violets and other flowers which contain but a small portion of essential oils is extracted by mingling the flowers with lard. This substance has the property of absorbing the oil and yielding it again by distillation or solution in alcohol. In a few cases the oil is not found ready formed in the plant but is generated by the action of water upon peculiar principles, as in the production of oil of bitter almonds. There are a few instances of artificial production.

1075. Where do they occur? 1076. How are they procured?

1077. Uses of the Essential Oils.—The essential oils are extensively used for many purposes; some in the manufacture of paints and varnishes, some for burning in lamps, some in medicine, and others in perfumery. Essences, perfumes, and cordials are solutions of certain of these oils in alcohol, with the addition in the case of cordials of a portion of sugar. In the preparation of perfumery, a single oil is rarely used by itself; a better result is obtained by skillful admixture of many.

1078. Composition.—The oils generally contain two proximate principles, one a solid, *stearopten*, the other a liquid, *elaiopten;* at common temperatures the latter holds the former in solution, but if cooled slowly the stearopten, which is a species of camphor, is usually deposited. Many of the essential oils are composed wholly of carbon and hydrogen, others contain oxygen in addition to these elements, and others sulphur.

1079. Oils composed of Carbon and Hydrogen.—This division includes many of the most common and most valuable of the essential oils. They have for the most part an identical chemical composition, which is expressed by the formula $C_{20}H_{16}$. The oils of orange, lemon, turpentine, pepper, juniper, parsley, citron, burgamot, caraway and others, however widely they differ in properties, have the same elementary composition and are isomeric. The oil of turpentine may stand as the representation of this class. It has a specific gravity of 0.864, boils at 320, is but slightly soluble in water,

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1077. What are the uses of essential oils? 1078. What is their composition? 1079. What is said of the composition of essential oils?

is readily soluble in alcohol, ether and the fixed oils. It has great solvent power, dissolving sulphur, phosphorus, caoutchouc, etc., readily. It is extensively employed as a solvent of resins in the manufacture of varnishes. Under the name of *camphene* it was formerly largely used as a source of light, but has been mostly superseded by the mineral oils.

1080. BURNING FLUID.—"Burning fluid," so called, is a solution of camphene or rectified turpentine in alcohol. The sole object of the camphene is to increase the proportion of carbon, and thus render the flame more luminous. Unmixed camphene may also be burned in lamps provided with tall chimneys. The effect of the chimney is to make a strong draft, and thus provide a liberal supply of oxygen in proportion to the large amount of carbon which the liquid contains. Without this provision, camphene burns like camphor, with much smoke, depositing a large part of its carbon in the form of soot or lamp-black.

1081. BURNING FLUID, "EXPLOSIVE."—The mixture of alcohol and camphene, known as burning fluid, is commonly spoken of as explosive. That this is not the fact, may be readily shown by pouring a little in a saucer and inflaming it. It burns, under these circumstances, as quietly as from the wick of a lamp. But if a can, containing burning fluid, be shaken up and then emptied of its liquid contents, it is found to contain an explosive atmosphere. To prove this, it may be tightly corked

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1080. What is the composition of "burning fluid?" 1081. What is said of the explosibility of "burning fluid?"

and fired through a small hole punched in the side. On applying a lighted taper to the opening, the can explodes with a loud report, and is torn to pieces by the force of the escaping gases. The small proportion of fluid remaining in the can, after every drop that can be poured out is removed, is sufficient to produce this effect.

1082. Explanation.—The principle of the explosion is precisely the same as that involved in the same experiment with hydrogen and air. The only variation consists in the substitution of the combustible vapor of alcohol and camphene, for hydrogen gas. It is the mixture of alcohol vapor and air, to which the effect is to be principally ascribed; the experiment may be made, indeed, as well with unmixed alcohol, or ether, as with burning-fluid. It may also be made with camphene, but in this case the vessel must be warmed, in order to vaporize the liquid in sufficient quantity.

1083. The above experiment may be performed with safety, in an open vial, by vaporizing a drop or two of either of the above liquids within it, and then applying a lighted taper to the mouth. in this case, the appearance of flame at the mouth of the vial, and a rushing noise, is all that is observed. This experiment will enable the student to disprove the alleged unexplosive character of certain fluids in use for purposes of illumination. In moderately warm weather it is sufficient

301

1082. What is the cause of the explosion? 1083. Describe another form of the experiment.

to fill the vial, and then to empty it, in order to form the explosive atmosphere.

1084. Oils containing Oxygen.—The essential oils of this kind are numerous and include the oil of bitter almonds, cinnamon, aniseseed, peppermint, wintergreen and others, with camphor and its modifications. The composition of these substances is various. They are used mostly in medicine and perfumery.

1085. Camphors.—These are concrete, volatile oils, containing oxygen; as previously stated, several of the oils when exposed to a low temperature, deposit solids. These are white and crystalline, and are frequently isomeric with the oils themselves. Common camphor is obtained from the *Laurus Camphora* of China and other Eastern countries, by distillation with water. It is afterwards purified by sublimation. It dissolves readily in alcohol, forming *spirits of camphor.* Its volatile character is the occasion of a singular appearance, when small bits of the substance are thrown upon warm water. The particles are seen to sail about as if they were possessed of life, owing to the propelling effect of the vapor which escapes beneath them. The composition of common camphor is $C_{20}H_{16}O_2$. Artificial camphors, are produced by the action of dry hydrochloric acid gas upon camphene. One of the compounds so formed has the composition $C_{20}H_{16}HCl$, in which hydrogen and chlorine supply the place of the two atoms of oxygen in the ordinary camphor. This compound is a white crystalline substance, having an

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1084. What oils contain oxygen? 1085. What are camphors?

aromatic odor and taste resembling that of gum camphor.

1086. Oils containing Sulphur.—This class of essential oils is more limited in number than the preceding. They are noted for their acrid, burning taste, and also for their peculiar unpleasant odor, which may be readily noticed in the breath after eating substances containing them. Onions, garlic, horseradish, assafœtida, black mustard, etc., furnish oils belonging to this class. The seeds of both black and white mustard yield on pressure a large quantity of a bland fixed oil, but they do not contain any essential oil ready formed. The seed of the black mustard, however, when crushed and moistened with water, undergoes a kind of fermentation, during which an essential oil is developed, which may be obtained by subsequent distillation. This is a colorless oil, has the composition $C_8H_5NS_2$; possesses a painfully penetrating odor, which produces a flow of tears, and when applied to the skin raises a blister.

1087. Artificial Essences.—Many of the essential oils are compounds of organic acids and bases. Several of them may be artificially produced. *Pine apple oil* is a compound of butyric acid with ether or oxide of ethyl. The butyric acid of the compound may be prepared from rancid butter or by fermenting sugar with putrid cheese. *Bergamot pear oil* is an alcoholic solution of acetates of the oxide of ethyl with acetate of oxide of amyl. The latter is the ether of the nauseous

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1086. What is said of oils containing sulphur? 1087. What is said of artificial essences?

and poisonous fusel oil, which has before been mentioned.

1088. *Apple oil* is a compound of valerianic acid with the same ether. The valerianic acid of the compound is also made from fusel oil. *Oil of grapes*, and oil of cognac, used to impart the flavor of French brandy to common alcohol, come from the same source. *Oil of winter-green* may be prepared from willow bark and wood vinegar. *Oil of bitter almonds* is prepared from coal tar. These artificial essences, although produced in several cases from poisonous substances, may be used as flavors with perfect safety. It is highly probable, and in many cases certain, that the flavor of the fruits themselves, is owing to the presence of these precise compounds in small quantities.

1089. EMPYREUMATIC OILS.—The volatile oils which are produced by the destructive distillation of vegetable and animal substances receive this general name. The oils of wood and coal tar are examples. Another empyreumatic oil is produced in the combustion of tobacco in ordinary pipes. This oil is extremely poisonous. It is to be understood that these oils do not exist ready formed in the substances from which they are obtained, but are produced in the re-arrangement of atoms which takes place when organic bodies are subjected to a high temperature.

1090. RESINS.—The resins, of which ordinary pine *rosin* may serve as an example, are formed by the action

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1088. What is artificial apple oil? Artificial oil of bitter almonds?
1089. What are empyreumatic oils? 1090. How are resins formed?

of oxygen upon the essential oils. Oil of turpentine may be thus partially converted into resin by long exposure to the air. On subsequently heating it, only a portion is found to be volatile, while a resinous mass remains behind. Turpentine, or pitch of pine trees, is thus formed in nature from the oil of turpentine as it exudes from the trees. But the conversion is only partial, so that the turpentine yields, on distillation, a portion of oil, while rosin remains behind. Resins are easily distinguished from gums by their insolubility in water; they are, on the other hand, readily soluble in alcohol or ether. They are not liable to decay, like most other substances of vegetable origin. Copal shellac, mastic and amber are all resins. The latter is found in certain coal mines and at the bottom of the sea, and has probably had its origin in the forests of some primeval age.

1091. Explanation.—The action of the oxygen of the air in the above case is similar to that which occurs in the conversion of alcohol into vinegar. A portion of the hydrogen is burned out, as it were, and removed in the form of water, while another portion of oxygen takes its place.

1092. Use of the Resins—Varnishes.—The resins are principally employed for the production of varnishes. These are simply solutions of resins in alcohol, ether, or spirits of turpentine; or an intimate mixture of the latter with fused resin and oil. In preparing copal var-

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1091. Explain the above transformation. 1092. What use is made of the resins? How are varnishes made?

nish, which is the most brilliant and durable, the resin is first fused, then incorporated with heated oil, and afterward diluted with spirits of turpentine. A common varnish for maps, engravings, and similar objects, is made by dissolving mastic with a little *venice turpentine* and camphor, in spirits of turpentine. Pounded glass is added to the pulverized material during the process of solution. The object is covered with a solution of isinglass before using this varnish, to prevent its absorption. Shellac, in alcohol, is employed to impart to wood or other material a resinous coating, which is afterward polished with rotten stone. Copal varnish is also similarly used. Shellac, dissolved in soda or potash, is sometimes used to give body to paints, as a substitute for part of the more expensive material.

1093. ROSIN SOAP.—The resins possess an acid character, and like fats, form soap with the alkalies. Common rosin is largely consumed, with fat and potash, in the manufacture of common brown soap. The greater hardness which it imparts depends on the formation of a certain portion of rosin soap in the mixture.

1094. SIZING.—The soap which is formed on boiling rosin with strong potash is used in sizing paper. Being mixed with the material from which paper is to be made, a solution of alum is afterward added to the pulp, and a compound of rosin and alumina thus produced in every portion of the mass. The pores of paper made from this material are thus completely filled, and the spreading of the ink prevented. A sur-

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1093. What is rosin soap? 1064. How is rosin used in sizing paper?

face sizing which is less effectual, is also given to paper by a solution of glue, applied after the paper is formed. When this is destroyed by erasure, its place may be supplied, and the spreading of ink prevented, by rubbing powdered rosin upon the spot from which the sizing has been removed.

1095. SEALING-WAX. — Sealing-wax consists, principally, of shellac. Venice turpentine is added to make it more inflammable and fusible, and vermilion or lamp-black to color it. *Ship pitch* is resin changed and partially decomposed by heat. *Shoemaker's wax* is made by a similar process.

1096. ROSIN OIL AND GAS.—Rosin is partially converted by dry distillation into an oil, which is largely used for adulterating other oils, and also for the purposes of illumination. A black pitch remains in the retort. The oil has the advantage of extreme cheapness, but owing to its large proportion of carbon, can only be burned in lamps furnished with tall chimneys. At a still higher temperature rosin is converted into gas, with a residue of carbon.

302

1097. GUM RESINS.—The dried juices of certain plants consist of mixtures of gum and resin. These mixtures are called *gum resins.* Water dissolves the gum, and holds the resin in suspension, thus forming what is called an emulsion. Alcohol, on the other hand, extracts the

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1095. What is the composition of sealing-wax? 1096. What are the products of the dry distillation of rosin? 1097. What is said of gum resins?

resin from their mixtures. Assafœtida, gamboge and opium are a few of examples of gum resins.

1098. CAOUTCHOUC. GUM ELASTIC.—Caoutchouc is a hydrocarbon obtained from the milky juice of certain trees in Asia, Africa and South America. This constituent of the juice hardens on exposure to the air, while the remainder is removed by evaporation. By the addition of a little ammonia, the milk may be retained in its liquid condition. Caoutchouc is soluble in ether, spirits of turpentine, oil of coal tar, and many other hydrocarbons. Sulphuret of carbon, a volatile liquid obtained by passing sulphur vapors over ignited charcoal, is also a complete solvent of India-rubber and gutta percha.

1099. VULCANIZED RUBBER.—Heated for a short time with sulphur, at 280°, or somewhat above this point, caoutchouc becomes remarkably changed in its nature, and is no longer stiffened by cold or softened by heat. It is then called *vulcanized rubber*, and constitutes the material out of which most India-rubber goods are now made. The *hard rubber* which is extensively employed for the manufacture of combs, knife-handles, pencil-cases, &c., is composed of pitch, India-rubber, sulphur, and magnesia. The mixture is softened at about 270°, then pressed into moulds to give it the required shape. It is afterward wrought like ivory.

1100. GUTTA PERCHA.—Gutta percha is identical in

1098. Mention the sources and properties of caoutchouc. 1099. How is caoutchouc vulcanized? What are the properties of vulcanized "rubber?" 1100. What is gutta percha? Mention some of its properties and uses.

composition with gum elastic, but possessed of quite different properties. Among them is its extreme toughness and comparatively slight elasticity. It is rendered soft and plastic by immersion in boiling water, and in this pasty condition may be moulded into any required shape. It can be vulcanized, like caoutchouc, and is then proof against elevation of temperature. It is employed as a substitute for caoutchouc where great elasticity is not required. Both of the above substances approach more nearly in their composition to the essential oils than to any other class of compounds.

Protein Bodies—Putrefaction.

1101. Vegetable Fibrin.—The glutinous mass which remains when dough is kneaded in water until all the starch is removed, is called *gluten* or vegetable *fibrin.* It differs from all the organic matter hitherto described, in containing nitrogen, with small quantities of sulphur and phosphorus. In the present state of our knowledge in respect to the protein bodies, we must abandon every formula designed to express their atomic constitution. They contain in a hundred parts: 55.16 carbon, 7.05 hydrogen, 21.81 oxygen, 16.96 nitrogen, with ½ to 1 per cent. sulphur and phosphorus in an unknown form. Gluten is a grey substance, and is the material which gives its cohesion to bread.

1102. Vegetable Albumen and Casein.—Vegetable

1101. State the composition and properties of vegetable fibrin. 1102. What is said of vegetable albumen and casein?

albumen is a similar substance, contained, in smaller quantity, in the juices of fruits and vegetables. It is coagulated by heat, like the white of egg, when the juices are boiled. Vegetable *casein* is another substance of very similar composition and properties, found principally in the seeds of leguminous plants. It precipitates like the curd in sour milk, when a little acid is added to an aqueous extract of the seeds. These substances derive their names from their resemblance to animal fibrin, albumen, and casein. Vegetable casein is also called *legumine*. All of these substances were at one time supposed to be compounds of a single substance, called *protein*, itself free from both sulphur and phosphorus. Later experimenters have not succeeded in isolating such a substance, and the theory is therefore abandoned. The name is retained in this work as a convenient designation of the class of substances here considered.

1103. Occurrence.—One or more of these substances is present in greater or less quantity in all parts of plants. They are found accumulated with starch, in the fruit and seed. The seeds of cereals, such as wheat and rye, and those of leguminous plants, such as peas and beans, contain them in large proportion.

1104. Characteristics.—If a bit of gluten be placed on the end of a wire and burned, a very different odor is produced from that of burning starch or wood. The smell approaches that of burning wool, and is a means

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1103. Where are the above substances found? 1104. Mention a peculiarity of these nitrogenous compounds.

of distinguishing organic matter which contains nitrogen. If boiled with potassa, the sulphur of gluten is extracted, and the solution will blacken paper moistened with sugar of lead. This reaction furnishes another means of detecting these nitrogenous substances.

1105. PUTREFACTION.—A still more important distinction of nitrogenous substances from those which contain no nitrogen, is their spontaneous putrefaction. Left to themselves, they are resolved, like blood and flesh, to which they are allied in composition, into a variety of other products. It is not strictly correct to say that this decomposition is spontaneous. The substance must first have been exposed to the air. An oxidation or slow combustion is then commenced, which, although entirely imperceptible in its effects, and checked at once by exclusion of air, ensures the subsequent putrefaction. It burns out a small portion of carbon and hydrogen, and thus removes, as it were, the keystone of the arch in every molecule. The atoms may then be supposed to fall together and re-arrange themselves as is required by the known products of their decomposition.

1106. PRODUCTS OF PUTREFACTION.—The re-arrangement which occurs in putrefaction, consists, essentially, in the combustion of the substance with oxygen, while the hydrogen divides itself between the nitrogen, phosphorus and sulphur, forming ammonia, phosphuretted

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1105. Describe the process of putrefaction? 1106. Mention some products of putrefaction.

and sulphuretted hydrogen. It is to these gases that the offensive smell which is given off in putrefaction is principally to be ascribed.

Fermentation—Bread Making.

1107. FERMENTATION.—Fermentation is a chemical action effected by certain substances and transferred to others, the primary substances being at the same time decomposed, though they do not communicate any of their elements to the new products. Any one of the nitrogenous substances above mentioned, while undergoing the change which is called putrefaction, is capable by its mere presence, of acting as a ferment. A little putrefying gluten, for example, added to a solution of sugar, will convert it into alcohol and carbonic acid. Here again the key-stone of the molecule is removed, or rather in this case *moved*. The motion of the atoms of the putrefying substance would seem to be the cause. The effect is analogous to that of heat, through whose agency, also, complex organic bodies are resolved into others of simpler constitution. The process of fermentation is usually accompanied by the growth of a microscopic fungus, known as the yeast plant, which occurs in the change of sugar into alcohol or of vegetable juices into wine, beer or vinegar.

1108. YEAST.—The first stage in the formation of yeast is the production of a microscopic vegetation,

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1107. What substances are capable of producing fermentation? 1108. What is the first stage in the process?

which consumes all the protein, converting it into the substance of a microscopic plant. Ordinary brewers' yeast is such a microscopic vegetation. Being produced, it passes immediately into the putrefaction above described, effecting, at the same time, the conversion of any sugar which may be present into alcohol and carbonic acid. By some, the growth of the microscopic plant itself, instead of its subsequent change, is supposed to be the cause of fermentation.

303

1109. Production of Yeast.—Yeast has not only the power of converting sugar into alcohol, but it at the same time occasions the production of more yeast from dissolved protein. In the ordinary process of beer brewing, the newly formed yeast collects on the surface of the fermenting vats. It is thence removed, to serve as the excitant of a new fermentation, or to be employed in the production of bread, which is, chemically considered, an analogous process.

1110. Yeast for Culinary Purposes may be produced by exposing a mixture of milk and flour for several hours to a temperature of about 90°. Sugar and salt added to a mixture of flour and water will have the same effect. The cook often fails to have the "yeast rise" from not keeping the mixture at the proper temperature. At a temperature below 70° the sugar is converted into lactic acid, and if it remains too long at

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1109. How is yeast produced? 1110. How may yeast be prepared for culinary purposes?

this temperature, and is afterwards raised to the proper temperature for generating carbonic acid and alcohol, the mass is found too sour for making good bread; by raising the temperature at once to 90°, and keeping it at that point good yeast will be formed free from any mixture of lactic acid. Boiling water destroys the fermenting properties of yeast, but unless boiled so long as to have its chemical nature entirely changed, it reacquires a fermenting power on exposure to air.

1111. DIFFERENT KINDS OF FERMENTATION.—The products of fermentation are different, according to temperature and other circumstances. Thus the same sugar which at 40° to 86°, with cheese used as a ferment, yields carbonic acid and alcohol, at a temperature of 86° to 95° is converted into lactic acid. The latter, by the further action of the curd, with slight elevation of temperature, is converted into butyric and carbonic acids. By the same ferment, at a still higher temperature, a portion of gum is produced with the lactic acid. These different processes of transformation have received, respectively, the names of the vinous, lactic, butyric, and viscous fermentations. The conversion of starch into sugar by diastase may be regarded as a species of fermentation. This substance is a slightly changed gluten. It is always produced in germination, and may be precipitated by alcohol in the form of white flakes from a concentrated infusion of malt. One part of it is sufficient to convert two thousand parts of starch into sugar.

1111. Mention several kinds of fermentation.

1112. Flour.—Fine flour makes less nutritious bread than the coarser varieties, because it contains a smaller proportion of gluten. Gluten being tougher than the starch, is not reduced to so fine a powder and is partially separated in the process of bolting. All grains contain sugar in small proportion. Sugar is therefore one of the constituents of flour.

1113. Deterioration of Flour.—When flour is kept for a considerable time it is very apt to absorb moisture and undergo a change by which the tenacity of the gluten is diminished. Flour from ground wheat is deteriorated in the same manner. As a consequence, such flour does not make light bread. To make light bread of such flour alum is sometimes added, but this adulteration or addition to the flour is injurious to health. An analysis of bread from twenty-five bakeries in London showed the presence of alum in all, and a second examination some weeks afterward gave the same result. It was found, however, that in many cases the alum was not added by the bakers but by the millers who prepared the flour. Liebig has shown that lime-water added to the dough in bread-making, whitens the bread, causes it to rise better, and that it is not injurious to health.

1114. Bread.—The "raising of bread" is a process of fermentation. The yeast employed in the process converts a portion of the starch of the flour into sugar, and

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1112. What is said of the nutritious properties of fine flour. 1113. How does flour deteriorate? How is it restored so as to make nice bread? 1114. What chemical principles are involved in making bread?

subsequently into alcohol and carbonic acid. The *sponge* is made light and porous by the gas bubbles which become entangled within it. A large part of the alcohol produced in the process escapes into the oven, and thence into the exterior air. It may be condensed and converted into *spirits* by the proper apparatus. This has been successfully done in large bakeries in Europe, but the process has not been found to be of any considerable economical importance. In baking a small portion of starch is always converted into gum. By moistening the baked loaf with water the gum is dissolved, and by a new heating, hardens into the shining surface which is often observed on bakers' bread.

1115. YEAST POWDERS.—The gas which is needed to make bread light, may be produced by other means than the process of fermentation. If carbonate of soda, for example, is kneaded into the dough, and tartaric acid subsequently added in proper proportion, the weaker carbonic acid is expelled. A light sponge is produced by its escape, without the loss of the starch and sugar which are consumed in the process of fermentation. Soda and tartaric acid prepared for this purpose are known under the name of *yeast powders*. Carbonate of ammonia being entirely volatile by heat, may be employed alone for the same purpose. A portion of the salt probably remains in the bread, and is more or less injurious on account of its alkaline character.

1115. What materials are sometimes substituted for yeast ?

1116. Test for Yeast Powders.—The great objection to the use of these powders in the preparation of bread, consists in their liability to contain soda or acid in undue proportion. Whether this is the case, may be ascertained by dissolving the powders in water and mixing the solutions. If the product is neutral to the taste and does not effervesce on the addition of either soda or acid, this fact will be evidence of their proper preparation. If otherwise, more or less injury is to be anticipated from their use. Excess of the alkalies especially interferes with the process of digestion, by neutralizing the acids which accomplish it. The use of soda and saleratus with sour milk is liable to the same objections.

1117. Their Effect on Health.—It may well be questioned whether bread prepared by this process is ever as healthy as that made with yeast. For even the neutral tartrate, formed when the materials are used in proper proportion, will tend to neutralize certain stronger acids which are constituents of the gastric juice. It may thus interfere, in a measure, with the process of digestion. If pure muriatic acid were substituted for the tartaric acid or cream of tartar, this objection would be removed. The product of its action on soda is common salt.

1118. Aerated Bread.—By a recently invented method, beautiful light bread is made without the use of any

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1116. What is the objection to the use of soda, &c., in bread? 1117. What is said in addition, of their effect on the health? 1118. How is aerated bread prepared?

kind of yeast or yeast powders. The flour is placed in iron cylinders and deprived of air by a powerful air pump, and made into dough with water holding in solution a large amount of carbonic acid gas under high pressure. The operation of mixing and kneading the dough is performed by machinery in the closed cylinder. The dough is then run out into pans and quickly baked, the carbonic acid gas relieved from pressure and exposed to heat expands and raises the dough to a light spongy consistence, unsurpassed by the best bread raised with yeast.

1119. Bread Baking.—When the prepared dough is exposed to the temperature of a hot oven (from 212° to 350°) it loses from ten to fifteen per cent. of the water which it previously contained, while another portion of the water enters into chemical combination with the flour, so that 100 pounds of flour make about 150 pounds of bread. While the carbonic acid gas developed by fermentation, liberated by yeast powders or supplied in the aerated bread by carbonated water, gives the dough a spongy texture, the heat applied in baking solidifies the dough and renders the spongy texture permanent. Baking converts a portion of the starch into gum, the gluten loses its tough qualities and unites with the starch. The heat of baking stops the fermentation and if sufficiently prolonged kills the yeast plant. In imperfectly baked bread some of the yeast retains its vitality and when eaten sets up a fermentation very injurious to delicate stomachs.

1119. What changes take place in baking bread?

1120. New and Stale Bread.—The crust of newly baked bread is dry and crisp while the interior of the loaf is soft and moist, but after a short time both parts of the bread undergo a change, the brown crust attracts moisture and grows softer, while the interior becomes more dry and hard. This change is produced by new combinations between the water and the solid atoms of the bread. If a loaf of stale bread is exposed in a closely covered vessel for half an hour to a temperature of 150°, it will again have the appearance of new bread with very little loss of weight since the first baking.

Coloring Matters.

1121. Indigo.—The vegetable dye-stuffs are extremely numerous. Indigo, madder and logwood are among the more important. Indigo is deposited from the colorless juice of certain plants by simple exposure to the air. It may be sublimed in purple crystals by rapid heating. By removing the oxygen absorbed in its production, the original colorless juice may be, as it were, reproduced from commercial indigo. This object is effected by the use of protosulphate of iron, which is converted into sulphate of the peroxide in the process. Caustic lime is at the same time added to dissolve the deoxidized indigo. The colorless solution is employed in dyeing; cloth impregnated with it becomes blue on

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1120. How does stale bread differ from new? 1121. What is said of indigo?

exposure to the air. A solution of indigo in concentrated sulphuric acid is also employed in dyeing.

1122. MADDER.—Madder is the ground root of the *rubia tinctorium.* This plant is cultivated extensively in India and Europe. It contains a red dye, produced by the action of the air or certain chemical agents upon the juices of the recent plant. This body is called *alizarine* and may be obtained in beautiful crystals. An infusion of the root in hot water contains a portion of this substance in solution.

1123. LOGWOOD.—This is a red wood, obtained from Spanish America and much employed in dyeing. Its coloring matter is called *hematoxyline.* By evaporating a decoction of the wood and re-dissolving in alcohol, this substance may be obtained, on a second evaporation, in the form of yellow crystals.

Dyeing.

1124. DYEING.—Few dyes can be permanently imparted to cloth without the intervention of some third substance, which shall, as it were, hold them together. Such a substance, with strong affinity for the coloring matter of the dye and also for the fiber of the cloth, is called a *mordant.* The fabric to be dyed being first impregnated with the mordant, is then introduced into the dyer's vat to receive its permanent color.

1125. MORDANTS.—Alumina and oxide of iron are the

1122. What is madder? 1123. What is logwood? 1124. Explain the theory of dyeing fast colors. 1125. What is said of mordants?

principal mordants employed. They may be "fixed" in the cloth by immersion in the acetates of these oxides. A subsequent exposure for several days to the air is essential, in order that the acetic acid may in part be expelled. A portion of it, however, remains, so that the oxides are, strictly speaking, in the condition of basic acetates. After this exposure, and subsequent washing in hot water, the fabric may be immersed in the dye. An ounce of madder heated with a pint of water will be sufficient for an experiment. The fabric is to be boiled for an hour or more with the unstrained decoction.

1126. PREPARATION OF THE MORDANT.—The solution of acetate of alumina is most conveniently prepared from alum, by the substitution of acetic for its sulphuric acid. This is accomplished by the addition of acetate of lead. Sulphate of lead is at the same time precipitated, and may be filtered off from the acetate which is formed. Three pounds of alum and two of sugar of lead to three gallons of water, are the proportions to be employed. This mordant produces a red color.

1127. VARIOUS COLORS BY THE SAME DYE.—By the use of different mordants, various colors may be produced from the same dye. Substitute four pounds of green vitriol for the alum used in the previous case, and the madder gives a deep black. Add four ounces of arsenic with the green vitriol, and a mordant is produced with which the dye will yield a beautiful purple.

1126. How is the aluminous mordant prepared? 1127. How are various colors produced from one dye?

In the latter case, the solution must be reduced to one-tenth of its original strength by the addition of water.

1128. Dyeing with Logwood.—By the employment of the last two mordants, mixed in equal proportions and diluted to half their strength by water, a mordant for dyeing black with logwood is obtained. For dyeing *purple* with the same material, a tin mordant is used. It may be prepared by dissolving tin in muriatic acid with the gradual addition of nitric acid, then precipitating and re-dissolving with potassa. The cloth being impregnated with this mordant and thoroughly dried, is passed through dilute sulphuric acid, to remove the potassa and leave the oxide of tin. After subsequent drying and exposure to the air, the fabric is ready for the dye.

1129. Mineral Dyes.—The dyes described in the following paragraphs, are distinguished from those before mentioned by containing no organic matter. They consist of colored salts or oxides precipitated in the fiber of the cloth. Although these substances belong, strictly speaking, to inorganic chemistry, they are here introduced to complete the survey of the subject of dyeing and calico printing.

1130. Prussian Blue.—A mineral blue may be produced by impregnating cloth with the solution of acetate of iron, before described as a mordant, and then immersing it in an acidified solution of prussiate of potash. Prussian blue is thus precipitated in the cloth.

1128. Describe briefly the process of dyeing with logwood? 1129 What are mineral dyes? 1130. How is a mineral blue obtained?

This blue is found to be brightened by passing it through a solution of sugar of lead.

1131. Mineral Green.—A mineral green is produced in the same manner by the employment of sesquichloride of chromium, and subsequent immersion in potassa. The color consists of sesquioxide of chromium, precipitated from the chromium salt by the action of the alkali. The solution of the sesquioxide of chromium is prepared by the addition of sugar to a solution of bichromate of potassa in dilute sulphuric acid. A part of the oxygen of the chromic acid being abstracted by the organic matter, it is converted into an oxide, which remains in solution.

1132. Chrome Yellow.—To produce a mineral yellow, the cloth may be impregnated with acetate or nitrate of lead, then dried and passed through sulphate of soda, to fix the lead as sulphate in the cloth. On finally immersing it in bichromate of potassa, the cloth becomes dyed with yellow chromate of lead. The above process modified by printing instead of saturating with acetate of lead, gives yellow figures on a white ground.

Calico Printing.

1133. White Figures.—If it is desired to obtain a design in white, on goods dyed with either of the above madder colors, the design is printed with a paste of tartaric acid upon the colored cloth. On subsequently

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1131. How is a mineral green produced? 1132. How is a mineral yellow produced? 1133. How is a white design on dyed goods produced?

immersing the goods in a bath of chloride of lime, chlorine is evolved in the tissue, and the color discharged only where the acid is printed. The white thus produced is of course in exact correspondence with the printed design.

305

1134. Printed Yellow and Blue.—To produce yellows on madder red and purple grounds, before described, tartaric acid is printed with the nitrate of lead, and the cloth immersed in bleaching liquid. The color of the printed portions is discharged by the combined action of the acid and bleaching liquor; the lead is at the same time fixed in the cloth as chloride of lead. On subsequent immersion in bichromate of potassa, the yellow figures of chromate of lead are produced as before. For blues on the same colored grounds, a mixture of Prussian blue, dissolved in bichloride of tin, with tartaric acid, is printed on the cloth. The discharge of the ground color beneath the figure, is effected, as before, by chloride of lime.

1135. Variegated Patterns.—All of the madder colors which have been mentioned, may be produced upon a single piece of white goods, by printing the different figures of the pattern with different mordants. This is accomplished by passing the fabric between different sets of rollers, each of which is supplied with a paste of the proper mordant, and so engraved that it

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1134. How are yellow and blue designs obtained on dyed grounds?
1135. How are variegated patterns produced?

yields the desired impression. On subsequently introducing the goods into the madder bath, the various colors are developed. The whole piece is at the same time transiently colored; but the dye may be readily removed from the unprinted portion by thorough washing. A white ground for the colors is thus obtained.

Relation of Plants to the Soil.

AGRICULTURAL CHEMISTRY.

1136. MINERAL CONSTITUENTS OF PLANTS.—The mineral substances which plants obtain from the soil, are known by analysis of the ashes which they yield on combustion. They consist of acids and bases, which enter into the composition of all fertile soils. The bases are potassa, lime, magnesia and oxides of manganese and iron. These are found combined in the ashes with silicic, sulphuric and phosphoric acids, and are accompanied by small proportions of common salt. The carbonic acid which is found in certain ashes is produced in the combustion of the plant. The ashes of all cultivated plants contain the above substances; but in different proportions according to the nature of the plant. The phosphates predominate in grains; lime exists in large proportion in grasses; potash in edible roots; and silicia in straw. The approximate composition of the ash of different plants is given in a table in the Appendix. In estimating the relative pro-

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1136. What mineral substances do plants obtain from the soil?

portions of the different constituents which are abstracted from the soil by different crops, the quantity of the crop, as well as the composition of its ash, is of course to be brought into this account.

1137. Composition of Soils.—Many of the above substances are contained in the soil in extremely small proportion. Soils are principally composed of vegetable matter in a state of decay, with clay, sand and carbonate of lime. The vegetable matter consists of the remains of plants of previous years, and the clay, lime and sand are the product of the gradual crumbling and decomposition of the rocky crust of the earth.

1138. Use of Vegetable Matter in Soils.—The wood, leaves and twigs of which vegetable matter is composed, furnish, in their gradual decay, the potash, silica, and other constituents of their own skeletons to form the framework of new plants. The organic matter is at the same time converted into ammonia and carbonic acid; these constitute the gaseous food on which all vegetable life is sustained.

1139. Addition of Vegetable and Animal Matter.—The addition of more of this material to the soil, in the form of peat or muck from swamps, is of great advantage, because it increases the supply of the two important classes of materials which have been mentioned. Animal matter of all kinds, whether decomposed, as in stable manure and guano, or in its original

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1137. Of what are soils composed? 1138. State the uses of vegetable matter in soils. 1139. What advantage is gained by the addition of vegetable and animal matter to soils?

condition in the form of flesh, wool, and bones, is a still more valuable addition to the soil. The reason of its higher value, consists in the fact that while it yields most of the other substances which decaying vegetable matter supplies, it furnishes ammonia, which is the rarest and most expensive one, in much larger proportion.

1140. Use of the Clay.—The clay in soils serves to retain the ammonia and certain other valuable materials, which would, otherwise, be washed away by descending rains. It seizes not only upon that which comes from the decaying humus, but finds particles in the drops of every shower, which it stores safely away for the future use of the plant. It serves also to retain moisture in the soil, and to impart to it the tenacity by which the roots are enabled to gain a firm hold upon the earth. Soils which contain but a small proportion of clay are for these reasons improved by its addition.

1141. Uses of the Sand.—Sand, where it exists in due proportion, gives the proper degree of porosity to the soil, and thus ensures the entrance of the air and fertilizing liquids, and the draining away of all excess of water. Access of air is important, because it brings with it fertilizing ammonia and carbonic acid, and by accelerating the decay of vegetable matter, produces more of these valuable substances.

1142. Uses of the Lime.—The lime in soils, beside serving directly as building material for all forms of

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1140. What purpose does clay subserve in the soil? 1141. What is the office of sand in soils? 1142. What is the office of lime on the soil?

vegetation, is the key which unlocks other treasures of the soil and supplies them, also, to the growing plant. The building material which is furnished, as before explained, by the decay of previous plants, is not sufficient. A portion of it never reaches the fields from which it was originally derived. Exported in the form of grain, or milk, or beef, it returns to the soil in some distant region or is poured into the rivers and the sea through the drains of populous cities. New supplies of potash and other material, are, therefore, demanded by the vegetation of every successive year.

1143. A large part of the materials referred to are locked up in hard grains of granite or other silicates which are found in the soils. Being insoluble in water and the other solvents of the soil, they are inaccessible to the plant. Lime has the property of forcing itself into the rocky prison of every such insoluble grain, and setting part of its inmates at liberty. At the same time it opens the door to the action of other agencies which liberate the rest. They are then floated away in the water which penetrates the soil, and being in due season absorbed, are built into the substance of the plant.

1144. ACTION OF LIME ON MINERAL MATTER EXPLAINED.—The action of lime, which has just been mentioned, is a simple consequence of its basic properties. It takes possession of part of the silicic acid of of the alkaline silicate in the rocky grains. Their potassa and soda being now combined with this acid in

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1143. How does it accomplish the object? 1144. Give the chemical explanation of its action?

small proportion, are soluble in the water which penetrates the soil.

1145. The water of the soil always contains a certain proportion of carbonic acid. This acid being itself material for vegetable nutrition, has also the property of dissolving those mineral substances which the plant needs for its support. By the joint action of carbonic acid and water, this transfer is constantly going on even without the aid of lime. But the latter substance very much acclerates the action, and thus adds greatly to the fertility of the soil.

1146. Action of Lime on Organic Matter.—Lime has another important effect on soils, in hastening the decomposition of their organic matter, and thus, indirectly supplying in large quantity, valuable materials, before mentioned, which these are adapted to furnish. As this decomposition proceeds in the presence of lime, part of the nitrogen of the organic matter takes the form of ammonia, and part is converted into nitrates, as will be remembered from the Chapter on Salts. But the proportion of either is practically immaterial, as both are found to subserve a similar purpose in building up the plant.

1147. All of the effects which have been mentioned, may be regarded as gradually produced in every soil which contains carbonate of lime as a constituent. When it is deficient in quantity, they are, of course,

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1145. What other decomposing agent exists in the soils? 1146. Mention another use of lime on the soil. 1147. How are the above mentioned effects increased? Mention another effect of lime.

increased by its addition in the form of chalk, marl, or limestone. These substances have also the effect of sweetening peaty and marshy soils, which are rendered sour from the presence of too large a proportion of vegetable matter, and thus rendering them fit for cultivation.

1148. BURNED LIME.—Burned or caustic lime has all these effects in a much greater degree, and therefore its extensive use as a fertilizer of the soil. It should be used cautiously on soils which contain but a small proportion of vegetable matter, for fear that in the more rapid decomposition which it stimulates, it may entirely exhaust the soil of this material. If employed in such cases it should be with admixture of vegetable matter, that the loss which it occasions may be completely replaced.

1149. EFFECT OF ASHES ON SOILS.—Potassa or soda applied in the caustic state, or as carbonates, have entirely analogous effects on the soil. They render the insoluble silicates soluble, by increasing in them the proportion of base, and also hasten the decay and conversion of vegetable matter. The admixture of lime or ashes with guano or decomposed manure is to be avoided, because of their effect to expel the ammonia which these substances contain. This may be prevented by previously incorporating the material with a large proportion of clay or vegetable mould, which shall serve as an absorbent of the liberated gas.

1148. In what form has lime the greatest effect? 1149. What other substances act similarly? What caution is to be observed in their use?

1150. Composts.—Composts consist of vegetable and other matter, heaped together for fermentation and partial decay in order to prepare them for application to the soil. In such mixtures, all alkaline materials, including lime, have an effect similar to that which they produce upon the organic matter of the soil.

1151. Guano.—Guano consists of the accumulated droppings of birds, and is principally obtained from certain rocky islands on the coast of South America. In these haunts of the heron, flamand, and other sea-fowl, it is accumulated, in some instances, to the depth of a hundred feet. The deposit is usually in smaller quantity, but amounts in the aggregate to millions of tons. The material was employed as a fertilizer by the natives of Peru and Chili, long before its introduction into England or the United States for the same purpose.

1152. Different Varieties.—The quality of guano differs materially, according to the source from which it is derived. The ammoniacal salts, on which its agency as a fertilizer principally depends, being soluble in water, the product of moist climates is of comparatively little value. The best is obtained from the coast of Peru, where rain seldom or never falls. The African, Patagonian and other varieties are much inferior.

1153. Agricultural Value.—The agricultural value of guano lies principally in the ammonia and phosphate of lime which it is capable of yielding to plants. These

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1150. What is said of composts? 1151. What is guano? 1152. What is said of different varieties of guano? 1153. On what does the agricultural value of guano depend?

constitute, in the best varieties, about one-third of the whole weight. Part of the ammonia is ready formed, and part is produced in the subsequent change which the nitrogenous matter of the guano experiences in the soil. The latter may be produced immediately by a chemical process, and its quantity accurately determined, In estimating the value of guano, it is customary to record the quantity of this *potential ammonia*, as if it were an existing constituent.

1154. ARTIFICIAL AMMONIA.—The constituents of the ammonia which we purchase in the form of guano at so great expense and bring from distant regions of the earth, exist in unlimited quantities at our very doors. Four-fifths of the atmosphere is nitrogen gas, and the ocean is an exhaustless reservoir of hydrogen. But, strange to say, the chemist with all his skill, cannot, except by circuitous and expensive methods, effect their combination. The discovery of some cheap and ready means of accomplishing this object, would transform the face of the earth, by the unlimited quantity of fertilizing material which it would supply. This result may, perhaps, be reached by patient investigation. But no sudden triumph over nature need be anticipated. Improvements in agriculture will, as a general thing, be only realized by the earnest co-operation of scientific and practical men, in laborious and oft-repeated experiment.

1155. EXHAUSTION OF SOILS.—When soils become ex-

1154. What is said of the artificial production of ammonia? 1155. What is said of the exhaustion of soils?

hausted of those substances which form the mineral food of plants, the growth of vegetation ceases. It is never absolute, but consists in a great reduction of that portion of their material which is in a condition to be appropriated by the growing plant. Such soils are gradually restored by rest. A gradual decomposition of their insoluble material occurs by means of agencies which have before been mentioned, and the soil is thus restored to its original condition. These effects are very much hastened by plowing in such a growth as can be obtained. Rye, buckwheat and clover are among the plants best adapted to the purpose. Vegetable matter is thus added to the soil, which, in its decay, hastens the decomposition of the soil itself.

1156. DEFICIENCY OF ONE OR MORE CONSTITUENTS.—The comparative exhaustion of some one or more of the constituents of the soil is a much more frequent occurrence. It is commonly the result of the cultivation of the same crop during many successive seasons, and the consequent reduction of those materials which the particular plant requires in largest proportion. Deterioration of soils from this cause is repaired by an artificial supply of the failing ingredients. It is more wisely guarded against by such a rotation of crops as shall make different demands upon the soil in successive years.

1157. MAINTENANCE OF FERTILITY.—The effect of decomposing animal matters on the soil has been already

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1156. What is said of deficiencies in particular constituents? 1157. What is said of the effect of decomposing animal matter in the soil?

considered. They return the very material which was abstracted from the soil, with the addition of nitrogenous matter originally derived from the air by the growing plant. In an enlightened system of rural economy, the production of these materials in large quantity and their careful preservation, is therefore an object of paramount importance. The addition of gypsum or dilute sulphuric acid to fermenting manures, is of great advantage in retaining their ammonia in the form of sulphate and preventing its escape into the air. When additional ammonia is required, it is most cheaply obtained in the form of guano. The phosphates, whose quantity may be often increased with advantage, are best supplied in the form of "super-phosphate of lime." Other materials are less frequently required. For further information on the subject of the present section, the student is referred to works which treat especially of Agricultural Chemistry.

1158. "SUPERPHOSPHATE OF LIME."—The method employed in the manufacture of "superphosphate of lime," has been already given in the Chapter on Salts. As in the case of guano, its agricultural value depends on actual or potential ammonia and phosphate of lime. In proportion as the phosphoric acid is in a soluble form, the value is much increased.

1158. What is said of superphosphate of lime?

CHAPTER III.

ANIMAL CHEMISTRY.

1159. Relations of Animal and Vegetable Life. —The life of animals is sustained by the consumption of material compounded and prepared by the plant, and converted into its own substance out of the materials of the earth and air. This is virtually true even of the carnivorous species, for the animals on which they feed have derived their support from the vegetable world. When they yield their own flesh as food, it is only a changed vegetable matter which they thus supply. It thus appears that plants are purveyors for animals; they take up inorganic matter and prepare it for the use of animals. All science shows that plants precede animals in the organic world. Animal compounds are in general more complex in their elementary composition and less permanent than substances of vegetable origin. Water and fat are found in the animal system and they contain only two or three elements; but other animal compounds are rich in nitrogen, sulphur, and phosphorus.

1159. How is the life of animals sustained?

Animal Solids—Bones, Flesh, etc.

1160. Bones.—Bones consist of earthy matter and a cartilaginous material commonly known as *gelatine.* The bone earth or mineral matter is principally phosphate of lime, and forms in mammiferous animals about two-thirds of the whole weight. The remaining third is cartilage. Either of these constituents may be removed from the bone without effecting its shape. By removal of the cartilage, a brittle, earthy framework remains. By removal of the earthy material a perfectly flexible mass is obtained, of a form entirely similar to that of the original bone. The first change may be effected by long digestion in dilute muriatic acid, and the latter by fire. If in the second process the cartilaginous matter is not entirely consumed, bone black or animal charcoal is produced, the uses of which have been already described.

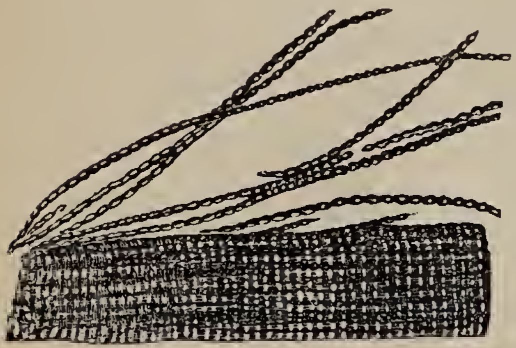
1161. Flesh.—Lean flesh or animal muscle is composed of fibrine, penetrated by a liquid which forms four-fifths of the whole, and is called flesh fluid, or juice of the flesh. It contains a peculiar organic acid possessing the flavor of broth, crystalline substances called *creatine* and *creatinine*, and certain salts. Being extracted by cold water and then heated, it forms a nourishing and highly flavored soup. Hot water coagulates its albumen and prevents its escape from the flesh.

1160. What is the composition of bone? How is it shown? 1161. Of what does flesh consist?

Gradual heating is on this ground to be recommended in the preparation of soups, while sudden exposure to a high temperature, both in boiling and roasting, yield more nutritious and highly flavored meats. The salts of potash prevail in the flesh fluid, while those of soda are more abundant in the blood. Unlike the blood, this fluid is acid in its reaction.

1162. STRUCTURE OF MUSCLE.—Lean meat or muscle consists of fibers enclosed in delicate membranous sheaths; these fibers are united into larger bundles which act together, constituting a muscle; each muscle is enveloped in a fibrous sheath, and in general contiguous muscles are separated by more or less fatty tissue which allows them to glide easily upon each other. Single muscular fibers when highly magnified are seen to possess transverse striations, they may also be torn apart and separated into numerous fibrillæ or smaller threads, as shown in figure 306, each fibrilla appearing somewhat like a string of beads. Each muscular fiber or bundle of fibrillæ is supplied with blood vessels and nerves too delicate to be shown in the figure, which although magnified 350 diameters, represents only a portion of a muscular fiber. Muscles possess the power of contracting and thus move the body. Some muscles not under the control of the will

306



1162. Describe the minute structure of muscles.

are also destitute of striations. They act more slowly than voluntary muscles. Such muscles are found in the blood-vessels and intestines.

1163. SKIN, TENDONS, LIGAMENTS.—The cartilaginous material above mentioned as a constituent of bones, is transformed by boiling water, without change of composition, into gelatine or glue. The skin, cellular membrane, tendons and ligaments of the body undergo the same change, and yield the same product. Gelatine may even be prepared from refuse leather, by first extracting the tannin, and thus reducing it to the condition of the original hide. The tannin obtained in the process may also be employed for tanning new hides. Hoofs, hair, horn, and feathers, although very similar substances, are not thus affected by boiling.

1164. GELATINE.—Gelatine is soluble in water, and yields a stiff jelly on cooling from a hot solution. On this property is based its use in the preparation of jellies for the table. The commercial article employed for this purpose and ordinary glue are essentially the same.

1165. The substance known as *isinglass*, is the dried air bladder of a species of sturgeon, and forms in its natural condition a soluble gelatine. Gelatine contains the four principal organic elements; nitrogen and oxygen being in somewhat larger proportion than in the protein bodies. Hoofs, hair, and other substances above mentioned, contain sulphur in addition. Gelatine is

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1163. What is said of tendons and ligaments? 1164. What is gelatine? 1165. Give the composition and properties of gelatine?

susceptible, like protein bodies, of putrefaction, and also of exciting fermentation. As starch is changed into sugar by the action of dilute sulphuric acid, so by the action of oil of vitriol, gelatine may be converted into a sweet crystalline substance called *glycocoll* or sugar of gelatine.

1166. Hides, Tanning.—A solution of gelatine forms with tannin or tannic acid a tenacious insoluble precipitate. The tanning of leather depends on the formation of this insoluble compound in the hides which are submitted to the process. They are immersed for this purpose in an infusion of oak and hemlock bark, until the combination has taken place throughout the whole thickness. They are thus secured against putrefaction and converted into firm, elastic leather. Hides may also be preserved by soaking them in alum and afterward in oil. Soft chamois leather is prepared by working the skin with fat alone.

307

Fats.

1167. Composition.—We have already seen that there are both acids and bases of purely organic origin, and that these may combine like the similar compounds of inorganic chemistry, to form salts. The animal fats and oils are mixtures of such compounds in different proportions. The principal of these organic salts are

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1166. What chemical combination occurs in tanning? 1167. What is said of the constitution of fats?

stearine, *margarine*, and *oleine*. Stearine is solid, oleine fluid and margarine occupies a middle position between the two. The difference of consistence in butter, lard, and tallow, is owing to varied proportions of these three substances which enter into their composition. Beside the fats contained in other parts of the body, the brain and nerves of animals contain, with albumen and water, certain peculiar acids and fats.

1168. Separation of Fats in Oil.—The stearine and oleine of whale oil separate spontaneously in cold weather. The cold which is sufficient to harden the former, leaves the latter in a fluid condition. This effect is often observed in lamps during winter weather. The case is quite analogous to the separation of cider into alcohol and water by freezing. The water congeals, and leaves the alcohol fluid. Both separations are imperfect. As the alcohol produced by the above process is diluted to a large extent with water, so the oleine retains a considerable portion of stearine in solution.

1169. Separation of Fats in Tallow and Lard.—*Stearine* is obtained from lard and tallow on a similar principle. It hardens on partially cooling the melted fat, forming a mass from which the fluid oleine may be separated by pressure. Stearine thus obtained is used in the manufacture of candles, while the oleine forms lard or tallow oil. The former has, of late years, given place to stearic acid, procured from the same

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1168. How may the constituents of oil be separated? 1169. How may the different fats of tallow be separated?

sources, by means to be hereafter described. Margarine may be separated from butter by similar heating and slow cooling. It is regarded by some chemists as a simple mixture of stearine and oleine and not a distinct substance.

1170. GLYCERINE.—*Glycerine* is the base of all the fatty salts which have been mentioned. It is a viscid, sweetish liquid containing the same elements as grape sugar, and in nearly the same proportion. On removing the stearic, and oleic acids from melted stearine or oleine, it remains in the liquid form. This removal may be effected by lime. The white lime compound floats upon the water which is used in the process, while glycerine is dissolved.

1171. STEARIC ACID.—The compound formed by lime, as described in the last paragraph, if tallow has been used in the process, is a mixture of *oleate* and *stearate of lime.* From these, *stearic* and *oleic acids* are liberated by the agency of diluted oil of vitriol. The material floats on the dilute acid, gradually losing lime and becoming transparent by its action. Sulphate of lime or gypsum is formed at the same time and sinks to the bottom of the vessel The stearic and oleic acids are drawn off while yet warm, and run into cubical moulds. The latter is subsequently removed from the mixture by gentle heat and pressure. The remaining stearic acid is then remelted and allowed to cool slowly. It is thus obtained in a brilliant white mass,

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1170. What is glycerine? How is it made? 1171. How is stearic acid made?

of crystalline texture, with the luster of mother of pearl. This material is principally employed in the manufacture of candles. Its superiority to stearine for this purpose, consists in the fact that it is less softened by heat. The two substances differ in their melting point about ten degrees.

1172. Soaps.—Soaps are compounds of stearic and oleic acids with caustic potash or soda.* They are produced by boiling fats with either of the alkalies, until the mixture becomes nearly or quite transparent. The glycerine which is expelled from the fats in the process, remains mixed with the soap which is produced. Potash soaps are soft. Soda soaps may be converted into a floating coagulum, and separated from the water used in their preparation by means of common salt. This method is employed to give them their hardness. The action depends on the insolubility of the soap in salt water. Salt added to potash soap seems to have the same effect. But its action in this case is due to a double decomposition, in which a floating soda soap is formed, chloride of potassium remaining in solution. Soaps may also be made without the use of water, by combining oil or fat with melted potash.

Hard soap is made with soda, the soda being able to absorb more than its own weight of water without becoming fluid. Potash soap is soft because of its great

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1172. How are potash and soda soaps prepared?

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* In the ordinary preparation for soap making, the lye is made to pass through lime in the leach tub, that its carbonic acid may be partially removed.

affinity for water; potash being deliquescent. The best hard soap usually contains 25 per cent. of water. Rosin is mixed with fat in the manufacture of soap to increase its hardness. § 1093. Silicate of soda is also largely employed in the manufacture of washing soap. A suitable proportion of this compound is said to improve the quality of the soap at the same time that it diminishes the cost of production. § 881.

1173. Liniments, etc.—Soaps are soluble in alcohol, forming the *tincture of soap* which is used for bruises. With the addition of camphor, this tincture forms *opodeldoc*, a compound more efficient than the simple tincture of soaps. Transparency is imparted to soap by the evaporation of an alcoholic solution of the well dried material. *Liniments* are soaps prepared from ammonia and oil by the simple agitation of the materials.

1174. Properties of Soaps.—Soaps which are prepared, as above seen, from oils and fats, have the property of dissolving more of the same material. On this property their cleansing effect principally depends. When they are dissolved, a portion of the alkali becomes free by the substitution of water as base. This free alkali adds to the cleansing effect, by its own affinity for the oils and other organic matter. Alkalies alone are not equally effectual; they tend to shrink the fiber of cloth, and thus protect it against a perfect purification. The strength of the tissue is at the same time gradually impaired.

1173. How are transparent soaps and liniments prepared? 1174. Explain the cleansing action of soap.

Soap is freely soluble in pure water, but in salt water it is insoluble; soap made from the oil extracted from the cocoanut is an exception to this rule, as it dissolves freely in salt water, and is hence much used as *marine soap.* Hard water, or water containing salts of lime or magnesia decompose soap, forming a slimy scum, hence such water is unfit for washing unless a portion of free alkali or an additional quantity of soap is added.*

Animal Fluids—Blood, Milk, Etc.

1175. The Blood is the most important and well known fluid of the animal system. In man and the higher animals the blood is red, being of a bright scarlet hue when taken from the arteries and of a somewhat darker hue when drawn from the veins. Healthy blood is about five per cent. heavier than water, and is always alkaline to test paper. It is unctuous to the touch and has a peculiar odor which differs in different animals. When first removed from the body the blood appears to be a uniform red liquid, but when viewed with a good microscope it is found to consist of two parts, a nearly colorless fluid called the blood plasma or the nutrient fluid, and an immense number of cir-

1175. What is the appearance of blood, and what solid bodies does it contain?

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* The hardness of water may be easily tested by adding a few drops of tincture of soap. If the water remains clear it is perfectly soft; if it becomes cloudy, it may be regarded as hard—the degree of hardness being proportioned to the degree of cloudiness caused by adding the tincture of soap.

cular or elliptical disk-shaped bodies or corpuscles floating in the fluid of the blood. In man and the mammalia generally, these corpuscles are circular, as shown in figure 308. But in birds, fishes, and reptiles, they appear generally, as shown in figure 309, of an elliptical form with a central nucleus. Besides the colored corpuscles some colorless bodies are seen, as at *a*, *a*, figure 309, which have a granulated appearance, they are called white corpuscles. In some cases the blood disks adhere together like rolls of coin, as in some parts of figure 308, but they gradually become disunited and scattered.

308

309

1176. Composition of the Blood.—If fresh blood is beaten with a branched stick, it is separated into a slightly alkaline liquid called the *serum*, a fibrous material called *fibrine*, and red globules, mentioned above, which sink, after a time, to the bottom of the vessel. The fibrine adheres in threads to the stick with which the operation is performed. It is analogous in composition and properties to the vegetable gluten

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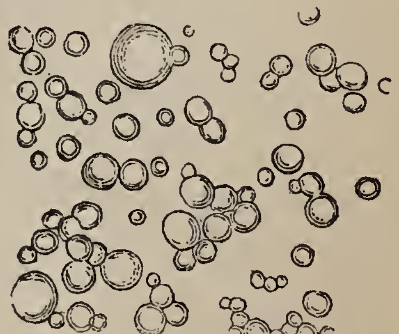
1176. Give the composition of blood.

from which it is formed. The serum contains albumen, and resembles the white of egg. The globules are also principally albumen, with a small proportion of a red coloring matter called *hematosine.* Albumen and fibrine both contain phosphate of lime or bone earth. The serum contains, also, certain salts, and a small proportion of fat. All of these substances together form but about one-fifth of the blood; the remaining four-fifths are water. When blood is left to stand, after being drawn from the body, the fibrine coagulates spontaneously, entangling and taking with it the red globules, and thus separating them from the serum.

1177. Milk.—Milk is analogous to blood in composition, as is implied in the office which it fulfills in the nutriment of the young animal. But casein takes the place of the fibrin of the blood, and fat is also found in milk in much larger proportion. This fluid also contains sugar, which is peculiar in its character and has therefore received the name of *sugar of milk.* The opacity and whiteness of milk are due to minute globules of fat which appear to be surrounded with a thin covering of insoluble matter, differing in its properties from fat, and probably composed of a modification of protein. Figure 310 shows the appearance of milk globules magnified 400 diameters. The size of milk globules varies from a mere point to $\frac{1}{2000}$ of an inch in diameter, the average

310



1177. What is the composition of milk?

being $\frac{1}{4000}$ of an inch. Butter is produced by the coalescence of the small particles of oil which are suspended in milk, and partially separated in the cream. The operation of churning breaks the envelope which surrounds the fat and brings the fat or butter into large masses. Chemically considered, butter is a mixture of oleine and margarine. On partially cooling melted butter, the latter collects at the bottom of the liquid oleine, which forms the other constituent; a portion at the same time remains in solution. Beside the above substance, butter contains phosphates and other salts, with certain neutral fats from which it derives its flavor.

If butter remains exposed for some time to the air, some volatile fat acids are formed having a disagreeable smell and taste; these cause the rancidity in butter.

If butter that has been rancid is boiled several times with double its quantity of water, these acids will be removed from it, and the butter, on cooling, will have regained its original flavor. Butter thus restored does not regain its original appearance, but it may be used in cooking.

1178. Cheese.—On exposure to the air for a considerable time, the sugar contained in milk is partially converted into lactic acid, and the casein is precipitated. One reason of this precipitation is to be found in the neutralization of the free alkali of the milk. The casein having thus lost its solvent assumes the solid form. The coagulation of milk may also be effected

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1173. Why is the curd separated by exposure to the air?

by *rennet*, which consists of an infusion of the lining membrance of the stomach of the calf. Its mode of action is not well understood. In making cheese the process is so conducted as to retain the fat or butter mingled with the solidified casein. This imparts to cheese its richness and excellence.

1179. Solid Milk.—Milk may be brought into the solid form by careful evaporation with a moderate heat. It must be constantly stirred during the process. A machine has been recently patented which secures all of these objects. With the addition of a little soda and gum, milk may be thus kept sweet in the solid condition for many months. The addition of water is all that is necessary to restore it to its original form.

1180. The Fluids Concerned in Digestion are the *saliva* secreted by the glands about the mouth, the *gastric juice* secreted by the stomach; the *bile* secreted by the liver and modified by the secretions of the gall bladder; the *pancreatic fluid* secreted by the pancreas. These fluids will be considered in connection with the process of digestion.

1181. The Saliva is a fluid secreted by the parotid and other glands shown at 1, 2, 3, figure 313, the ducts of which empty themselves into the cavity of the mouth. This fluid lubricates the mouth, moistens the food and facilitates the act of deglutition. In addition to mucus the saliva contains a peculiar organic princi-

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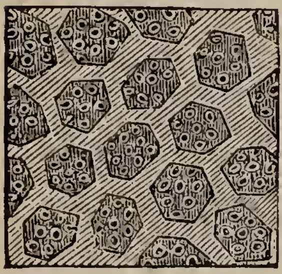
1179. How is solid milk prepared? 1180. What fluids are concerned in digestion? 1181. What are the properties of saliva?

ple termed *ptyalin*, resembling albuminate of soda, which is very prone to putrefaction. Ptyalin has the property of converting starch, even in the granular form into dextrin and into sugar. The flow of saliva into the mouth is greatly increased by the movements of the jaws in mastication. Hence food that is thoroughly masticated is more readily digested than that which is swallowed without sufficient mastication.

1182. THE GASTRIC JUICE, as its name implies, is a fluid poured out from the lining membrane of the stomach. This important secretion is the principal agent in effecting the digestion of the albuminoid portions of the food, but it exerts scarcely any action upon starchy and fatty constituents. Figure 311 gives a magnified view of the honeycomb appearance of the lining membrane of the stomach, in which are seen the orifices of the glands which pour out the gastric juice. Figure 312 shows longitudinal sections of the gastric glands from the stomach of a dog, *c*, *d*, being their orifices, and *e*, *f*, the closed portions imbedded in the walls of the stomach. These follicles or glands are covered with a delicate network of blood-vessels terminating in veins which surround their outlets upon the surface of the mem-

311



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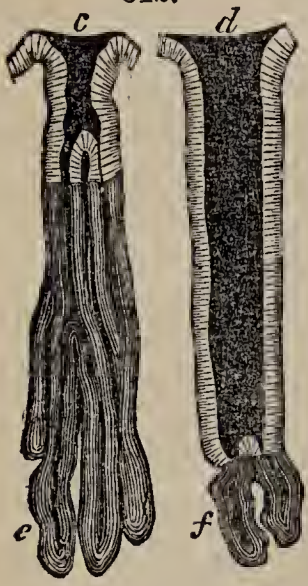

1182. Where is the gastric juice formed?

branes, while nerves without number pervade the entire structure. While the stomach contains no food, and is inactive, no gastric fluid is secreted, and mucus which is either neutral or slightly alkaline covers its surface. But as soon as food or other foreign substances enter the stomach, the mucus membrane, previously quite pale, becomes slightly turgid and reddened with the influx of a larger quantity of blood, the gastric glands commence secreting actively, and an acid fluid is poured out in minute drops which gradually run together and flow down the walls of the stomach, or soak into the substances introduced.

1183. PROPERTIES OF GASTRIC JUICE.—When separated from mucus by filtration it is a colorless limpid liquid, having a peculiar odor, and an acid reaction from the presence of lactic and hydrochloric acids. It sometimes contains phosphoric acid combined with lime. It contains also common salt, chlorides of calcium and magnesium, and some traces of iron.

The gastric juice contains also a small quantity of a peculiar nitrogenous organic compound termed *pepsin*, upon which, in conjunction with the free acid, its remarkable solvent and digestive powers depend. Pepsin is an albuminoid body, soluble in water, but insoluble in alcohol. Its aqueous solutions are precipitated by corrosive sublimate, by salts of lead, and by solutions of tannic acid. When boiled it loses its peculiar power of effecting digestion. Fibrin or coagulated albumen plunged into gastric juice, at the temperature of the

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1183. What are the properties of gastric juice?

body, swells up and becomes gradually disintegrated and dissolved. This property of dissolving fibrin and analogous substances has been verified by experiments on animals; and in one remarkable instance in a human being, in whose stomach there was a fistulous opening.

Medicinal pepsin consists of the dried mucus scraped from the interior of the stomach of animals (the sheep and the pig). It is sometimes incorporated with starch. *Soluble pepsin* consists of this substance dissolved in a solution of chloride of sodium. It is supposed to supply additional digestive power to those whose stomachs are unable to secrete a sufficient quantity of pepsin.

1184. THE PANCREATIC FLUID is secreted by the pancreas. It resembles saliva in some respects. It has an alkaline reaction and putrefies rapidly. It possesses in an eminent degree the power of changing starch into sugar, and it appears to assist in an important manner in the digestion of starchy food, which is not rendered soluble by the action of the gastric juice. In this respect the pancreatic fluid resembles saliva, but its characteristic property is to assimilate oily matters. It forms an emulsion with all oils and fats when mixed with these substances at the temperature of the body. Chemically, this appears to be a process of saponification, by which glycerine is produced and the fatty acids are set free.

1185. THE BILE is a viscous yellow or greenish fluid of a strong bitter taste. The quantity of bile daily

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1184. What is said of pancreatic fluid? 1185 What is said of the bile?

secreted by the liver has been estimated at seventeen or twenty-four ounces, but the amount varies under a great variety of circumstances. The bile secreted by the liver differs much in appearance from that which is taken from the gall bladder where it accumulates as in a reservoir. The gall bladder is an organ largely supplied with very large blood-vessels, from which it secretes mucus, and perhaps other principles, which, added to the bile as it comes from the liver, gives to cystic bile its peculiar character.*

1186. COMPOSITION OF BILE. — Bile has a specific gravity of 1.024, and possesses a slightly alkaline reaction. It mixes with water in all proportions, giving it a yellow color and a viscid frothy consistence. 100 parts of ox bile contain 9.2 parts of solid matter. The bile essentially consists of salts of two pecucliar organic acids, in which soda is the base, namely, the *cholate* and *choleate* of soda, of *cholesterine* and fat as well as mucus and coloring matter. The cholic and choleic acids are of the nature of resinous and fatty acids, and were formerly included under the name *bilin* or resin of the bile. Their salts give to the bile a saponaceous character. Hence ox gall is a powerful detergent, and is much used as such in manufactures and the arts.

1186. Of what is the bile composed ?

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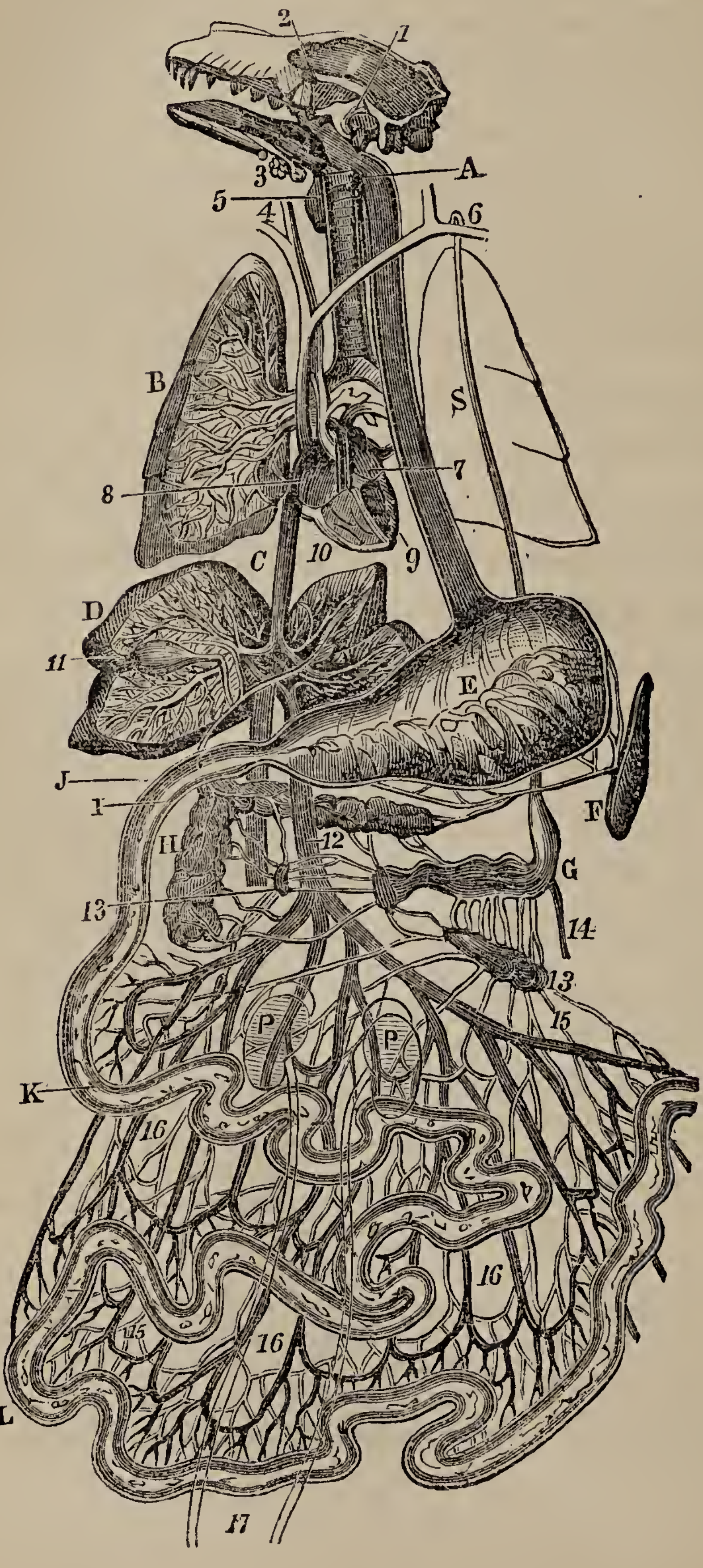
* Bile for analysis is taken from the gall bladder so that we do not know the chemical difference between hepatic bile and cystic bile. But bile as found in the liver has a sweetish taste, while bile from the gall bladder is very bitter. Some animals, as the horse, have no gall bladder, from which it is inferred that the gall bladder exercises no very important influence upon the bile which is collected into this organ from the liver.

VIEW OF THE NUTRITIVE SYSTEM OF A DOG.

313.



Cholesterine when obtained in a pure state consists of colorless scales, lighter than water, which melt at 293°. Briefly, we may say, that analysis of 1000 parts of bile gives water 908 parts, mineral matter containing much soda 12 parts, cholic and choleic acids, with mucus and fat, 80 parts. No albumen is found in the bile, but its organic constituents contain a small percentage of nitrogen. It also contains a notable quantity of sulphur. Sugar is not an ingredient in normal bile, but it is remarkable that this substance is rapidly formed after death from one of the constituents of the liver itself. The action of the bile in digestion in the living body does not admit of any satisfactory chemical explanation. It is supposed to assist in preparing starch and oil for absorption and for being carried into the blood.

1187. Progress of Digestion.—The food received into the mouth is broken up and comminuted by the teeth, and at the same time it is moistened and lubricated by the saliva which acts upon the starchy portions to change them into sugar. The muscles of

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1187. Describe the general course of digestion?

In figure 313 is shown the arrangement of the organs of a dog, which are concerned in nutrition. *A* is the trachea; *B*, lungs; *C*, vena cava; *D*, liver; *E*, stomach; *F*, spleen; *G*, receptacle of the chyle; *H*, pancreas; *I*, duodenum; *J*, entrance of biliary and hepatic ducts; *K*, jejunum; *L*, ileum; *P*, kidneys with supra-renal capsules above. The ureters or tubes which carry away the water discharged by the kidneys are seen on each side of 17, and they may be traced back to the kidneys. *S*, the thoracic duct through which the chyle passes to join the blood. 1, 2, 3, the parotid and other salivary glands; 4, jugular and subclavian veins; 5, situation of thymus and thyroid glands; 6, entrance of thoracic duct into the left subclavian vein near the jugular; 7, left auricle of the heart; 8, right auricle; 9, left ventricle; 10, right ventricle; 12, vena portæ which conveys blood from the intestines to the liver; 13, mesenteric glands; 14, lymphatic vessels; 15, lacteals; 16, branches of the portal vein; 17, ureters.

deglutition then act and carry the masticated food into the stomach, where it remains for a considerable time and is moved about by the muscular contractions of the stomach until it is thoroughly mingled with the gastric juice and a considerable portion is dissolved, forming a semi-fluid mass called chyme. The delicate blood vessels extended upon the lining membrane of the stomach absorb some portions of the liquid food, but the greater portion passes through a valvular opening into the intestines, where it meets with the pancreatic liquid and the bile, by the action of which it is still further digested and dissolved. As it moves onward through the intestines the nutrient portions in a fluid state are taken up by peculiar vessels called lacteals, and carried into the common receptacle of the chyle (*receptaculum chyli*). From this receptacle the chyle is carried by the thoracic duct to the left subclavian vein, which empties into the right auricle of the heart. The nutrient portions of the food are thus carried in a fluid condition, to the heart, where they mingle with the blood and join the general circulation. The organs here referred to are shown in figure 313. That part of the food which is not rendered soluble by digestion, and is hence unfit for assimilation, is left unabsorbed by the lacteals and passes off through the intestines in the form of excrementitious matter.

1188. PREPARATION OF FOOD.—Most of the food used by man is prepared by cooking. By boiling, vegetable

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1188. How is food changed by boiling? Why do domestic animals fatten more rapidly on cooked food than on raw?

acids, sugar, gum, and vegetable albumen are partially removed; solid tissues are softened so that they are more readily broken up by mastication, and rendered more permeable by the saliva and gastric juice. Cells containing starch grains are broken by steam formed within. Starch grains themselves, shown in Figure 284, page 489, may be broken up by pressure so as to assume the appearance shown in Figure 314, but boiling causes them to swell up, and separates the layers as shown in Figure 315. By further boiling, the starch asssumes a gelatinous consistence, and gradually changes first into gum and then into sugar. Hence boiling aids mastication and causes a commencement of those chemical changes which digestion is intended to complete. Much of the food that is taken raw passes through the system unchanged, and of course is useless for the purpose of nutrition. Nutrition depends not merely upon the amount of food taken into the stomach but upon the amount digested and absorbed. It is well known that domestic animals fatten more readily on vegetables or grain that have been boiled than if they are fed upon the same food uncooked.

314

315

Cooking meat is designed principally to soften the fibrous tissues of which it is composed, and to melt the fat and to cause it to flow out from the cells in which it is contained. The different effects of gradual and rapid heating, either in water or in the oven have been already mentioned in Section 1161.

1189. Liebig's Extract of Meat is prepared by putting a pound of lean meat chopped fine into a pint of cold water, to which is added four drops of muriatic acid and a half a teaspoonful of salt. After standing for an hour the liquid is strained through fine muslin, when it is ready for use. The shreds of meat which remain are nearly white and almost tasteless, while the liquid contains most of the nutritious principles of the meat in a fluid condition, especially adapted to the use of invalids. This juice of meat is given cold without cooking, as boiling would coagulate the albumen and fibrin, and render it less digestible.

1190. The Effect of Salt when rubbed upon raw fresh meat is to draw out the juices of the meat so that its fibers contract and a brine is formed without the addition of any other liquid. Meat thus deprived of its juices is less nutritious than fresh meat, and men fed upon salt meat alone, unless supplied with albumen and fibrin from fresh vegetables, soon become affected with scurvy.

1191. Animal Nutrition.—It is evident from Paragraph 1176 compared with 1190, that much of the ma-

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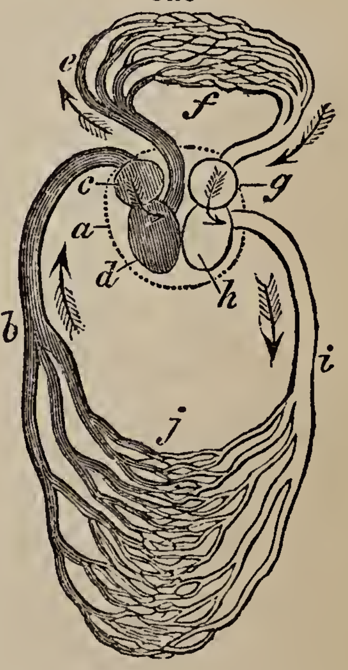
1189. How is Liebig's extract of meat prepared? 1190. Why is salted meat less nutritious than fresh? 1191. What materials are found ready formed in the blood?

terial required to build up the body is found ready formed in the blood. It has been transferred to it from the vegetable world without material change in composition. Thus the fiber which is required for muscle, and fat to fill out the tissues, only require to be built into their places in the animal frame, as a mason lays up a wall from materials provided to his hand. For the production of other animal substances, essential changes are required. The power of selection and appropriation of the proper materials for every organ and every secretion, is found to reside in innumerable minute cells, which are distributed in every part of the body, and endowed with peculiar powers according to the offices they are designed to fulfill.

1192. Circulation of the Blood.—In order that all parts of the animal frame should be built up by the materials contained in the blood, that fluid is carried to every part in a system of tubes called arteries, and the portion of the blood not thus appropriated, together with particles which have exhausted their vital activity, is returned to the central organ, the heart, by another series of canals called veins. Figure 316 gives a general view of the circu-

316



1192. What is the object of the circulation of the blood? Describe the general course of the circulation and how it is effected?

lation of the blood in the higher animals. The heart is a double organ consisting of four cavities or sacs, two auricles and two ventricles, contained within the dotted circle *a*; the vena cava, *b*, delivers the blood and fluids obtained from the digestion of food into *c*, the right auricle which contracts and forces the blood into *d*, the right ventricle. The right ventricle contracts and forces the blood through the pulmonary artery *e*, into *f*, the system of minute blood-vessels in the lungs; *g* is the left auricle which receives the blood from the pulmonary veins, or veins of the lungs, and delivers it to the left ventricle, *h*, which then contracts and propels it through the aorta, *i*, to the systemic capillaries, *j*, from which it is collected by the veins and carried back to the heart through the vena cava, *b*. During life the blood is constantly flowing through this endless circuit, receiving nutrient fluid from the chyliferous ducts, and oxygen from the lungs, distributing its nutrient materials to all parts of the system, and receiving in return the effete matter of the tissues to be carried out of the system.

Chemical Changes in the Animal Body.

1193. Certain important changes which are constantly occurring in the animal body remain to be considered. The body is not the same in any two successive moments of its existence. Every breath exhales a portion of its substance into the atmosphere, and every effort,

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1193. What is said of changes in the animal body?

whether of brain or muscle, is accompanied by some transformation in the material of which it is composed.

1194. CHANGES IN THE BLOOD.—By comparing the blood of animals with their food, it will be evident that certain materials have been not only modified, but entirely transformed in its production. Starch and sugar are important constituents of the food, but they form no part of healthy blood. They are transformed into fat or other material as soon as they enter the circulation, and in this new form constitute the fuel from which the heat of the animal body is derived. Other changes which occur in the blood will be mentioned in subsequent paragraphs.

1195. RESPIRATION consists in the introduction of air into the animal system, and the removal of gases and vapors no longer useful in the animal economy. Respiration is effected in the lungs, which in the higher animals consist of millions of minute air-cells, communicating with the atmosphere by means of the trachea, or windpipe, and its minute branches called bronchi.

1196. THE LUNGS completely fill the cavity of the chest and by the expansion and contraction of the sursounding walls they are alternately enlarged and diminished in size. When the chest expands by the movements of the ribs and diaphragm, the pressure of the atmosphere forces the air through the nose or mouth and trachea, (windpipe) into the lungs. The

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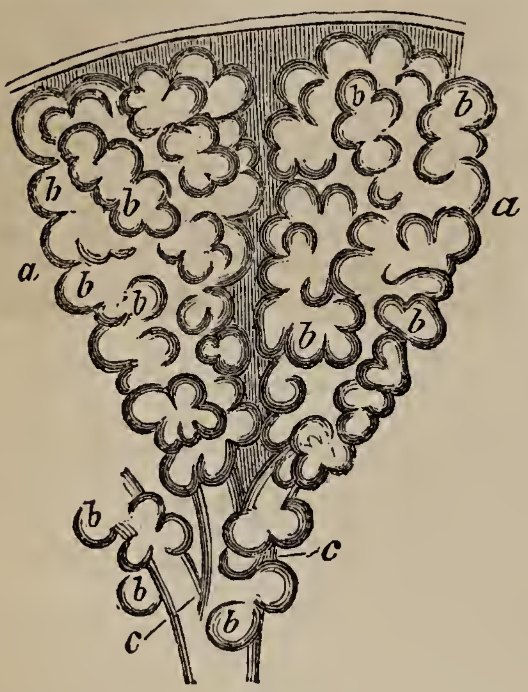
1194. Mention certain changes in the blood? 1195. What is respiration? 1196. Describe the structure of the lungs?

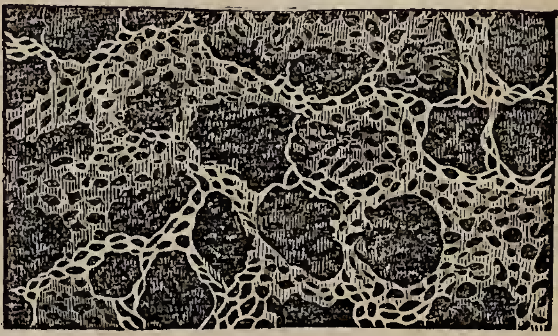
subsequent contraction of the chest expels the air. The general form and position of the lungs are shown in Figure 313. The lungs are divided into a multitude of smaller portions called lobules, *a*, *a*, Figure 317, each of which is supplied with a bronchial tube, *c*, *c*, by which it receives air from the trachea or windpipe. The bronchial tubes open into air-cells which are seen in clusters upon their sides and ends. The air-cells vary from $\frac{1}{120}$ to $\frac{1}{1200}$ of an inch in diameter. Their walls are formed of delicate membrane, continuous with the walls of the branches of the bronchial tubes to which they are attached. This membrane is folded upon itself so as to form a sharp edged border at each circular orifice between contiguous air-cells or between the cells and the bronchial passages. Numerous fibers of elastic tissue are spread out between contiguous air-cells, and many of these are attached to the outer surface of the membrane forming the cells, giving them additional strength and power of recoil after distension. Outside the cells a network of capillary (hair-like) blood-vessels is spread out so densely that the interspaces or meshes are even narrower than the vessels, which are on an average

317



$\frac{1}{3000}$ of an inch in diameter. The arrangement of the cells and capillaries is shown in figure 318. Between the atmospheric air in the cells and the blood in these vessels, nothing intervenes but the thin membrane of the cells and capillaries and a delicate epithelial lining of the former. The exposure of the blood to the air is the more complete because the folds of membrane between contiguous cells, and often the spaces between the walls of the same, contain only a single layer of blood-vessels, both sides of which are thus at once exposed to the air.

318



1197. Animal Heat.—The oxygen which is necessary for the slow combustion of the material above mentioned, (§ 1194), is taken into the blood in the course of its passage through the lungs. It passes on with them, through the arteries, into the minute capillary vessels which are distributed throughout the body In these vessels their combination takes place, with the same production of carbonic acid and evolution of heat as if the material were burned in air or oxygen gas. The carbonic acid thus formed is carried back to the lungs in the venous blood, and there exhaled through the thin membrane of the air-cells, and exchanged for a new supply of oxygen gas. In view of the relations of starch and sugar to the process of respiration, as

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1197. What is the source of animal heat?

above shown, they have been termed the *respiratory constituents* of the food.

1198. In cold weather a larger amount of oxygen is inhaled with every breath, in consequence of the greater density of the air. Respiration is also involuntarily hastened, and the blood from the two causes combined, becomes more thoroughly impregnated with oxygen gas. The transformation or combustion of the respiratory constituents of the blood, proceeds more rapidly in consequence, and more internal heat is produced to oppose the external cold. This is one of the provisions of nature by which the animal body is enabled to resist the influence of the seasons and of climate. Labor has the same effect as cold in hastening respiration and necessitating a larger supply of food.

1199. CHANGE IN COLOR OF THE BLOOD.—From the fact that the globules of the blood undergo a change of color in the lungs, where oxygen is absorbed, it is presumed that they serve, by absorption of the gas, as the medium for its conveyance through the body. As a consequence of the changed color of the globules, arterial blood is of a bright scarlet, while venous blood is dark red. The same change of color which takes place in the lungs, may be readily produced by agitating blood drawn from the veins with air or oxygen gas. It is probable that the blood globules serve not only as carriers of oxygen to all parts of the sys-

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1198. What is said further of respiration? **1199.** What change of color does the blood experience in the lungs?

tem, but that they act as the retorts and receivers, so to speak, where important changes in the blood plasma are effected, by which it is fitted to be built up into the various tissues.

1200. CHANGES IN RESPIRED AIR.—Examination of the air expired from the lungs shows that about 5 per cent. of the oxygen inhaled has disappeared, and that carbonic acid, containing nearly as much combined oxygen has taken its place. An increased amount of watery vapor is also exhaled, showing that a portion of oxygen has united with hydrogen to form water. This increase of moisture and expansion by the heat of the lungs causes the volume of expired air and vapor to be somewhat greater than the amount taken into the lungs. Figure 319 shows the method of estimating the

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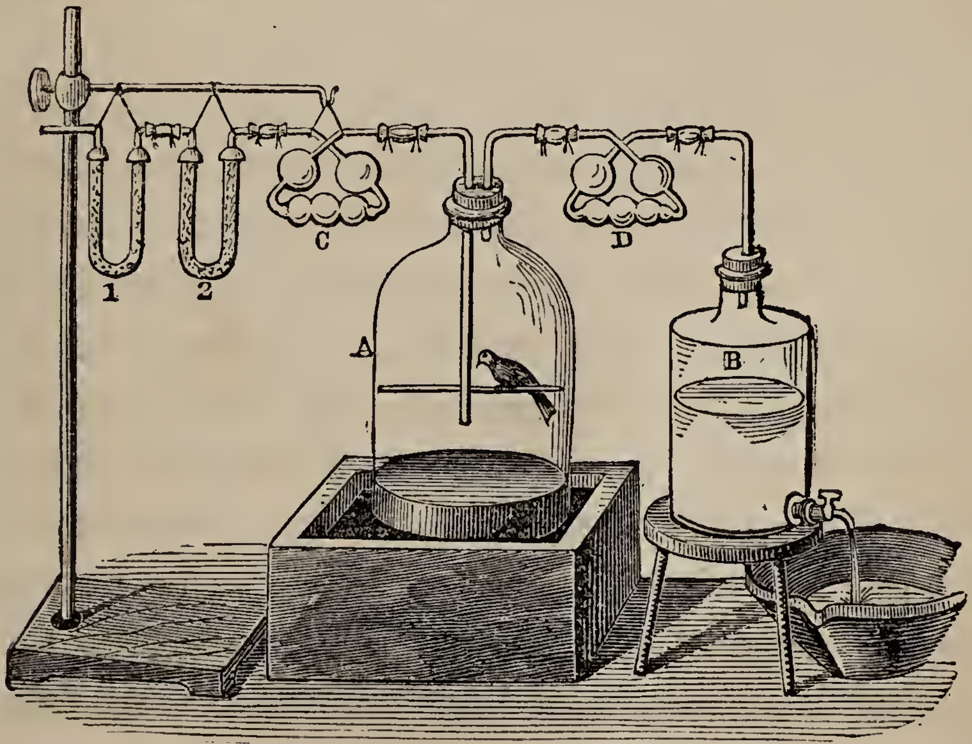

1200. What changes does air undergo in the lungs? How is this shown?

amount of carbonic acid exhaled by a bird or any other small animal. The bird is placed in a bell glass, *A*, standing over mercury. The tubes 1 and 2 contain pumice stone moistened with a solution of caustic potash to absorb all the carbonic acid from the air which enters the bell glass; the bulbs, *C*, contain lime water, and if it remains clear it is known that the air passing through contains no carbonic acid. The vessel, *B*, contains water, and as it is allowed to escape, atmospheric air is drawn through the tubes, and through the bell glass where the bird is confined. The bulbs, *D*, contain caustic potash to absorb the carbonic acid from the air expired by the bird. The increased weight of these bulbs (weighing them before and after the experiment) shows the amount of carbonic acid expired.

1201. OXIDATION THROUGHOUT THE SYSTEM.—If animals are made to respire pure hydrogen or nitrogen, they still continue for some time to exhale carbonic acid. It is therefore inferred that the oxygen is carried to all parts of the system in the blood, and that the change of oxygen to carbonic acid takes place in the capillaries where carbon is taken up from worn-out tissues. Through these delicate blood vessels, smaller than hairs, the vital fluid courses on, bearing oxygen and other nutrient material to the tissues, taking up the products of waste, and itself changing from bright red arterial to dark venous blood, which returns to the lungs for a new supply of the life-bearing oxygen.

1201. Where is the change of oxygen to carbonic acid and water effected?

1202. AMOUNT OF AIR RESPIRED.—The average capacity of the human lungs is reckoned at 225 cubic inches. The lungs are never emptied of air, but about 30 cubic inches are changed at every respiration. The number of respirations varies from 14 to 18 per minute, consuming about 500 cubic inches of air. About twelve times this amount of air are required to carry off the products of respiration and preserve the atmosphere in a suitable condition for the performance of healthy respiration. It is thus evident that free ventilation is essential to health.

1203. ALL ANIMALS REQUIRE AIR.—No animal can live without air. Fishes live on air dissolved in the water in which they live. Insects breathe through elastic tubes opening at their sides. Cold blooded animals require but little air, but any animal confined in a limited supply of air will soon die. A fish confined in a jar of water covered with oil can live but a short time. A bird or a mouse placed under the receiver of an air pump, faints and soon dies if the air is exhausted. The continued life of all animals depends upon the oxidation of food taken as nutriment.

1204. RELATIONS OF FOOD AND TEMPERATURE.—In proportion as the draft of a furnace is increased, more fuel must be supplied for its combustion. For the same reason more respiratory food must be taken into the system, in proportion as more atmospheric oxygen is inhaled. The fact that a larger quantity is required

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1202. What amount of air is required for healthy respiration? 1203. Why do all animals require air?

in northern climates thus receives a scientific explanation. The preference entertained in arctic regions for certain kinds of food is also accounted for by the same necessity for increased resistance to the external cold. The train oil and fat which the Greenlander consumes with avidity, is a better fuel in the animal body than the starch which forms a principal part of the food consumed in warmer climates. The chemical reason of this difference is found in the fact, that starch and allied substances contain oxygen and in larger proportion. They are, as it were, in their natural condition, partially burned or oxidized substances.

1205. CHANGE OF THE ANIMAL TISSUES.—In proportion to the muscular or nervous activity of the animal, the substance of the body is disorganized and returned to the blood from which it was produced. From the blood it is finally removed by the kidneys, principally in the form of *urea* and *uric acid*, and thrown off as waste material from the system. These substances, although organic, may be figuratively regarded as the ashes of the consumed muscle and other nitrogenous constituents of the body. A portion of the carbon and hydrogen of the animal organs has at the same time disappeared, like the elements of respiratory food, in the form of water and carbonic acid.

1206. UREA.—Urea, when separated from its solution is obtained as a white crystalline solid. Its mole-

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1204. What is said of the relations of food and temperature? 1205. What change takes place in the tissues of the body? 1206. What is said of urea?

cule contains four atoms of hydrogen, to two each of carbon, nitrogen, and oxygen. When left in contact with the mucus with which it is accompanied in the secretion of the kidneys, it is speedily converted, by combination with four molecules of water, into carbonate of ammonia. Urea may also be artificially produced from cyanic acid and ammonia. This cyanate is identical with urea in composition, and is converted into urea by solution in water and evaporation. It was among the first of organic bodies artificially produced. Uric acid contains the same elements with a larger proportion of oxygen, and also yields ammonia by its decomposition. Besides the above substances, the secretion of the kidneys contains various soluble salts, which have formed part of the body. The insoluble salts are removed from the system by other means.

1207. Disappearance of Fat.—Starvation.—When the supply of respiratory food is deficient, nature avails herself of the fat previously stored in the animal body, as fuel to sustain the animal heat. It is taken up by the blood, and burned in the capillary vessels, as before described. This happens in the case of the bear and other hybernating animals. Lying dormant during the winter season, their fat is consumed, and they emerge lean from their dens in the spring. Where food is deficient and there is no accumulation of fat to supply its place, the muscle and other portions of the body are consumed, and death by starvation is the consequence.

1207. What is said of the disappearance of fat?

1208. Repair of the Tissues.—As fast as the worn out matter of the muscles and other organs is removed, its place is supplied in the healthy body by new material from the blood. Through it, also, the phosphates of the soil and the vegetable world are transferred to the skeleton of the animal, and in smaller proportion to other parts of the frame. The blood is itself renewed by the materials of the food.

1209. Varieties of Food.—It is implied in the foregoing, that the two classes of substances which enter into the composition of the food of animals, subserve very different purposes in the animal economy. The first class, of which starch and sugar are the principal, serve, by their gradual combustion, to sustain the animal heat. They are included, as above stated, under the general name of *respiratory food.* The protein bodies, on the other hand, all of which contain nitrogen, are appropriated in the formation of blood and muscle; they make up the *sanguineous* or *plastic* food. In view of the fact that the respiratory food enters also, in a changed form, into the composition of the blood, the former term can scarcely be regarded as distinctive. The latter, which designates the office of the protein bodies in furnishing material to build up the organs of the body, is much to be preferred.

1210. Salads and Summer Sours. — Physiological research establishes the fact that acids promote the separation of the bile from the blood, which is then

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1208. How are the tissues repaired? 1209. Mention two classes of food? 1210. What is the use of acid fruits as food?

passed from the system, thus preventing fevers, the prevailing diseases of Summer. It is a common saying that fruits are "cooling," and also berries of every description; it is because the acidity which they contain aids in separating the bile from the blood. Hence the great yearning for greens, lettuce and salads, in the early Spring, these being eaten with vinegar. Hence, also, the taste for something sour, for lemonades, on an attack of fever. But, this being the case, it is easy to see that we nullify the good effects of berries in proportion as we eat them with sugar, or even with sweet milk or cream. If we eat them in their natural state, fresh, ripe, perfect, we are not likely to eat too many, or to eat enough to hurt us, especially if we eat them alone, and not taking any liquid with them whatever.

1211. PROPORTIONS OF FOOD.—For the economical sustenance of animals, it is of importance that a proper relation of quantity should be maintained between these two varieties of food. Respiratory food alone, provides no material for supplying the waste of the organized tissues. Plastic food, on the other hand, is especially adapted to this end, but it is poor fuel for sustaining the heat of the body. Yet in lack of other material, it is diverted from its natural use, and thus appropriated at great economical disadvantage.

1212. Nature teaches us something on this subject, in the composition of milk and those grains which consti-

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1211. What is said of the importance of due proportion of the two kinds of food? 1212. What does nature teach on this subject?

tute the principal food of man. It will be found by reference to the table in the Appendix, that the quantity of respiratory matter in these substances, is from three to six times greater than that of the plastic material. When the object is to fatten an animal, the proportion of respiratory matter may be considerably increased by the use of potatoes, rice and other farinaceous food. Being furnished in excess, it accumulates in the body in the form of fat. Working animals, on the other hand, must be supplied with nitrogenous or plastic food in large proportion. The use of bacon with peas, beans, and eggs, and many other popular mixtures of food, are accounted for on the principle above stated. For the development of most of the views presented in this chapter, the world is indebted to the distinguished Liebig.

CHAPTER IV.

CIRCULATION OF MATTER.

1213. The relations of the three kingdoms of nature have been already incidentally considered in former parts of this work. It remains to present the subject in a single view. It is obvious, at a glance, that the soil does not furnish all the material which is required for the wants of vegetable life. The level of our meadows is not lowered by removal of successive crops, nor does the forest dig its own grave at its roots as it lifts its ponderous trunks into the air. The atmosphere, as well as the soil, contributes to the increase of mass, whether of wood or grain, and indirectly feeds all races of animal existence. The relation of the three kingdoms of nature is thus established.

1214. Water is one of the principal agents in the system of circulation of matter, which constitutes the life of the globe we inhabit. In the fulfillment of its office, it passes incessantly from sky to earth, now mingling with the currents of the atmosphere, and anon with those which form the arteries and veins of

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1213. What proves the relation of the three kingdoms of nature?
1214. How does water serve in the circulation of matter?

the great world of waters. Lifted into the atmosphere by the sun, it descends again in dew and rain, corroding and dissolving the rocks on which it falls, and distributing them widely over land and sea.

1215. It settles through the stony crust of the earth, into the dark recesses of the rocks where crystals blossom out of the formless stone, and supplies them with the material for their wonderful architecture. It penetrates the soil, and supplies the same material to the roots of plants for the still more wonderful creations of leaf, and fruit, and flower. Again it hastens through brooks and rivers on its course, and pours its burden into the sea, for the use of the innumerable forms of vegetable and animal life which inhabit its waters. The coral insects build up solid islands out of the matter it provides. Countless shell-fish clothe themselves in the same rocky garments, and finally cast them aside, to be buried under the slime of the sea and harden, in the course of ages, into stone. The water which has served these various offices, climbs anew into the heavens upon the solar rays, and again descends in the rain, repeating forever its round of service to the earth.

1216. The further relations of the three kingdoms of nature may be presented in a single picture. Imagine a giant tree, the representative of all the vegetation of the earth, spreading wide its branches as a shelter for man and beast. Let us suppose them to subsist en-

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1215. What distinct office does it fulfill ? 1216. How may further relations of the three kingdoms be illustrated ?

tirely upon its fruit, and to warm themselves by fires made from its branches. The tree, through its leaves, draws its supply of gaseous food from the atmosphere, and through its roots, its mineral sustenance from the soil. It has purified the air in the process, of gases which would become noxious by accumulation, and returned to it the oxygen which is the vitalizing breath of the animal world. The mingled material of its food, worse than worthless to animals, has, at the same time been transformed into wood and fruit, and other forms of vegetable matter.

1217. At this point, without interruption in the circuit, commences the return of material to the atmosphere from which it was derived. Animals that feed upon the fruit of the tree, already breathe much of it back again to the air while they live, and the rest is restored by their death and subsequent decay. Leaves that fall and moulder, and branches that are burned as fuel, make the same return of the elements of which they are composed, to the great reservoirs of the atmosphere and earth. And what happens thus to leaf and fruit, happens also at last to the parent tree itself. One by one its giant branches fall and moulder, and melting again into the air, add to its inexhaustible stores of fertility, and provide the material for a new round in the grand system of circulation.

1218. What happens beneath the single tree, occurs also in every flower that lifts its petals to the sun, and

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1217. Explain the return of matter to the atmosphere? 1218. Illustrate the extent of these relations?

is a thousand times repeated in every forest upon the face of the earth. No limits of distance or of size restrict the mutual relations and dependencies of nature. The exhaled carbon of the polar bear feeds the lotus of Egyptian plains, and the breath of the southern lion is redistilled in the fragrance of the Norwegian pine. The particle of matter that once burned in the fire of the poet's brain and floated with his song upon the air, now blooms in the mountain flower and anon lies buried in its mould.

1219. According to the view thus presented, it will be seen that the sun is the great material source of the life of the world. He wings the vapors that rise from the sea, and fall again to make their ministering circuit in the earth. The solar rays are the agents also, in the transformation of matter, which takes place in every leaf and blossom, and provides the animal kingdom with its food.

1220. No less is the sun the source of all the mechanical power which is known upon the earth. The falling flood of Niagara is but the recoil of the spring which is bent in evaporation from the sea and earth. All force which is derived from the fall of water, is thus traceable to the sun, which lifted it in the form of cloud and vapor. The energies of fire and steam, are only other forms of the force inherent in the solar rays, originally exercised in the organization of the vegetable matter which serves as fuel. Immediately produced

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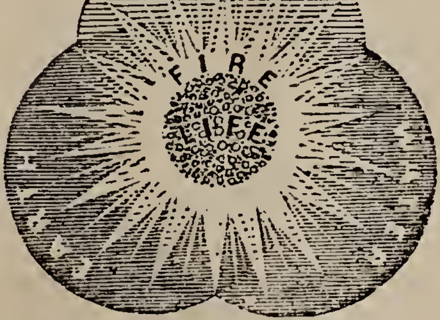
1219. What is the material source of the life of the world? 1220. Show how it is the source of mechanical power?

by oxidation and the heat which it evolves, they find their ultimate source, as well as their precise equivalent, in the deoxidizing influence of the solar rays. The forces of the human body are fed by consumption of similar materials, and may therefore be traced to the same source.

1221. Every planet that surrounds with its orbit the great centre of our system, is equally dependent upon his influence. Held in their courses by his attraction, and encircling him in ceaseless revolution, they draw from the parent orb the strength and beauty which clothes their lesser spheres. What wonder, that in vague acknowledgment of his influence, heathen have acknowledged the sun as their God, and worshiped at his shrine. How natural that Christian nations should find in his life-giving power, a fitting emblem of the glory and beneficence of the great Father of the Universe, by whom all suns and systems, are, and were created.

1221. What further influence has the sun?



PART V.

CHEMICAL PHILOSOPHY.

THE MODERN THEORIES AND NEW NOMENCLATURE.

CHAPTER I.

ELEMENTS.

1222. Classified according to their Atomicity.—The most recent classification of the elements is the division of them into families or groups, *according to the number of atoms of hydrogen they can combine with or replace.* Some of the elements, for example, combine with or replace hydrogen in the proportion of *one* atom to *one* atom of hydrogen; these are technically called *monatomic*, *uni-equivalent*, or *monad* elements. There are other elements which combine with or replace hydrogen in the proportion of *one* atom to *two* atoms of hydrogen; these are called *biatomic*, *bi-equivalent*, or *dyad* elements. There are other elements which combine with or replace hydrogen in the proportion of *one* atom to *three* atoms of hydrogen; these are *triatomic*, *ter-equivalent*, or *triad* elements. There are others which combine with or replace hydrogen in the

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1222. What is the most recent plan of classification of the elements? What is understood by the term monatomic? Define dyads, triads, tetrads, etc., atomicity.

proportion of *one* atom to *four* atoms of hydrogen; these are called *tetratomic*, *quadri-equivalent*, or *tetrad* elements. There are yet two other classes. The members of one of these classes combines with or replaces hydrogen in the proportion of *one* atom to *five* atoms of hydrogen; these are called *pentads*. The members of the other class replace or combine with hydrogen in the proportion of *one* atom to *six* atoms of hydrogen; these are called *hexads*. This power of combining with or replacing hydrogen is called the *atom-fixing power* or the *atomicity* of the elements. Hofmann employs the term *quantivalence* instead of the term atomicity; he consequently designates the elements *univalent*, *bivalent*, *trivalent*, &c., instead of monatomic, biatomic, triatomic, &c.

1223. The atomicity of the elements is indicated by attaching dashes or Roman numerals to their symbols; thus, a monad element, say chlorine, is indicated thus, Cl' or Cl^{I}; a dyad element, say oxygen, thus, O'' or O^{II}; a triad element, say boron, thus, B''' or B^{III}; a tetrad element, say carbon, thus, C'''' or C^{IV}, &c. The Roman numerals are more convenient than the dashes for the higher numbers, and are, therefore, more frequently employed. It is not necessary to indicate the atomicity of a monad element, for if no accent or numeral be attached to the symbol of an element it is understood that that element is a monad.

1224. In the following table the more commonly

1223. How is the atomicity of the elements indicated? 1224. Give the list of monads. How many atoms of hydrogen can one atom of copper replace? Give the list of dyads.

occurring elements are grouped according to their atomicities, and the specific gravities of the gaseous and vaporizable elements in their gaseous state are given, as well as the atomic weights of the elements. If the student has not already committed to memory the names and symbols of the more commonly occurring elements, he must do so now.

TABLE.

Classification of the more commonly occurring elements according to their atomicity, with their symbols, their atomic weights, and the specific gravities of the gaseous and vaporizable elements in their gaseous state.

Names of the Elements.	Symbols.	Atomic Weights.	Sp. gr. of Gases. H = 1.
MONADS—			
Hydrogen	H	1	1
Chlorine	Cl	35.5	35.5
Bromine	Br	80	80
Iodine	I	127	127
Fluorine	F	19	—
Potassium	K	39	—
Sodium	Na	23	—
Silver	Ag	108	—
DYADS—			
Oxygen	O^{II}	16	16
Barium	Ba^{II}	137	—
Strontium	Sr^{II}	87.5	—
Calcium	Ca^{II}	40	—
Magnesium	Mg^{II}	24	—
Zinc	Zn^{II}	65	32.5
Cadmium	Cd^{II}	112	56
Mercury	Hg^{II}	200	100
Copper	Cu^{II}	63.5	—
Cobalt	Co^{II}	58.8	—
Nickel	Ni^{II}	58.8	—

Names of the Elements.	Symbols.	Atomic Weights.	Sp. gr. of Gases. H = 1.
TRIADS—			
Boron	$\mathrm{B}^{\mathrm{III}}$	11	—
Gold	$\mathrm{Au}^{\mathrm{III}}$	196.7	—
Aluminum	$\mathrm{Al}^{\mathrm{III}}$	27.5	—
TETRADS—			
Carbon	C^{IV}	12	—
Silicon	$\mathrm{Si}^{\mathrm{IV}}$	28.5	—
Tin	$\mathrm{Sn}^{\mathrm{IV}}$	118	—
Lead	$\mathrm{Pb}^{\mathrm{IV}}$	207	—
Platinum	$\mathrm{Pt}^{\mathrm{IV}}$	197.4	—
Palladium	$\mathrm{Pd}^{\mathrm{IV}}$	106.5	—
PENTADS—			
Nitrogen	N^{V}	14	14
Phosphorus	P^{V}	31	62
Arsenic	As^{V}	75	150
Antimony	Sb^{V}	122	—
Bismuth	Bi^{V}	208	—
HEXADS—			
Sulphur	S^{VI}	32	32
Chromium	$\mathrm{Cr}^{\mathrm{VI}}$	52.5	—
Manganese	$\mathrm{Mn}^{\mathrm{VI}}$	55	—
Iron	$\mathrm{Fe}^{\mathrm{VI}}$	56	—

1225. There are some elements which have apparently more than one atom-fixing power. We shall refer more at length to this subject in a future chapter; we merely notice it now because the student may have observed in some other books that nitrogen, arsenic, and phosphorus are described as triad elements, whilst in the above table they are given as pentad elements; the fact is, they sometimes act as triads, sometimes as pentads, and sometimes even as monads. Sulphur can

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Give the list of triads; of tetrads; of pentads; of hexads. 1225. What fact is mentioned in regard to nitrogen, arsenic, phosphorus, and sulphur?

act as a hexad, tetrad, or dyad element, and therefore it is frequently given as a dyad element.

1226. ALTERATION OF THE ATOMIC WEIGHTS OF SOME OF THE ELEMENTS.—If the student compares the atomic weights of oxygen, sulphur, and many of the other elements in the above table, with the atomic weights which have been given them in the former part of this work, he will see that the atomic weights assigned to these elements in this part are just double the atomic weights assigned to them in the first part of the book. The system of atomic weights given in the first part is founded upon the hypothesis of Dalton, that, if there is only one combination of two elements, the compound must be *binary;* that is, composed of one atom of each of the elements. At the time that Dalton stated this as a principle, water was the only known compound of hydrogen and oxygen; therefore, according to Dalton's hypothesis, it must be composed of an atom of each of its elements, and therefore, taking the atom of hydrogen to weigh *one*, the atom of oxygen must weigh *eight*, and the rational formula of water must be HO. But oxygen and hydrogen unite by *volume*, to form water, in the proportion of 1 volume of the former to 2 volumes of the latter element; therefore, if Dalton's hypothesis be correct, the hydrogen atom must occupy double the volume the oxygen atom occupies. Now, if this were the case, we should expect a difference in their dilation and compression when subjected to the same variations

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1226. What change has been made in the atomic weights of oxygen, sulphur, carbon, and others? What was Dalton's hypothesis?

of temperature and pressure; but it has been proved by experiment that there is no difference in this respect between the two gases; they expand and contract alike, the pressure being the same for equal additions or subtractions of heat, and they also experience the same change in volume for equal pressures. This uniformity in expansion and contraction extends to all gases, and also to vapors, at some distance above their points of condensation. This uniformity of gases in their relations to heat and pressure have led scientific men to believe that in the same *volume* or *bulk* all gases contain the same number of ponderable atoms set at equal distances, and whose natural repulsion is expressed by the same law. Now, as 1 volume of oxygen is 16 times heavier than 1 volume of hydrogen, and as, according to the law just stated, equal volumes of the two gases contain the same number of atoms, it follows that the atom of oxygen must be 16 times heavier than the atom of hydrogen, and not 8 times, as Dalton considered; and therefore the rational formula for water will not be HO, but must be H_2O, as 2 volumes of hydrogen unite with 1 volume of oxygen to form water.

1227. If hydrogen be taken as unity, both as regards the specific gravity of gases and vapors and as regards their atomic weights, it should follow from this law of volumes that the same numbers should express their densities and atomic weights; and this is the case, as

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What is the present belief of philosophers in regard to the relation between the same volume of different gases and the number of atoms? Illustrate.

the table shows, with some few exceptions, which we must notice. The exceptions are phosphorus, arsenic, mercury, cadmium, and zinc. The densities of the vapors of these bodies, compared with that of hydrogen, are not the same as their atomic weights; but although the atomic weights and vapor densities of these bodies are not the same, they stand in a very simple ratio to each other; thus, the vapor densities of phosphorus and arsenic are twice that of their atomic weights, whilst the vapor densities of mercury, cadmium, and zinc, diverge from the law in precisely the opposite direction to phosphorus and arsenic, for the specific gravities of mercury, cadmium, and zinc, are just half that of their atomic weights. Taking, therefore, an atom of hydrogen to occupy 1 volume, an atom of arsenic or an atom of phosphorus will only occupy half a volume; whilst an atom of cadmium or an atom of zinc, or an atom of mercury, will occupy 2 volumes. We are unable at present to explain why the vapor densities of these five bodies do not conform to the general law; but we may just allude to the fact that their volatile compounds follow the same law as other volatile compounds. This law will be explained hereafter.

1228. The new system of atomic weights is supported, not only by the vapor densities of the elements, but also by their specific heats, and is in harmony with the law of isomorphism, as will be shown hereafter, and it is

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1227. What follows from the law of volumes? What elements form exceptions to this law? 1228. What other facts support the new system of atomic weights?

also more in harmony with chemical facts than the old system of atomic weights

CHAPTER II.

BASIC BODIES.

1229. THE DIFFERENT CLASSES OF COMPOUNDS TO WHICH THE TERM BASE IS APPLIED.—Bases are bodies which unite with acids, and form with them the class of compounds termed salts. There are three classes of compounds to which the term base is applied. These are—

1st. Compounds composed of metals, or compound radicals playing the part of metals and oxygen. Ex.—$Na_2O(NH_4)_2O$, $Zn''O$, Fe'''_2O_3. The bases of this class are frequently called anhydrous bases.

2d. Compounds composed of metals, or compound radicals playing the part of metals and hydrogen and oxygen. Ex.—$NaHO$, NH_4HO, $Zn''H_2O_2$, $Fe'''_2H_6O_6$. The bases of this class are frequently called hydrated bases.

3d. Compounds composed of hydrogen and nitrogen, and hydrogen and phosphorus. Ex.—NH_3. This class of bases has not been alluded to in the former part of this book.

1230. LIST OF THE MORE IMPORTANT BASES BELONGING TO THE 1ST AND 2D CLASSES.—The following is a list of

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229. Define the term base. What are the different classes of bases?

more important bases belonging to the 1st and 2nd classes, and the student, before proceeding further, must commit to memory the names and symbols of these bases.

TABLE.—*A List of the more commonly occurring Anhydrous and Hydrated Bases.*

Potassic oxide (potash)	K_2O	Potassic hydrate (hydrate of potash, caustic potash)	HKO
Sodic oxide (soda)	Na_2O	Sodic hydrate (hydrate of soda, caustic soda)	$NaHO$
Ammonic oxide	$(NH_4)_2O$	Ammonic hydrate	$(NH_4)HO$
Argentic oxide	Ag_2O		
Baric oxide (baryta)	BaO	Baric hydrate (hydrate of baryta)	BaH_2O_2
Strontic oxide (strontia)	SrO	Strontic hydrate (hydrate of strontia)	SrH_2O_2
Calcic oxide (lime, quicklime)	CaO	Calcic hydrate (hydrate of lime, slaked lime)	CaH_2O_2
Magnesic oxide (magnesia)	MgO	Magnesic hydrate (hydrate of magnesia)	MgH_2O_2
Zincic oxide	ZnO	Zincic hydrate	ZnH_2O_2
Cadmic oxide	CdO	Cadmic hydrate	CdH_2O_2
Manganous oxide	MnO	Manganous hydrate	MnH_2O_2
Nickelous oxide	NiO	Nickelous hydrate	NiH_2O_2
Cobaltous oxide	CoO	Cobaltous hydrate	CoH_2O_2
Plumbic oxide (litharge)	PbO		
Cupric oxide	CuO	Cupric hydrate	CuH_2O_2
Ferrous oxide	FeO	Ferrous hydrate	FeH_2O_2
Ferric oxide (sesquioxide of iron)	Fe_2O_3	Ferric hydrate	$Fe_2H_6O_6$
Chromic oxide (sesquioxide of chromium)	Cr_2O_3	Chromic hydrate	$Cr_2H_6O_6$
Aluminic oxide (alumina)	Al_2O_3	Aluminic hydrate	$Al\ H_6O_6$
Mercurous oxide	Hg_2O		
Mercuric oxide	HgO		
Stannous oxide	SnO		
Stannic oxide	SnO_2	Stannic hydrate	$SnH\ O$
Bismuthous oxide	Bi_2O_3		
Antimonious oxide	Sb_2O_3		
Platinic oxide	PtO_2		
Auric Oxide	Au_2O_3		

NOTE.—A large figure upon the line indicates the number of molecules of the compound on the right of it, and it, of course, multiplies all the elements composing the compound, as $3(HN_4)HO$ signifies 3 parts of ammonic hydrate. A figure below the line multiplies the elements on the left hand of it; or, if placed underneath a bracket, the number of molecules of the compound represented in the bracket.

When a metal forms two oxides, the termination *ous* is applied to the one containing the least quantity, and the termination *ic* to the one containing the largest quantity of oxygen. Ex.—Ferr*ous* oxide. Ferr*ic* oxide.

1231. The student will notice that the hydrates of several of the basic oxides are not given in the table. Some of the oxides do not form hydrates, at least they have not as yet been obtained; normal hydrates of other oxides, as the plumbic, have not yet been obtained, but only basic hydrates; and as the insertion in the table of these basic hydrates would only tend to confuse the student, they have been omitted.

1232. A few of the oxides in the table, as the auric and the platinic, have almost equal claims to be classed as acids, as they combine with strong bases.

1233. The student will notice that in this list of bases some of the elements, viz., iron, mercury, and tin, have two different atom-fixing powers, and these are not the only metals which possess this property, but they are the only metals which the table exhibits as possessing this character. Mercury in mercurous oxide is monatomic, and in mercuric oxide diatomic. Tin in stannous oxide is diatomic,* and in stannic oxide tetratomic. Iron in ferrous oxide is diatomic, and in ferric oxide is triatomic; in the Table of Elements iron is placed in the class of hexads, because there is an oxide of iron, ferric acid, having the formula FeO_3. For the same reason chromium is placed in the Table of Elements in the list of hexads, because in chromic acid the metal acts as an hexad.

1232. What is said of auric and platinic oxides? 1233. What is said of the atomicity of iron and zinc?

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* The prefixes *di* signifying two, *tri* three, *tetra* four, *penta* five, *hexa* six, *hepta* seven, &c., are employed.

1234. When a diatomic element replaces oxygen in these basic bodies the only alteration in the formula is the replacement of the oxygen by the diatomic element; thus, the formula for potassic sulphide is K_2S, and the formula for potassic sulph-hydrate is KHS.

1235. When a monad electro-negative element replaces the oxygen in these compounds the formula becomes somewhat changed; thus, the general formula for the compounds formed by the union of an electro-negative monad, say chlorine, with monad metals is—

$$MCl$$

The general formula for the compounds formed by the union of chlorine with dyad metals is—

$$M^{\mathrm{II}}Cl_2$$

The general formula for the compounds formed by the union of chlorine with tetrad metals is—

$$M^{\mathrm{III}}Cl_4$$

The general formula for compounds formed by the union of chlorine with triad metals is—

$$M^{\mathrm{IV}}Cl_3{}^{*}$$

Many chemists write ferric chloride, chromic chloride, and aluminic chloride, in accordance with this general formula, whilst other chemists write these chlorides thus: Fe_2Cl_6, Cr_2Cl_6, and Al_2Cl_6. The reasons for writing these chlorides so will be stated hereafter.

1234. How does the formula of a base change when the oxygen is displaced by a diatomic element or compound? 1235. Write the general formulas for compounds of chlorine with diatomic, triatomic, and tetratomic metals.

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[*] The same general formulæ apply to the other monad electro-negative elements, as iodine, bromine, flourine; we have simply to substitute the symbol of the particular electro-negative element for that of chlorine.

EXERCISES.

1236. Write out the symbols of the following compounds:

1. Sodic chloride. 2. Calcic iodide. 3. Stannic chloride. 4. Argentic bromide. 5. Ammonic chloride. 6. Sodic sulphide. 7. Sodic sulph-hydrate. 8. Ferrous sulphide. 9. Ferrous chloride. 10. Ferric chloride. 11. Ferric sulphide. 12. Bismuthous iodide. 13. Chromic sulphide. 14. Mercurous chloride. 15. Mercurous sulphide. 16. Mercuric chloride. 17. Mercuric sulphide. 18. Aluminic chloride.

1237. Write out the names of the following compounds:

19. $Cu''S''$. 20. $Fe''F_2$. 21. Fe'''_2Br_6. 22. $Mn''Cl_2$. 23. $Mg''H_2S''_2$. 24. $Ca''Br_2$. 25. NH_4HS''.

1238. Bases belonging to the Third Class.—The following are the members of the third class:

Ammonia	H_3N
Phosphuretted hydrogen	H_3P

The hydrogen in these bodies can be replaced in part or altogether by metals or compound electro-positive radicals. Ex.—KH_2N (potassic dihydric nitride), K_3N (potassic nitride), Cu''_3P_2 (cupric phosphide).

1239. Ammonia combines with acids; but phosphuretted hydrogen, on account of its weak basic character, has been combined with only two, hydrobromic and hydriodic, acids. There are two other hydrogen compounds which have a close affinity with the two

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1238. In what way may the hydrogen of ammonia be replaced?

we have just described; these are arsenuretted hydrogen (H_3As), and antimonuretted hydrogen (H_3Sb); these two hydrogen compounds have not been combined with acids, but when the hydrogen has been replaced by compound radicals they behave with acids like the similar compounds of nitrogen and phosphorus. We may just remark, in conclusion, that the hydrogen in the radical NH_4 can be replaced by metals and compound radicals.

1240. THEORY OF TYPES.—According to this theory, the various chemical compounds are framed or constituted on the pattern or type of one or other of a small number of well-known compounds; the types we shall notice here are—

(1) Water,	$\left.\begin{matrix}H\\H\end{matrix}\right\}O$	the type of the oxides, sulphides, &c.
(2) Hydrochloric acid,	$\left.\begin{matrix}H\\Cl\end{matrix}\right\}$	the type of the chlorides, bromides, iodides, fluorides, and cyanides.
(3) Ammonia,	$\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$	the type of the nitrides, phosphides, arsenides, antimonides.

1241. Bodies belonging to the same type must be analogous in constitution, and yield analogous reactions. And they are supposed to be derived from these types by substitution; thus, potassic or sodic hydrate may be regarded as water in which one atom of hydrogen has been replaced by potassium or sodium, for

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1240. What compounds are selected as types of chemical combinations? 1241. How are the different bodies derived from their types?

if we add potassium or sodium to water, the following reaction occurs:

$$K + \left.\begin{matrix}H\\H\end{matrix}\right\}O = \underset{\text{Potassic hydrate.}}{\left.\begin{matrix}K\\H\end{matrix}\right\}O} + H$$

In accordance with this view, potassic or sodic oxide is water in which both atoms of hydrogen have been replaced by an equal number of atoms of the metal; thus, the formula of potassic oxide on this type theory is $\left.\begin{matrix}K\\K\end{matrix}\right\}O$. The hydrated bases are therefore frequently styled the primary bases, and the anhydrous bases the secondary bases.

1242. Potassic or sodic chloride is formed from its type, hydrochloric acid, by substituting the metal in the place of the hydrogen; thus, sodic chloride can be formed by adding sodium to hydrochloric acid:

$$HCl + Na = NaCl + H.$$

Ammonic chloride, NH_4Cl, may be viewed as HCl in which the hydrogen has been replaced by the electro-positive radical NH_4.

1243. Potassic dihydric nitride, $\left.\begin{matrix}K\\H\\H\end{matrix}\right\}N$, may be viewed as ammonia in which one atom of hydrogen in the ammonia has been replaced by one atom of potassium; this potassium compound and the corresponding sodium

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Give the example of potassium and water. 1242. How is sodic chloride formed?

one can be obtained by passing a current of dry ammonia over the metal. Potassic nitride, $\left.\begin{matrix}K\\K\\K\end{matrix}\right\}N$, may be viewed as ammonia in which the three atoms of hydrogen have been replaced by three atoms of potassium.

1244. An atom of a dyad element replaces the two atoms of hydrogen in water, and its hydrate is constructed on a double atom of water; for example, baric oxide and baric hydrate are formulated thus according to the type system—

$$\left.Ba''\right\}O\text{, and }\left.\begin{matrix}Ba''\\H_2\end{matrix}\right\}O_2.$$

1245. As one atom of a triad element replaces three atoms of hydrogen, the oxides of these elements are constructed on three atoms of water, and their hydrates on six atoms of water. Ex.—Ferric oxide and ferric hydrate are formulated according to the type system thus—

$$\left.\begin{matrix}Fe'''\\Fe'''\end{matrix}\right\}O_3\text{ and }\left.\begin{matrix}Fe'''\\Fe'''\\H_6\end{matrix}\right\}O_6.$$

1246. The oxides of tetrad elements are constructed on a double atom of water.

1247. The chlorides, &c., of dyad elements are constructed on two atoms of hydrochloric acid; the chlorides, &c., of triad elements, on three atoms of hydrochloric acid; the chlorides, &c., of tetratomic elements

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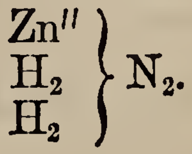
1243. How is potassic nitride formed? 1244. How is baric oxide constructed? 1245. How are oxides of triads formed?

on four atoms of hydrochloric acid, &c.; the general formulæ given at Par. 1235 are examples of this construction.

1248. An atom of a dyad metal replaces two atoms of hydrogen in ammonia, and this compound is constructed on a double atom of the type,



$$\left.\begin{matrix}\mathrm{Zn''}\\ \mathrm{H_2}\\ \mathrm{H_2}\end{matrix}\right\}\mathrm{N_2}.$$

CHAPTER III.

ACID SUBSTANCES.

1249. Characteristics of an Acid.—In the earlier period of chemistry an acid was considered to be an oxidized body which had a sour taste, reddened litimus, and neutralized alkalies; this definition, as we have elsewhere stated, is now too limited. In accordance with the most recent views, an acid may be defined as a compound containing one or more atoms of hydrogen, *which become displaced by a metal* when the latter is presented to the compound in the form of a basic hydrate; the compound produced by the metallic substitution is termed *a salt.* The hydrogen capable of being so displaced may be conveniently termed *displaceable hydrogen.*

1247. How are chlorides of dyads and triads formed? 1249. Give the new definition of acid and salt.

1250. Examples of the substitution of a metal for the hydrogen in acids:

1st Ex.—Substitution of potassium for the hydrogen in hydrochloric acid:

$$\underset{\text{Hydrochloric acid.}}{HCl} + \underset{\text{Potassic hydrate.}}{KHO} = \underset{\text{Potassic chloride.}}{KCl} + \underset{\text{Water.}}{H_2O}$$

2d Ex.—Substitution of potassium for the hydrogen in nitric acid:

$$\underset{\text{Nitric acid.}}{HNO_3} + KHO = \underset{\text{Potassic nitrate.}}{KNO_3} + H_2O$$

3d Ex.—Substitution of one atom of potassium for one of the atoms of hydrogen in sulphuric acid:

$$\underset{\text{Sulphuric acid.}}{H_2SO_4} + KHO = \underset{\text{Hydric potassic sulphate.}}{KHSO_4} + H_2O$$

4th Ex.—Substitution of two atoms of potassium for the two atoms of hydrogen in sulphuric acid:

$$H_2SO_4 + 2KHO = \underset{\text{Potassic Sulphate.}}{K_2SO_4} + 2H_2O$$

1251. The student must not suppose that the hydrogen in acids can only be displaced by a metal when the latter is presented to the acid compound in the form of hydrate, for it can also take place when the metal is in the form of a basic anhydride, and it can take place in many cases when the metal is in the metallic state.

1252. Examples of the substitution of a metal for the displaceable hydrogen when the metal is in the form of a basic anhydride:

1250. Give examples of such substitution. 1251. What other displacement is possible?

(1). $Na_2O + 2HCl = \underset{\text{Sodic chloride}}{2NaCl} + H_2O$

$Zn''O + H_2SO_4 = \underset{\text{Zincic sulphate.}}{Zn''SO_4} + H_2O$

1253. Examples of the substitution of a metal for the displaceable hydrogen in acids when the metal is in the metallic state:

$$Na + HCl = NaCl + H$$
$$Zn'' + H_2SO_4 = Zn''SO_4 + H_2$$

1254. ACIDS EITHER MONOBASIC OR POLYBASIC.—Acids containing one atom of displaceable hydrogen are said to be *monobasic;* those containing two atoms of displaceable hydrogen are said to be *dibasic;* those containing three such atoms are said to be *triabasic,* &c. Acids of greater basicity than unity are frequently termed *polybasic acids.*

1255. Acids, we have shown, were formerly divided into two groups; viz., oxygen acids and hydrogen acids; but according to the definition just given, and also according to the view Davy took of their constitution, all distinction is abolished; but as it will be convenient hereafter to distinguish the acids formerly termed hydrogen acids from those which were termed oxygen acids, we will term the first set acids containing simple or non-oxygenated compound radicals, and the second we will term acids containing compound oxygenated radicals.

1256. The names and symbols of the following acids, and their anhydrides, must be committed to memory:—

1252–53. Give examples of substitution of anhydrides and of metals. 1254. Define monobasic, dibasic, &c. 1255. How are acids now classified?

LIST OF THE MORE COMMONLY OCCURRING ACIDS.

Acids containing simple or non-oxygenated compound radicals.

Hydrochloric acid (muriatic acid) . .	HCl.
Hydrobromic acid	HBr.
Hydriodic acid	HI.
Hydrofluoric acid	HF.
Hydrocyanic acid . . .	$HCN = HCy$.

Hydrosulphuric acid (sulphuretted hydrogen) H_2S.

Acids containing compound oxygenated radicals.

ACIDS.		ACID ANHYDRIDES.	
Nitric acid (hydric nitrate) .	HNO_3	Nitric anhydride	N_2O_5
Chloric acid	$HClO_3$	Chloric anhydride (not yet obtained)	
Sulphurous acid (Di-hydric sulphite)	H_2SO_3*	Sulphurous anhydride . . .	SO_2
Sulphuric acid (Di-hydric sulphate)	H_2SO_4	Sulphuric anhydride . . .	SO_3
Carbonic acid (Di-hydric carbonate)	H_2CO_3*	Carbonic anhydride . . .	CO_2
Oxalic acid (Di-hydric oxalate .	$H_2C_2O_4$	Oxalic anhydride (not yet obtained)	
Chromic acid (Di-hydric chromate)	H_2CrO_4*	Chromic anhydride . . .	CrO_3
Arsenious acid (Tri-hydric arsenite)	H_3AsO_3	Arsenious anhydride . . .	As_2O_3
Arsenic acid (Tri-hydric arseniate)	H_3AsO_4	Arsenic anhydride . . .	As_2O_5
Phosphoric acid (Tri-hydric phosphate)	H_3PO_4	Phosphoric anhydride . . .	P_2O_5
Boracic acid (Tri-hydric borate)	H_3BO_3	Boracic anhydride . . .	B_2O_3
Silicic acid (Tetra-hydric silicate)	H_4SiO_4	Silicic anhydride	SiO_2

1257. The student will notice that all the non-oxygenated oxides in the list have only one atom of displaceable hydrogen, and therefore are monobasic, with the

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1256. Give the symbol of nitric and of sulphuric acid, &c.

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* Sulphurous, carbonic, chromic, and arsenious acids have not yet been obtained; they are supposed to exist in solution, but suffer decomposition when their solutions are evaporated.

exception of sulphuretted hydrogen, which has two displaceable atoms and is therefore dibasic. In the list of oxygenated acids, nitric and chloric acids are the only monobasic acids; sulphurous, sulphuric, carbonic, oxalic, and chromic acids are dibasic; arsenious, arsenic, phosphoric, and boracic acids are tribasic; and silicic acid is tetrabasic.

1258. Formulæ of the Acids according to the Type Theory.—All the non-oxygenated acids, with the exception of sulphuretted hydrogen, are constructed on the type or pattern of one atom of hydrochloric acid. Sulphuretted hydrogen is considered to be constructed on the type of one atom of water; its formula is therefore $\left.\begin{matrix}H\\H\end{matrix}\right\}S$. The monobasic oxygenated acids are considered to be constructed on the type of one atom of water; the formula of nitric acid is therefore, according to this theory, $\left.\begin{matrix}H\\NO_2\end{matrix}\right\}O$, and that of chloric acid $\left.\begin{matrix}H\\ClO_2\end{matrix}\right\}O$. The dibasic acids are considered to be constructed on the type of a double atom of water; the formula of sulphurous acid is therefore $\left.\begin{matrix}H_2\\SO''\end{matrix}\right\}O_2$, that of sulphuric acid $\left.\begin{matrix}H_2\\SO_2\end{matrix}\right\}O_2$, that of carbonic acid $\left.\begin{matrix}H_2\\CO''\end{matrix}\right\}O_2$, that of oxalic acid $\left.\begin{matrix}H_2\\C_2O_2''\end{matrix}\right\}O_2$, and that of chromic acid $\left.\begin{matrix}H_2\\CrO_2\end{matrix}\right\}O_2$. The tribasic acids are con-

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1257. Which of the above are monobasic acids? 1258. How are the dibasic acids constructed?

sidered to be constructed on the type of three atoms of water; the formula of arsenious acid therefore becomes $\left.\begin{matrix}H_3\\As'''\end{matrix}\right\}O_3$, that of arsenic acid $\left.\begin{matrix}H_3\\AsO'''\end{matrix}\right\}O_3$, that of phosphoric acid $\left.\begin{matrix}H_3\\PO'''\end{matrix}\right\}O_3$, and that of boracic acid $\left.\begin{matrix}H_3\\B'''\end{matrix}\right\}O_3$. Tetrabasic acids are considered to be constructed on the type of four atoms of water; the formula of silicic acid therefore becomes $\left.\begin{matrix}H_4\\Si''''\end{matrix}\right\}O_4$.

1259. In the former part of this book we have noticed two other oxygenated acids; viz., hyposulphurous acid and hyposulphuric acid; the former acid, which is also called dithionous acid, has not been obtained, neither has its anhydride, but, judging from the composition of its salts, its formula must be $H_2S_2H_2O_4$* Hyposulphuric acid, also called dithionic acid, has been obtained, but not its anhydride; the formula of the acid is $H_2S_2O_6$.

1260. RELATION OF THE ACID ANHYDRIDES TO THE ACIDS.—The acid anhydrides stand as regards their composition in the same relation to the acids as the basic anhydrides stand to the basic hydrates; and the acid anhydrides, like the basic anhydrides, are divided from the hydrates by decomposition of these latter bodies into the anhydrides and water. Examples:

How are tribasic acids constructed? 1260. How are the anhydrides related to the acids?

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* Dithionous acid is an example that all the hydrogen in an acid is not necessarily displaceable by a metal; thus, the formula of sodic hyposulphite is $Na_2S_2H_2O_4$; that of baric hyposulphite is $BaS_2H_2O_4$; thus, we see that only one-half the hydrogen in hyposulphurous acid is displaceable by a metal.

(1) $$\underset{\text{Chromic acid.}}{H_2CrO_4} \quad - \quad H_2O \quad = \quad \underset{\text{Chromic anhydride.}}{CrO_3}$$

(2) $$\underset{\text{Calcic hydrate.}}{CaH_2O_2} \quad - \quad H_2O \quad = \quad \underset{\text{Calcic oxide.}}{CaO}$$

1261. Some of the acids, such as sulphurous, carbonic, and chromic acids, are so readily split up into their anhydrides and water that they can not be isolated from their solutions, as they immediately decompose into these substances. Other acids, on the contrary, can not be decomposed into their anhydrides and water; the anhydrides in these cases are obtained from their salts. Some anhydrides, such as chloric and oxalic, are so unstable that they have not been obtained.

1262. We will now show by examples the different stages in the decomposition of monobasic, dibasic, tribasic, and tetrabasic acids, into their anhydrides and water, as, theoretically, all acids can be so decomposed.

1263. In the decomposition of monobasic acids there can be only *one stage*, and *two* atoms of acid are required in the decomposition. Example:

$$\underset{\text{Nitric acid.}}{2HNO_3} \quad - \quad H_2O \quad = \quad \underset{\text{Nitric anhydride.}}{N_2O_5}$$

1264. In the decomposition of bibasic acids there can be only *one stage*, and only *one* atom of acid is required in the decomposition. Example:

$$\underset{\text{Sulphuric acid.}}{H_2SO_4} \quad - \quad H_2O \quad = \quad \underset{\text{Sulphuric anhydride.}}{SO_3}$$

1265. In the decomposition of tribasic acids there can be three stages:—1st, in which two atoms of acid are

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1261. What is said of sulphurous and carbonic acids? 1263. Describe the decomposition of monobasic and dibasic acids.

required, and one-third of the hydrogen in the form of water is removed, *a tetrabasic acid remaining.* 2d, in which one atom of the acid is required, and two-thirds of the hydrogen is removed in the form of water, a *monobasic acid remaining.* 3d, in which two atoms of acid are required, all the hydrogen being removed in the form of water, the acid anhydride remaining. Examples:

(1)	$2H_3PO_4$ Trihydric phosphate.	—	H_2O	=	$H_4P_2O_7$ Tetrahydric phosphate. (Pyrophosphoric acid.)
(2)	H_3PO_4	—	H_2O	=	HPO_3 Monohydric phosphate. (Metaphosphoric acid.)
(3)	$2H_3PO_4$	—	$3H_2O$	=	P_2O_5 Phosphoric anhydride.

1266. The student will see that there can be two stages in the decomposition of a tetrabasic acid—1st, in which *one-half* the hydrogen is removed in the form of water, a *bibasic acid* remaining; 2d, in which the whole of the hydrogen is removed, the acid anhydride remaining. Examples:

(1)	H_4SiO_4	—	H_2O	=	H_2SiO_3 Dihydric silicate. (Metasilicic acid.)
(2)	H_4SiO_4	—	$2H_2O$	=	SiO_2 Silicic anhydride.

1267. When there are two or three different varieties of an acid, as in the case of phosphoric and silicic acids, the common one is termed the ortho-acid; orthophosphoric acid means the trihydric phosphate, orthosilicic acid means the tetrahydric silicate. The different

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1265. Describe the decomposition of a tribasic acid. 1267. What does the prefix ortho- signify?

salts of the ortho-acids are also distinguished by the prefix ortho-, as ortho-phosphates, ortho-silicates.

1268. PROPERTIES OF THE ANHYDRIDES.—All acid anhydrides are more or less quickly converted into the corresponding acids by the action of water or of hydrates; in the dry state, or when dissolved in ether or other liquids which do not change them into acids, they are without action on litmus or other vegetable colors.

1269. A few combinations of anhydrides with acids are known; thus, the body called Nordhausen sulphuric acid is a combination of sulphuric acid and sulphuric anhydride. A combination of hydrochloric acid and sulphuric anhydride is also known.

1270. The anhydrides of the polybasic acids combine with ammonia, forming a peculiar class of acids. Ex.—Sulphamic acid, NH_3SO_3; carbamic acid, NH_3CO_2; oxamic acid, $NH_3C_2O_3$, &c.

1271. NOMENCLATURE OF ANHYDRIDES AND ACIDS.—Many chemists have abandoned the term anhydride, and simply employ a prefix to indicate the quantity of oxygen in this class of compounds; thus, they name N_2O_5 nitric pentoxide, SO_3 sulphuric trioxide, CO_2 carbonic dioxide, &c.

1272. The most systematic names for the acids containing simple or non-oxygenated radicals would be hydric chloride, hydric cyanide, hydric bromide, and they are frequently so named.

1268. What are the properties of the anhydrides? 1270. What is sulphamic acid?

1273. The systematic names of the acids containing oxygenated acid radicals are inserted in the table in parenthesis.

1274. Answers to the following exercises must now be written out.

EXERCISES.

26. State the specific gravities of oxygen, chlorine, phosphorus vapor, nitrogen, mercury vapor, referred to that of hydrogen as unity.

27. Give the formulæ of sulphuric, sulphurous, hyposulphuric and hyposulphurous acids.

28. Explain what is meant by the terms monobasic, dibasic, and tribasic acids, and give examples of each class.

29. Write out the formulæ of ortho-silicic acid and ortho-phosphoric acid.

30. In what proportions by volume do H and Cl unite to form hydrochloric acid?

31. In what proportions by volume do N and H unite to form NH_3?

32. In what proportions by volume do phosphorus vapor and H unite to form PH_3?

33. In what proportions by volume do N and O unite to form nitrous oxide (N_2O) and nitric oxide (N_2O_2)?

34. Give the formulæ for carbamic, sulphamic, and oxamic acids.

CHAPTER IV.

SALTS.

1275. Salts and their Classification.—When the displaceable hydrogen of an acid is displaced, either wholly or partially, by a metal, the compound produced is called a salt. It will at once be evident to the student that when there is only one atom of displaceable hydrogen in the acid that it will also be replaced by one atom of a monad metal, and therefore only one class of salts can be formed. But when there are two displaceable atoms of hydrogen, two classes of salts may be formed with a monad metal; viz., one class in which only one atom of the hydrogen has been displaced by one atom of the metallic monad, the other atom of hydrogen remaining in the salt; the other class in which both atoms of hydrogen have been displaced by an equal number of atoms of a metallic monad, or by one equivalent of a dyad metal.

1276. It will also be evident that when there are three displaceable atoms of hydrogen in the acid there can be three classes of salts; viz., one in which one atom of the hydrogen only has been displaced, the

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1275. Define a salt. 1276. What acids are capable of forming three classes of salts?

other two atoms remaining in the salt; another class, in which one atom of hydrogen remains, the other two having been displaced either by two atoms of one monad metal or by two different monad metals, or by one atom of a dyad metal; and a third class, in which also the three atoms have been displaced either by three atoms of a monad metal or by one atom of a monad and one atom of a dyad metal, or by one atom of a triad metal.

1277. ACID SALTS AND NORMAL OR NEUTRAL SALTS.—A salt which contains displaceable hydrogen is called an *acid* salt; a salt which contains no displaceable hydrogen is called a *normal* or *neutral** salt.

1278. *A normal salt, then, is one in which the displaceable hydrogen of the acid is all exchanged for an equivalent amount of a metal, or of a positive compound radical.*

1279. *An acid salt is one in which the displaceable hydrogen of the acid is only partially exchanged for a metal or positive compound radical.*†

1280. The general formulæ of all the different classes of salts are given in the table, and illustrated by examples. These general formulæ ought to be committed to memory.

1278. What is a normal salt? 1279. What is an acid salt?

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* The term normal ought only to be employed, and the term neutral should be applied only to those salts which have no action on vegetable colors.

† There is also a class of salts called basic salts, but these we shall not explain at present.

GENERAL FORMULÆ OF SALTS.		EXAMPLES.	
Nitrates	$M'NO_3$	Sodic nitrate	$NaNO_3$
	$M''(NO_3)_2$	Calcic nitrate	$Ca''(NO_3)_2$
	$M'''(NO_3)_3$	Bismuthous nitrate	$Bi'''(NO_3)_3$
Chlorates	$M'ClO_3$		
	$M''(ClO_3)_2$		
	$M'''(ClO_3)_3$		
Acid sulphites	$M'HSO$	Hydric potassic sulphite	$KHSO_3$
Sulphites	M'_2SO_3	Potassic sulphite	K_2SO_3
	$M''SO_3$	Calcic sulphite	$Ca''SO_3$
	$M'''_2(SO_3)_3$		
Acid sulphates	$M'HSO_4$	Hydric sodic sulphate	$NaHSO_4$
Sulphates	M'_2SO_4	Sodic sulphate	Na_2SO_4
		Sodic ammonic sulphate	$NaNH_4SO_4$
	$M''SO_4$	Baric sulphate	$Ba''SO_4$
	$M'''_2(SO_4)_3$	Aluminic sulphate	$Al_2'''(SO_4)_3$
Acid carbonates	$M'HCO_3$		
Carbonates	M'_2CO_3		
	$M''CO_3$		
	$M'''_2(CO_3)_2$		
Acid oxalates	$M'HC_2O_4$		
Oxalates	$M'_2C_2O_4$		
	$M''C_2O_4$		
	$M'''_2(C_2O_4)_3$		

GENERAL FORMULÆ OF SALTS.		EXAMPLES.	
Acid chromates . .	$M'HCrO_4$		
Chromates . . .	M'_2CrO_4 $M''CrO_4$ $M'''_2(CrO_4)_3$		
Acid phosphates . .	$M'H_2PO_4$	Dihydric sodic phosphate .	NaH_2PO_4
	M'_2HPO_4	Hydric disodic phosphate . Hydric ammonic sodic phosphate	Na_2HPO_4 $NaNH_4HPO_4$
	$M''HPO_4$	Hydric magnesic phosphate .	$Mg''HPO_4$
Phosphates . .	M'_3PO_4	Tripotassic phosphate . .	K'_3PO_4
	$M''M'PO_4$	Calcic potassic phosphate .	$Ca''KPO_4$
	$M''_3(PO_4)_2$	Calcic phosphate . .	$Ca''_3(PO_4)_2$
	$M'''PO_4$	Bismuthous phosphate . .	$Bi'''PO_4$
Acid arseniates . .	$M'H_2AsO_4$ M'_2HAsO_4 $M''HAsO_4$		
Arseniates . . .	M'_3AsO_4 $M''M'AsO_4$ $M'''_2(AsO_4)_2$ $M''''AsO_4$		
Acid arsenites . .	$M'H_2AsO_3$ M'_2HAsO_3 $M''HAsO_3$		

GENERAL FORMULÆ OF SALTS.

Arsenites . . .	M'_3AsO_3 $M''M'AsO_3$ $M''_3(AsO_3)_2$ $M'''AsO_3$
Acid borates . . .	$M'H_2BO_3$ M'_2HBO_3 $M''HBO_3$
Borates	M'_3BO_3 $M''M'BO_3$ $M''_3(BO_3)_2$ $M'''BO_3$
Acid silicates . . .	$M'H_3SiO_4$ $M'_2H_2SiO_4$ $M''H_2SiO_4$ M'_3HSiO_4 $M''MHSiO_4$
Silicates	M'_4SiO_4 $M''M'_2SiO_4$ M''_2SiO_4 $M'''MSiO_4$ $M'''_2M''(SiO_4)_2$ $M'''_4(SiO_4)_3$

1281. It was considered unnecessary to give examples of all the salts of the different acids; examples of the silicates has not been given, as the composition of many of them has not, in my opinion, been well determined.

1282. Many chemists make the name of the salt to terminate in *um*, instead of in *ic*, as potassi*um* nitrate, hydric potassi*um* sulphate.

1283. The formulæ for the following salts must be written out, along with the combining proportions of the electro-positive elements, the electro-negative radical, and the salt.

Example:—Hydric disodic phosphate, Na_2HPO_4 . . $\begin{cases} Na_2 = 46 \\ H \;\;= 1 \\ P \;\;= 31 \\ O_4 \;= 64 \end{cases}$

Atomic weight of the salt . 142

EXERCISES.

35. Ammonic nitrate.
36. Baric nitrate.
37. Potassic nitrate.
38. Cupric nitrate.
39. Plumbic nitrate.
40. Ferric nitrate.
41. Potassic chlorate.
42. Calcic chlorate.
43. Baric chlorate.

1282. What termination is used in place of *ic* by some authors?

44. Calcic sulphite.
45. Hydric sodic sulphite.
46. Magnesic sulphite.
47. Stronic sulphite.
48. Ammonic sulphate.
49. Zincic sulphate.
50. Ferric sulphate.
51. Cobaltous sulphate.
52. Ferrous sulphate.
53. Cupric sulphate.
54. Hydric potassic carbonate.
55. Baric carbonate.
56. Magnesic carbonate.
57. Sodic carbonate.
58. Hydric ammonic oxalate.
59. Nickelous oxalate.
60. Argentic oxalate.
61. Cadmic oxalate.
62. Ferrous oxalate.
63. Argentic chromate.
64. Plumbic chromate.
65. Sodic chromate.
66. Calcic chromate.
67. Potassic chromate.
68. Trisodic phosphate.
69. Magnesic ammonic phosphate.
70. Triargentic phosphate.
71. Plumbic phosphate.
72. Ferric phosphate.
73. Hydric cupric arseniate.

74. Dihydric sodic arseniate.
75. Triargentic arseniate.
76. Magnesic ammonic arseniate.
77. Hydric cupric arsenite (*Scheele's green*).
78. Triarsenite of silver.
79. Hydric calcic arsenite.

1284. The combinations of the metals with the non-oxygenated acid radicals have already been explained at par. **1235**; but in order that the student may experience no difficulty, we will explain them a little more fully. Chlorine, bromine, iodine, fluorine, and cyanogen, are monatomic; the following general formulæ will therefore express their combinations with the metals; M being the symbol for the metal, and X for the acid radical.

Formula when the metal is monatomic .. MX.
Formula when the metal is diatomic .... $M''X_2$.
Formula when the metal is triatomic .. $M'''X_3$.
Formula when the metal is tetratomic .. $M''''X_4$*

We have already noticed that ferric, aluminic, and chromic chlorides are formulated somewhat differently (par. **1235**) by many chemists.

1285. When sulphur acts as a diatomic element the compounds formed by its combination with the metals correspond in composition to the oxides, having sulphur in the place of oxygen.

1285. What compounds does sulphur form with the metals

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* These formulæ also express the composition of the compounds formed by the union of these electro-negative bodies with the monatomic, diatomic, triatomic and tetratomic non-metallic elements.

1286. Write out the names of the following salts:

80. $Ca''So_4$.
81. $KClO_3$.
82. $Sr''CO_3$.
83. $As'''Cl_3$.
84. $Cu''H_2SiO_4$.
85. Fe'''_2Cl_6.
86. NH_4NO_3.
87. $Ba''SO_3$.
88. Na_2HAsO_4.
89. $Ca''HAsO_3$.
90. $Ba''I_2$.
91. $Bi''Cl_3$
92. $Pb''(NO_3)_2$.
93. K_2CrO_4.
94. NH_4HS.
95. Fe''_2SiO_4.
96. Na_3BO_3.

1287. Double Salts.—It has already been remarked that salts combine with each other, but by no means indiscriminately. With a few exceptions, which need not be considered, the combining salts have always the same acid—sulphates combining with sulphates, chlorides with chlorides. Their *bases or their metals* belong to different natural families.

1288. Several of the magnesian sulphates contain, as we have seen, seven atoms of water, and that one of these atoms possesses functions altogether different from those of the other six atoms; it can be replaced, for instance, by anhydrous sulphates not isomorphous with the magnesian sulphates, as, for instance, by potassic sulphate. When this atom of constitutional or saline water, as it has been called by Graham, is replaced by an anhydrous salt, a double salt, of course, is produced. Examples: The formula for crystallized magnesic sulphate is $Mg''SO_4, H_2O + 6H_2O$; the formula for crystallized magnesic potassic sulphate is $Mg''SO_4, K_2SO_4 + 6H_2O$.

1289. Sulphates of the triatomic metals often unite with sulphates of the monad metals or radicals; the

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1287. How are double salts formed? 1288. What displacement of a water atom may occur in magnesian sulphates?

important group of salts termed alums are examples of this class of double salts. The general formula for the alums is $M_2'''(SO_4)_3, M'_2SO_4 + 24H_2O$. M_2''' represents any of the following metals: Al_2''', Cr_2''', Fe_2''', or Mn_2'''; the M'_2 represents K_2, Na_2, or $(NH_4)_2$.*

The formula for ordinary or potash alum is $Al_2'''(SO_4)_3, K_2SO_4 + 24H_2O$; it may be called either aluminic dipotassic sulphate, or aluminic dipotassic tetrasulphate.

1290. "Instances are common in which two different haloid salts unite with each other; compounds of this description are most usual between the chlorides, iodides, and bromides of the less oxidizable metals, with those of the metals contained in the alkalies and alkaline earths; the double chloride of platinic chloride and potassic chloride ($2KCl,PtCl_4$), and the double iodide of mercuric iodide and potassic iodide $2KI, HgI_2$), are good instances of such compounds. Bonsdorff proposed to consider these compounds in the light of salts, in which the chloride and iodide of the more electro-negative metal (platinum, gold, &c.), acted the part of an acid toward the electro-positive chloride (chloride of potassium, sodium, &c.; but this view is not tenable. Such salts are never resolved by electric action into their constituent chlorides, and the acid reaction of the higher chlorides is not neutralized or modified by combination with the chlorides of the alkaline metals; in

1289. What is the general formula for the alums? 1290. How do haloid salts unite?

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* According to some chemists, the general formula for alums is $M'''M'(SO_4)_2 + 12H_2O$.

fact, the constituent chlorides themselves are salts. These double haloid salts may be named in one or other of the following ways. Taking the double chloride of platinum and potassium as an example, platinic and dipotassic chloride, or platinic dipotassic hexchloride.

1291. "Many double salts may be formed by fusion with each other, though they can not be procured by the usual method of crystallization from a solution containing equivalent quantities of the two salts. Chloride of sodium, for example, may be melted with an equivalent amount of calcic, strontic, or of baric chloride, and in each case a compound salt is obtained which has a much lower fusing-point than either of its component chlorides in a separate form, but the double salt is decomposed when it is dissolved in water."

1292. BASIC SALTS OR SUBSALTS.—Many basic oxides of the metals can unite with their salts in a manner analogous to that by which water of crystallization is retained in ordinary instances; salts containing an excess of base, i. e., *salts containing a larger number of equivalents of the metal or compound electro-positive radical than the acid contains of displaceable hydrogen are termed basic salts or subsalts.*

1293. "The tendency to the formation of subsalts is limited to certain acids and bases. It is, indeed, one of the peculiarities of the monad bases, such as the alkalies and argentic oxide, that they do not form basic salts; whilst the dyads, such as the oxides of copper, lead,

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1291. What double salts may be formed by fusion? 1292. What is basic salt?

mercury, and zinc, have a strong tendency to do so; while the oxides of the triads, when basic, such as the oxides of antimony and bismuth, have a still greater propensity to form basic salts. No general rule can be laid down for the acids, but among the common acids those which most frequently form basic salts are the sulphuric, nitric, carbonic, and acetic acids."

1294. NOMENCLATURE OF THE BASIC SALTS.—The prefixes di, ter, tetra, &c., are employed, and generally the word basic is added. Ex.—Tribasic cupric sulphate, $Cu''So_4$, $2(Cu''O'', H_2O'')$; dibasic plumbic nitrate, $Pb''2NO_3$, $Pb''O''$, H_2O.

1295. OXYCHLORIDES, &c.—Many of the basic oxides can unite with the haloid salts of the metals. Ex.—Diplumbic oxydichloride, $Pb''O''$, $Pb''Cl_2$; octoplumbic hept-oxydichloride, $7Pb''O''$, $Pb''Cl_2$.

1296. ANHYDRO-SALTS, OR SALTS COMBINED WITH AN ACID ANHYDRIDE.—We have seen that the acid anhydrides can combine with acids and also with ammonia (pars. 1269, 1270), forming with this last body a peculiar class of acids; the acid anhydrides can also combine with salts. We know, for example, two chrome salts having the following composition:—K_2CrO_4, CrO_3, and K_2CrO_4, $2CrO_3$; there is also a salt of soda of this composition, Na_2SO_4, SO_3, and no doubt many of the silicates contain silicic anhydride united with a silicate. Some chemists name the two chromates we have given as potassic anhydrochromate and potassic dianhydro-

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1294. How are the basic salts named? 1296. Give an example of combination between an acid anhydride and a salt.

chromate; the old names were bichromate and terchromate. Other chemists write the formula of the bichromate thus, $K_2Cr_2O_7$, and the sulphuric salt thus, $Na_2S_2O_7$. The most common salt of boracic acid, viz., borax or biborate of soda according to the old nomenclature, appears to be a metaborate united with boracic anhydride, $2NaBO_2, B_2O_3$.

1297. Write out the formulæ for the following salts:

EXERCISES.

97. Aluminic diammonic tetrasulphate (ammonia alum).
98. Ferric dipotassic tetrasulphate (iron alum).
99. Tribasic mercuric sulphate.
100. Platinic diammonic hexchloride.
101. Auric sodic tetrachloride.

1298. The character of the Salts formed by the union of Acids with Ammonia and with Phosphuretted Hydrogen.—Ammonia unites, as has already been stated, with acids, and the salts formed are the same in character as those which are formed when ammonic hydrate unites with acids. Ex.—

$$NH_3 + HCl = \underset{\text{Ammonic chloride.}}{NH_4Cl}$$

$$2NH_3 + H_2SO_4 = \underset{\text{Ammonic sulphate.}}{(NH_4)_2SO_4}$$

1299 Phosphuretted hydrogen unites directly with hydriodic and hydrobromic acids when they are presented to it in the nascent state (see par. 1239), form-

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1298. How is ammonic sulphate formed?

ing compounds isomorphous with the corresponding salts in the nitrogen series:—

$$\mathrm{PH_3} \quad + \quad \mathrm{HI} \quad = \quad \underset{\text{Phosphonic iodide.}}{\mathrm{PH_4I}}$$

$$\mathrm{PH_3} \quad + \quad \mathrm{HBr} \quad = \quad \underset{\text{Phosphonic bromide.}}{\mathrm{PH_4Br}}$$

1300. We will close the chapter by giving a few examples of ammonic salts in which one or more atoms of the hydrogen have been replaced by a metal. (See par. 1248.)

Dimercuric diammonic dichloride, $\mathrm{HG_2''H_4N_2Cl_2}$; this compound is formed when an aqueous solution of mercuric chloride is treated with ammonia.

Platinic diammonic dichloride, $\mathrm{Pt''H_6N_2Cl_2}$.

Cupric diammonic sulphate, $\mathrm{Cu''H_6N_2SO_4}$.

CHAPTER V.

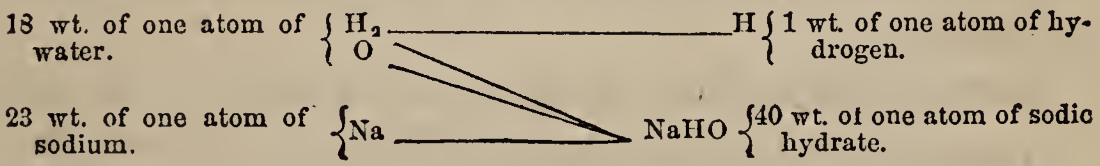
MODE OF EXPRESSING CHEMICAL CHANGES.

1301. The following exercises are given in order to make the student acquainted with the mode of expressing chemical changes by diagrams. The weight of the substances added and those which are produced must be stated as shown in the following examples:—

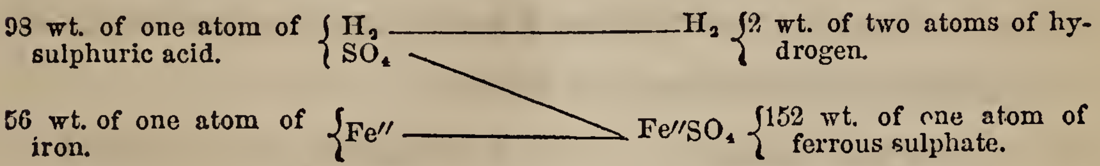
Ex. 1.—If sodium be added to water, sodic hydrate

1299. How is phosphonic bromide formed?

will be formed. What element must be set free? To find the answer to this question, the student must first write down the symbols of the substances added together, viz., the symbol for sodium and the symbol for water; he has then to replace, as shown in the following diagram, one atom of hydrogen in the water by one atom of sodium; this substitution converts the water into sodic hydrate, and the hydrogen which is replaced is the element which is set free, and when we have discovered this we have answered the question. The following is one of the modes of expressing chemical changes, and it is the one best adapted for the beginner.

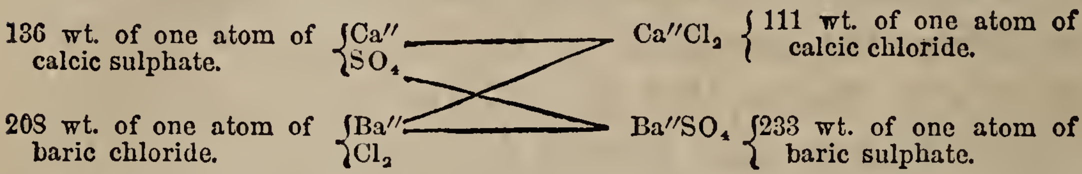


Ex. 2.—If sulphuric acid be added to iron, hydrogen will be set free. What compound must be formed? It is evident that the iron must take the place of or substitute the hydrogen in the sulphuric acid, therefore ferrous sulphate will be the compound formed; and as iron is diatomic, one atom will replace the two atoms of hydrogen in the sulphuric acid, and therefore two atoms of hydrogen will be set free, thus—



Ex. 3.—If a solution of calcic sulphate be added to a solution of baric chloride, what other substance besides baric sulphate will be formed? Here we learn that the barium is subitituted for the calcium in the sul-

phate, and the calcium and the chlorine, being set free in the presence of each other, unite and form calcic chloride, which is the other substance formed, thus—



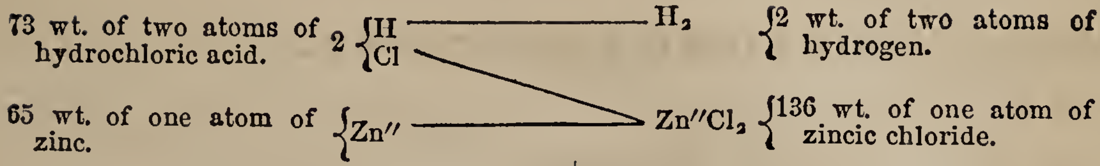
1302. In the preceding examples only one atom of each of the substances which were directed to be added together had to be employed, and never more than two substances were produced. In the following examples the number of atoms of the different substances employed will vary, and two or three substances may be produced.

Three examples are given, and another mode of expressing chemical changes, which it will be well for the student to practice, as it is the one generally adopted by chemists at the present time; at the first, the student had better express the changes by the first mode, and afterward express them by the second or equational mode.

1303. In the following examples and in many of the exercises we shall simply name the substances brought together under the head of "Substances added," and the substance or substances formed, under the head of "Substances formed or set free."

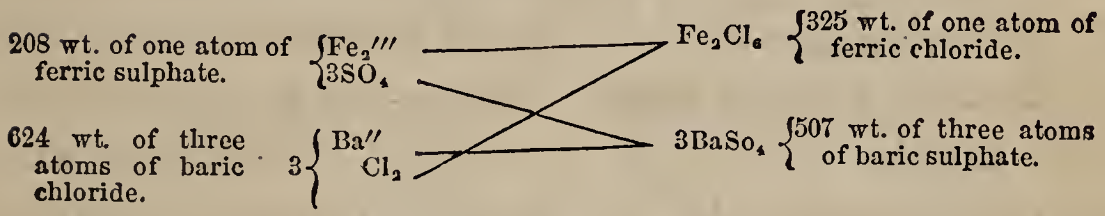
	Substances added.	*Substances set free or formed.*
Ex. 4.—	Hydrochloric acid.	Zincic chloride.
	Zinc.	And —— ?

1301. What exchange of bases occurs in Example 3? 1303. What is the physical state of the element set free in Example 4?



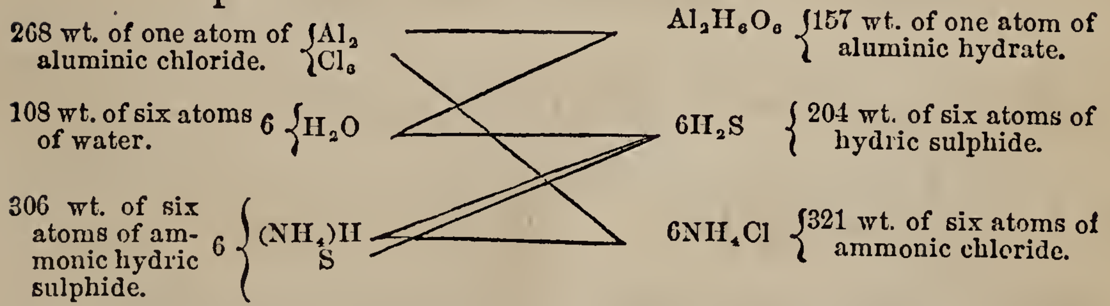
$$2HCl \quad + \quad Zn'' \quad = \quad Zn''Cl_2 \quad + \quad H_2$$

Substances added.	Substances set free or formed.
Ex. 5.—Solution of ferric sulphate.	Ferric chloride.
Solution of baric chloride.	And —— ?



$$Fe_2 3SO_4 \quad + \quad 3BaCl_2 \quad = \quad Fe_2Cl_6 \quad + \quad 3BaSO_4$$

Substances added.	Substances set free or formed.
Ex. 6.—Solution of aluminic chloride.	Aluminic hydrate.
Ammonic hydric sulphide.	And —— ?



$$Al_2Cl_6 + 6H_2O + 6NH_4HS = Al_2H_6O_6 + 6H_2S + 6NH_4Cl^*$$

Under what circumstances is water represented in the reaction?

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* This is an example in which water comes into play; and the student must observe that in the exercises where water does come into play it will not be stated as one of the substances added. When the word *solution* is employed, as in Examples 3, 5, and 6, it is introduced for the purpose of informing the student that the chemical change takes place when the substances are dissolved in water; but water must not on this account be introduced as one of the substances *added;* it must *only* be introduced when it *takes part in the chemical change*, as in Example 6.

EXERCISES.

	Substances added.	*Substances set free or formed.*
102.	Solution of argentic nitrate.	Argentic iodide.
	Solution of potassic iodide.	And ——— ?
103.	Potassic chloride.	Sodic chloride.
	Boiling solution sodic nitrate.	And ——— ?
104.	Hydrochloric acid.	Ferric chloride.
	Iron.	And ——— ?
105.	Solution disodic hydric phosphate.	Sodic chloride.
	Solution calcic chloride.	And ——— ?
106.	Solution sodic carbonate.	Sodic nitrate.
	Solution strontic nitrate.	And ——— ?
107.	Solution of cupric sulphate.	Cupric sulphide.
	Hydric sulphide.	And ——— ?
108.	Solution of potassic chloride.	Plumbic chloride.
	Plumbic nitrate.	And ——— ?
109.	Boiling solution potassic hydrate.	Potassic zinc oxide. K_2ZnO_2
	Zinc.	And——— ?
110.	Solution of potassic hydrate.	Potassic zinc oxide.

	Substances added.	*Substances set free or formed.*
	Potassic nitrate.	And ——— ?
	Zinc.	
111.	Boiling solution potassic hydrate.	Potassic zinc oxide.
	Solution arsenious acid.	And ——— ?
	Zinc.	
112.	Antimonious sulphide.	Antimonious chloride.
	Hydrochloric acid.	And ——— ?
113.	Sulphurous acid.	Sulphuric acid.
	Solution of iodine.	And ——— ?
114.	Solution sodic hyposulphite ($Na_2S_2H_2O_4$.)	Sodic tetrathionate. ($Na_2S_4O_6$).
	Solution of iodine.	And ——— ?
115.	Solution of oxalic acid.	Manganous sulphate.
	Manganic dioxide (MnO_2).	And ———
	Sulphuric acid.	
116.	Cuprous oxide (Cu_2O).	Ferrous chloride.
	Solution of ferric chloride.	And ———
	Hydrochloric acid.	
117.	Ferrous sulphate.	Ferric sulphate.
	Solution of potassic permanganate ($K_2Mn_2O_8$).	And ——— ?
	Sulphuric acid.	
118.	Solution potassic chlorate	Ferric chloride.

	Substances added.	*Substances set free or formed.*
	Ferrous chloride.	And ——— ?
	Hydrochloric acid.	
119.	Solution of potassic iodide	Manganous sulphate.
	Manganic dioxide.	And ——— ?
	Sulphuric acid.	
120.	Arsenious zincide (As_2Zn_3).	Zincic sulphate.
	Sulphuric acid.	And ——— ?

121. When a small quantity of water is added to pentachloride of phosphorus (PCl_5), oxytrichloride of phosphorus and some other substance is formed. When an excess of water is added to the pentachloride, phosphoric acid and some other substance is formed. Express each reaction by an equation.

122. When manganic dioxide is strongly heated, it is decomposed; a complex oxide of manganese, Mn_3O_4, is produced. What other substance is formed or set free?

123. When silicic anhydride, calcic fluoride, and sulphuric acid, are heated together, calcic sulphate and some other substances are formed. What are the other substances, and how many equivalents of each are formed?

124. If sulphurous anhydride be transmitted through water in which finely divided manganic oxide is suspended, manganesic hyposulphate (manganesic dithionate), $Mn''S_2O_6$, is formed if the liquid be kept cool. Express the reaction by an equation.

125. Silicic tetrafluoride is decomposed by water into hydrofluosilicic acid, H_2SiF_6, and some other substance. What is the other substance, and how many equivalents of each are formed?

126. If zinc filings be digested in a solution of sulphurous acid, zincic hyposulphite (zincic dithionite) $Zn''S_2H_2O_4$, and other substances, are formed. What are the other substances, and how many equivalents of each are produced?

127. If chlorine be transmitted through a weak and cold solution of potassic hydrate, potassic hypochlorite ($KClO$) and other substances are formed. Express the reaction by an equation.

128. If chlorine be transmitted through a hot or concentrated solution of potassic hydrate, potassic chlorate and other substances are formed. Express the reaction by an equation.

129. If a current of hydric sulphide be transmitted through a solution of sulphurous acid, pentathionic acid ($H_2S_5O_6$) and other substances are formed. Express the reaction by an equation.

130. When calcic hydrate and an excess of sulphur are boiled together in water, persulphide of calcium ($Ca''S_5$) and other substances are formed. Express the reaction by an equation.

131. When phosphorus is boiled with baric hydrate in water, baric hypophosphite ($Ba2PH_2O_2$) and another substance is formed. What is the other substance?

132. When a solution of ammonia is added to a solution of mercuric chloride, dichloride of dimercurammo-

nium ($Hg''_2H_4N_2Cl_2$) and another substance is formed. Express the reaction by an equation.

133. If phosphuretted hydrogen is passed through a solution of nitrate of silver, phosphoric acid and other substances are formed. Express the reaction by an equation.

134. Give as many methods as you can, from the preceding exercises in this chapter, for the preparation of oxygen.

135. Can you name any method for the production of ammonia from nitric acid?

136. What is the action of chlorine on a dilute solution of potash?

137. What is the composition of arsenuretted hydrogen? and state as many methods as you can for its preparation.

138. Name one or more methods for the preparation of hydric sulphide.

139. What is the action of ammonia on corrosive sublimate?

140. Give the reaction of potassic permanganate on a solution of a ferrous salt in the presence of sulphuric or hydrochloric acid.

141. Give a method for the preparation of potassic chlorate.

142. How would you prepare phosphuretted hydrogen?

143. Give as many methods as you can for the preparation of hyposulphuric acid and the hyposulphites.

144. What change does sodic hyposulphite experience when brought into contact with iodine?

CHAPTER VI.

ATOMS AND MOLECULES, AND THEIR VOLUMES AND WEIGHTS.

1304. Specific Heat.—Equal weights and equal volumes of *different* substances require the addition of different quantities of heat to produce the same alteration in their temperature; hence, different bodies at the same temperature, and whose bodies and weights are equal, contain *unequal* quantities of heat. One pound of water, for example, requires more than thirty times as much heat as one pound of mercury requires to produce the same elevation of temperature; as mercury requires a less amount of heat than water to raise it a given number of degrees, it is said to have a *less capacity for heat* than water. The quantities of heat required by the different substances, expressed relatively to the quantity of heat required to raise the temperature of an equal weight of water from 0° to 1° C, are called the *specific heats* of the various substances. Thus, for instance, the statement that the specific heat of mercury is 0.033 implies it will only require one thirtieth of the quantity of heat necessary to raise a given weight of water from 0° to 1° C to raise an equal weight of mercury from 0° to 1° C, or, to

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1304. Define specific heat.

state it in a different manner, that the quantity of heat which would raise the temperature of any given quantity of mercury from 0° to 1° C, would raise the temperature of an equal quantity of water only from 0° to 0.033°C.

1305. ATOMIC HEAT OF THE ELEMENTARY BODIES.—Equal weights of the elementary bodies require the addition of different quantities of heat to produce the same alteration in their temperature; but if, in place of equal weights, we compare together quantities of the elementary bodies in the proportion of their atomic weights, we find, with a very few exceptions, that they require equal amounts of heat to raise them through an equal number of degrees of temperature, if the *new atomic weights are adopted;* in other words, *the same quantity of heat is required to heat an atom of all simple bodies to the same extent. The product of the specific heat into the atomic weight is the atomic specific heat*, or, as Regnault terms it, *the atomic heat of the body.*

1306. The intimate relation which exists between the specific heat of elementary bodies and their atomic weights was first pointed out by Dulong and Petit, and they deduced the law that the *specific heat of an elementary body is inversely as its atomic weight.* So that an atom of any simple substance, whether its volume be great or small, has the same capacity for heat, and requires the same quantity of heat to raise its temperature through a given number of degrees, as an

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1305. What relation exists between atomic weight and specific heat?
1306. State Dulong and Petit's law.

atom of any other elementary substance. *If the old atomic weights are adopted*, some of the elements have double the capacity for heat that the others possess; but if the new atomic weights are adopted, this difference vanishes, and all the elements then have, when taken in the proportion of their atomic weights, an equal capacity for heat, with about three exceptions.

Specific and Atomic Heats of the more commonly occurring Solid Elements.

Names of Solid Elements.	Specific heat of equal weight.	Atomic Weights.	Products of specific heat multiplied by atomic weight.
Carbon — Diamond	0.147	12	1.764
Carbon — Graphite	0.200		2.400
Carbon — Wood charcoal	0.242		2.904
Silicon	0.176	28	4.928
Boron (crystallized)	0.250	11	2.750
Sulphur (between 0° and 100° C.)	0.2026	32	6.483
Magnesium	0.2499	24	5.998
Zinc	0.09555	65	6.2108
Cadmium	0.05669	112	6.3482
Aluminum	0.2143	27	5.786
Iron	0.11379	56	6.3722
Nickel	0.10863	59	6.409
Cobalt	0.107	59	6.313
Manganese	0.1217	55	6.6934
Tin	0.05623	118	6.6356
Copper	0.09515	63.5	6.0419
Lead	0.0314	207	6.4999
Mercury (solid)	0.03192	200	6.384
Platinum	0.03243	197.2	6.3952
Iodine	0.05412	127	6.8732
Bromine (solid)	0.0843	80	6.744
Potassium	0.16956	39	6.6128
Sodium	0.2934	23	6.748
Phosphorus	0.1887	31	5.8497
Arsenic	0.0814	75	6.105
Antimony	0.05077	122	6.1939
Bismuth	0.03084	210	6.4764
Silver	0.05701	108	6.157
Gold	0.03244	196.7	6.380

1307. The three elements, carbon, silicon, and boron, appear to form exceptions to the law of Dulong and Petit; but as they each form allotropic modifications, and as the specific heat of carbon, and probably that of the other two varies with its allotropic modifications, it is difficult to decide which modification is to be regarded as the state in which the substance enters into combination; perhaps it may hereafter be found that each modification has a different atomic weight, as well as a different specific heat. There are other difficulties attaching to the determination of the specific heat of silicon and boron; one of these difficulties is that of obtaining them perfectly pure.

1308. Sir B. Brodie has proved that in a certain acid containing carbon, the carbon is in the form of graphite, and he arrives at the conclusion that the number 33 is the atomic weight of the graphite. This view of the atomic weight of graphite is supported by its specific heat; for if we multiply the specific heat of graphite by 33, its atomic heat conforms to the law of Dulong and Petit, thus:

$$0.200 \times 33 = 6.600.$$

1309. ATOMIC HEAT OF COMPOUND BODIES.—Regnault, from an extensive series of experiments on a great variety of compound bodies, has arrived at the conclusion that *in all compound bodies of the same atomic composition, and of similar chemical constitution, the specific heats are inversely as the atomic*

1307. What elements form apparent exceptions? 1309. What is said of the specific heat of compounds?

weights. "There are, however, several exceptions to this law. Whether the exceptions arise from the same disturbing influences which affect carbon, silicon, and boron, or to some other cause, it is not less true that the law in question is worth attention, for it is verified in the case of many groups of analogous bodies, *provided the new atomic weights are adopted for the elements.*

1310. "THE NEW SYSTEM OF ATOMIC WEIGHTS IS IN HARMONY WITH THE LAW OF ISOMORPHISM.—Isomorphous bodies possess similar atomic structures; their composition ought then to be expressed by analogous formulæ, and they are so represented by adopting the new atomic weights. Thus, cuprous sulphide, which is isomorphous with the sulphide of silver, Ag_2S, is represented by the formula Cu_2S. Argentic sulphate and anhydrous sodic sulphate receive the analogous formulæ—

$$Ag_2SO_4 \text{ and } Na_2SO_4$$

"The isomorphous sulphates of the magnesian series are represented by the formula—

$$MSO_4 + 7H_2O.$$

"The double sulphates of the same series receive the formula—

$$MSO_4 + M_2SO_4 + 6H_2O.$$

"Lastly, the composition of the alums is represented by the formula—

$$M_23SO_4 + M_2SO_4 + 24H_2O.\text{"*}$$

1310. What relation exists between atomic weight and isomorphism?

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* Introduction to Chemical Philosophy. By Dr. A. Wurtz.

1311. ATOMS AND MOLECULES.—It is admitted by most chemists at the present time that an element may combine with itself; that hydrogen in the free state may be a hydride of hydrogen; the symbol for hydrogen in the free state is therefore HH, and not H, and so with the other elements. The atoms of most of the elements in the free state are considered to be united in pairs, and not to exist detached; consequently, on this hypothesis, an elementary body, when it is liberated from its combination with other bodies, combines with itself; also, when it enters into combination with another element, double decomposition ensues, for example:—

$$HH + ClCl = 2HCl.$$

We have therefore to distinguish between *atoms* and *molecules*. An atom is the smallest quantity of an element which can exist in a compound; it is chemically indivisible. A molecule is a group of atoms, forming the smallest quantity of a *simple* or *compound body* which can exist in a free state, or is able to take part in, or result from, a reaction. The symbol H represents an *atom* of hydrogen, whilst the symbol HH or H_2 represents a *molecule* of hydrogen.

1312. EVIDENCE OF THE DUALITY OF ELEMENTARY MOLECULES.—We will arrange the facts into three classes, which appear to prove that the atoms of the elements in their free state, *are united in pairs*.

1313. 1ST CLASS.—In a great many of the chemical

1311. Define atom and molecule? 1313. What reaction between potash and chlorine prove the existence of atoms in pairs?

combinations, in which *an element* is one of the combining bodies, an even number of atoms of the element is required. The atoms of the element appear, therefore, to be associated in *binary groups.* Examples:

1. When chlorine acts upon potash, potassic hypochlorite or potassic chlorate is formed. The following is the reaction when potassic hypochlorite is produced:

$$2KHO + Cl_2 = \underset{\text{Potassic hypochlorite.}}{KClO} + KCl + H_2O.$$

When potassic chlorate is formed, the following reaction takes place:

$$6KHO + 3Cl_2 = 5KCl + KClO_2 + 3H_2O.$$

2. When sulphur is fused at a gentle heat with an alkaline hydrate, or boiled with an aqueous solution of the alkali, two compounds, dipotassic pentasulphide and potassic hyposulphite, are formed:

$$6KHO + 6S_2 = K_2S_2O_3 + 2K_2S_5 + 3H_2O.$$

3. There does not exist a single organic compound upon which we can effect any reaction by employing an *uneven* number of atoms of chlorine. In every case it is Cl_2, or a multiple thereof, which determines the reaction; *the compound may contain an uneven number* of atoms. The following are examples of this statement:

$$\underset{\text{Acetic acid.}}{HC_2H_3O_2} + Cl_2 = \underset{\text{Monochloracetic acid.}}{HC_2H_2ClO_2} + HCl.$$

$$HC_2H_3O_2 + 3Cl_2 = \underset{\text{Trichloracetic acid.}}{HC_2Cl_3O_2} + 3HCl.$$

1314. 2ND CLASS.—There are a great number of de-

What reaction between sulphur and an alkali? What between acetic acid and chlorine?

compositions which cannot be explained in any satisfactory manner unless we admit that *the atoms of the same elements are capable of entering into combination with each other.*

1315. Let us first take the case of hydrogen. In 1843 Wurtz discovered a combination of hydrogen and copper, a combination which gives with hydrochloric acid a curious reaction, cuprous chloride being formed, whilst there is a tumultuous disengagement of hydrogen. But it is known that hydrochloric acid is not decomposed by copper; how, then, can it be by a combination of copper with hydrogen, unless the affinity of copper for chlorine were not supplemented by the affinity of hydrogen for hydrogen? Thus regarded, this reaction becomes a double decomposition of remarkable simplicity:

$$\underset{\text{Cuprous hydride.}}{HCu} + HCl = \underset{\text{Cuprous chloride.}}{CuCl} + \underset{\text{Hydride of hydrogen.}}{HH.}$$

On the other hand, this reaction is inexplicable if free hydrogen is considered as formed of a single atom. In fact, if copper by itself is incapable of decomposing hydrochloric acid, this would be still more the case with hydride of copper; for, in the former case, in order to decompose the hydrochloric acid, there would be only one affinity to conquer—that of chlorine for hydrogen; whilst in the second case there are two, for to this first affinity must be added that of copper for hydrogen, and however small this latter may be, it

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1315. Explain the reaction between hydride of copper and hydrochloric acid. What is concluded from this reaction?

must be considered as a new obstacle. In a word, if copper does not decompose hydrochloric acid, hydride of copper should have still less tendency to decompose it.

1316. "But it may be said, the hypothesis of the duality of the molecule of hydrogen is insufficient to explain the difference between the two reactions in question; for if hydrogen, in order to be disengaged in the free state, requires to combine with itself, why is not this affinity of hydrogen for hydrogen exerted in the case of hydrochloric acid? It would only require that two molecules of hydrochloric acid should act upon the copper:

$$\mathrm{Cu_2} + 2\mathrm{HCl} = 2\mathrm{CuCl} + \mathrm{HH}.$$

Such is the objection; it is removed by taking into consideration the polarity of the elements, a subject to which Sir B. Brodie first directed attention.

1317. "The hydrogen in hydride of copper shows so great a tendency to unite with the hydrogen of the hydrochloric acid, because it finds itself in these two combinations in a state of opposite polarity. The hydrogen of the hydrochloric acid is positive in respect to the hydrogen of the hydride of copper:

$$\overset{+}{\mathrm{Cu}}\overset{-}{\mathrm{H}} + \overset{+}{\mathrm{H}}\overset{-}{\mathrm{Cl}} = \mathrm{HH} + \mathrm{CuCl}.$$

1318. "Analogous considerations apply to the molecule of free oxygen. There are reactions which can only be explained by admitting the duality of this

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1316. What objection is urged against the theory? 1317. What is the theory of polarity of the elements?

molecule, formed, like that of hydrogen, of two atoms. And these reactions have for their object—1, the *decomposition* of the molecule of oxygen, and, 2, the *reconstruction* of the molecule of oxygen.

"1. Oxygen and nitrogen combine with difficulty under the influence of the electric spark; but the combination of these two bodies is easily effected in the presence of hydrogen. Here I think is the interpretation of this fact. The molecule OO being attacked by hydrogen, one atom of O combines with H_2, whilst the other atom of oxygen, which may be considered in the nascent state, combines with nitrogen.

2. "The oxides of gold, silver, and mercury, on being placed in a solution of peroxide of hydrogen (hydric peroxide) H_2O_2, decompose and are decomposed by that body, although *apart* the peroxide and the metallic oxides are perfectly stable; the metallic oxides lose the whole of their oxygen, whilst the peroxide loses one half, and thus becomes converted into water, and the molecule of oxygen is reconstructed:

$$Ag_2\overset{-}{O} + \overset{+}{H}_2\overset{-}{O}\;\overset{+}{O} = Ag_2 + OO + H_2O.\text{"*}$$

1319. 3RD CLASS.—If two or more atoms of the same element are capable of entering into combination, there will be a *difference in properties* between the *molecules* and the *atoms* of the elements, as there is between a chemical compound composed of unlike elements and

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1318. How is the combination of oxygen with nitrogen in the presence of hydrogen explained?

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* Introduction to Chemical Philosophy. By Dr. A. Wurtz.

the elements of which it is composed. That the elements do not possess under all circumstances the same physical and chemical properties, but that the same element differs as much in properties under different conditions, as some compounds composed of unlike elements differ from their elements, is evidenced by the *allotropic* modifications of some of the elements, and by the *nascent* compared with the *ordinary state* of the elements.

1320. THE WEIGHT AND VOLUME OF AN ATOM AND OF A MOLECULE.—The student will see from what has been advanced that there is good evidence for believing that the atoms of most of the elements in the free state are united in pairs; this being the case, we shall have to distinguish between the weight and volume of a *molecule* and the weight and volume of an *atom*. The hydrogen atom being taken as unity, both as regards volume and weight, it will be seen from the following table that, with some exceptions, the molecular weight of an element is twice its own atomic weight, and that the molecular volume of an element in the gaseous or vaporous condition is the same as the molecular volume of hydrogen, at the same temperature and pressure; and as the atom of hydrogen is taken to occupy one volume, the molecule, or two atoms of hydrogen, must occupy two volumes. Mercury, cadmium, zinc, phosphorus, and arsenic, are exceptions to this rule; the atomic weight of mercury, cadmium, and zinc, is equal

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1319. What facts prove that elementary bodies are not always the same?
1320. How must molecular weight compare with atomic weight?

to twice their specific gravities, therefore the molecular structure of these three elements is monatomic, whilst the molecular structure of phosphorus and arsenic is tetratomic, as the specific gravities of these two elements is twice that of their atomic weights; in other words, an atom of mercury, of cadmium, or of zinc vapor occupies two volumes, whilst four atoms of phosphorus or arsenic vapor occupies two volumes.

TABLE.—*The Atomic and Molecular Weights and Volumes of the Gaseous and Vaporizable Element.*

Names of the Elements.	Atoms.				Molecules.			
	Symbols.	Atomic weight, H = 1.	Sp. gr., H = 1.	Atomic volume.	Symbols.	Molecular weight, HH = 2.	Sp. gravities, HH = 2.	Molecular volume.
Hydrogen.........	H	1	1	H	HH	2	2	H H
Chlorine..........	Cl	35.5	35.5	Cl	ClCl	71	71	Cl Cl
Bromine vapor.....	Br	80	80	Br	BrBr	160	160	Br Br
Iodine vapor.......	I	127	127	I	II	254	254	I I
Oxygen............	O	16	16	O	OO	32	32	O O
Sulphur vapor.....	S	32	32	S	SS	64	64	S S
Nitrogen...........	N	14	14	N	NN	28	28	N N
Zinc vapor........	Zn	65	32.5	Zn	Zn	65	65	Zn
Cadmium vapor....	Cd	112	56	Cd	Cd	112	112	Cd
Mercury vapor.....	Hg	200	100	Hg	Hg	200	200	Hg
Phosphorous vapor.	P	31	62	P	PPPP	124	124	P P P P
Arsenic vapor......	As	75	150	As	AsAsAs As	300	300	As As As As

1321. THE VOLUME OF THE ATOM AND MOLECULE OF COMPOUND RADICALS.—There are certain compound monatomic radicals which act the part of elements, and which, like the elementary molecules, occupy two volumes *when in the free state*, but *become halved* in combination; thus, the radical ethyl in the free state is represented by the formula C_4H_{10} or C_2H_5, $C_2H_5 =$ , in the combined state by $C_2H_5 =$ , as, for example, in iodide of ethyl, C_2H_5I. Ammonium, if it could be obtained in the free state, would in like manner, no doubt, be $(NH_4)_2$, and would occupy two volumes. There are, on the other hand, some biatomic compound radicals which resemble the diatomic metals, mercury, cadmium and zinc, in that an atom of these bodies occupies two volumes.

1322. THE VOLUME OF THE MOLECULES OF GASEOUS COMPOUNDS.—In studying combinations by weight we have seen that the atomic weight of a compound is equal to the sum of the atomic weights of the elements composing it. *But the measure or volume of a compound gas is not always equal to the sum of the measures or volumes of the elementary gases which compose it; contraction or condensation frequently takes place.*

1323. The molecules of ninety-nine per cent. of all known gaseous or volatile compounds, irrespective of the number of volumes of their elements which enter

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1321. What is said of ethyl and ammonium in the free state? 1322. What is said of the volume of compound gases?

into their constitution, occupy, like the molecule of hydrogen, *two volumes:* consequently, their molecular weight and their vapor-density correspond, if the specific gravity of the *molecule* of hydrogen = 2 be taken as the standard. If, on the other hand, the *atom* of hydrogen = 1 be taken as the standard for the specific gravity of gases, then the specific gravity of compound bodies in their gaseous state will only be the halves of their atomic weights.

1324. We have already noticed (1226) that the gaseous and vaporizable elements in their gaseous state expand and contract alike, the pressure being the same, for equal additions or subtractions of heat, and they also experience the same change in volume for equal pressures; this is not only true of the gaseous elements, but it is true of every gas or vapor, whether simple or compound, and, therefore, it is considered that *equal volumes of gases contain* (not the same number of atoms, for most compound gases are not comparable to simple gases in this respect) *the same number of molecules* under identical conditions of temperature and pressure.

1325. Aid derived from the specific gravity of Volatile Compounds in determining the Molecular and Atomic Weights of Bodies.—As, with the few exceptions we shall presently notice, the molecules of all compound bodies occupy two volumes; this consideration, as well as others, guides chemists in deter-

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1323. What is the relation of atomic weight to specific gravity of compound gases? 1324. What is the theory relating to molecules of compound gases?

mining the molecular formulæ of compound bodies. Formulæ are chosen which correspond to two volumes of vapor if purely chemical considerations are not opposed; thus, the formulæ assigned to ferric chloride, aluminic chloride, and chromic chloride, is Fe_2Cl_6, Al_2Cl_6, and Cr_2Cl_6, and not $FeCl_3$, $AlCl_3$, and $CrCl_3$, because the former formulæ correspond to two volumes of vapor, and the latter only to one. But the vapor-densities of volatile compounds are also most useful in determining the atomic weights of the simple or compound radicals they contain; thus, the following are the weights of one volume of the subjoined metallic chlorides in a state of vapor:

	Weight of one volume of vapor.	Proportion of the constituents therein.	
		Metal.	Chlorine.
Mercuric chloride . .	135.5	100	35.5
Bismuthous chloride .	157.25	104	53.25
Stannic chloride . .	130	59	71

If the molecules of these chlorides occupy, like almost all other molecules, two volumes, the above numbers must be doubled to represent the vapor-density of the molecules, thus:

	Weight of two volumes of vapor.	Proportion of the constituents therein.	
		Metal.	Chlorine.
Mercuric chloride . .	271.0	200	71.0
Bismuthous chloride .	314.5	208	106.5
Stannic chloride . .	260	118	142

We learn from these figures that in the molecules of mercuric chloride there is 200 of mercury united with 71 of chlorine; we therefore infer that 200 is the atomic weight of mercury, and that it is diatomic, as 2 atoms of chlorine are united with it. In like manner we infer that the atomic weight of bismuth is 208, and that it is triatomic;* that the atomic weight of tin is 118, and that it is tetratomic. The student will see that it has been inferred or assumed that in the two volumes of vapor of these chlorides there was one atom only, not two or more atoms, of the metal under examination. It is necessary to have further confirmation on this point before it can be absolutely assumed as true; we therefore refer to the specific heats of these metals, and we find that their specific heats confirm the view that in two volumes of the vapor of these chlorides there is but one atom of the respective metals.†

1326. OTHER PHYSICAL AIDS IN THE DETERMINATION OF ATOMIC WEIGHTS.—To show the student still further the different evidence the chemist appeals to in determining the atomic weight of bodies, we will return to the consideration of the evidence for the atomic weights which have been adopted for phosphorus, arsenic, cadmium, mercury, and zinc. We have seen that the vapor-densities of these five elements are anomalous; that their atomic weights and atomic volumes do not correspond; to make them harmonize, the atomic weights of phosphorus and arsenic would have to be doubled, and the atomic weights of the other three

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1325. How does vapor-density aid in determining atomic weight?

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* The bismuth in this chloride is a triad, but in other compounds it is a pentad.

† These examples are taken from Dr. Hofmann's volume on "Modern Chemistry," to which we refer the student for further illustrations.

elements would have to be halved; but the atomic heats of these five elements, calculated from their atomic weights, coincide with the atomic heats of the other elements, which would not be the case if their atomic weights were altered. Again, a molecule of their gaseous compounds occupies, like a molecule of other gaseous compounds, two volumes (par. 1226); whereas, if, for example, the atomic weights of phosphorus and arsenic were doubled, the vapor-densities of their hydrogen compounds would correspond to four volumes, and an alteration in their atomic weights would be in opposition also to purely chemical evidence. The preponderance of evidence is therefore in favor of the present atomic weights of these five elements, although their atomic weights and vapor-densities are not in unison.

1327. Exceptions to the Law.—There are, we have said, exceptions to the law that a molecule corresponds to two volumes of vapor. The molecule of chloride of ammonium, of cyanide of ammonium, of iodide of phosphonium (PH_4I), of pentachloride of phosphorus, of sulphuric acid, and of a few other compounds, corresponds to four volumes of vapor. Many of these exceptions have been satisfactorily accounted for, inasmuch as they decompose when heated into two simpler compounds, and a molecule of each of these two compounds occupies two volumes. So that at the temperature at which their density is taken we are operating on two and not one molecule. Examples:

1326. What elements form exceptions to this law? 1327. How are the exceptional cases of compound vapors accounted for?

Ammonic chloride decomposes into $\overset{\text{2 vols.}}{NH_3} + \overset{\text{2 vols.}}{HCl}$
Sulphuric acid " " $SO_3 + H_2O$
Pentachloride of phosphorus " " $PCl_3 + Cl_2$

This disjunction of the more complex molecule into two less complex ones is only temporary, for when the temperature becomes lowered the two recombine and reform the original molecule; this temporary disjunction is termed *dissociation.*

1328. THE FORMULÆ OF COMPOUNDS INDICATE THE VOLUME AS WELL AS THE ATOMIC PROPORTIONS.—The student will see from all that has been stated that the formulæ of compounds represent, not only the atomic, but also the volume proportions in which the elements are combined: thus, HCl represents a compound composed of one atom or one volume of each of its elements; PH_3 represents a compound composed of one atom, or half volume of the vapor of phosphorus, and three atoms or three volumes of hydrogen; $HgCl_2$ represents a compound composed of one atom, or two volumes of the vapor, of mercury and two atoms or two volumes of chlorine.

1329. Answers to the following exercises must now be written out by the student.

EXERCISES.

145. What is meant by the expression "specific heat"?

146. Define the difference between "molecule" and

What is meant by dissociation? 1328. What is the full meaning of the formula?

"atom," and give examples to show the distinction between the two.

147. Name the more important exceptions to Dulong and Petit's law regarding the atomic heat of the elements.

148. How many volumes of their respective elements are contained in two volumes of each of the following gases:—HCl, Steam, and NH_3?

149. A volume V of sulphureted hydrogen is decomposed by an excess of bromine. What is the volume of the resulting hydrobromic acid?

150. Explain fully the meaning of the following symbols:—O_2, H_2, Cl_2, Br_2, I_2, C, N_2, S, P, CO_2, SO_3, H_2O, and NH_3.

151. State the vapor-density of HCl, NH_3, PH_3, and steam, referred to that of hydrogen as unity, and state the relation which the density of these compounds bears to their molecular weights.

152. In what proportions by volume do the following elements unite to form the respective compounds:—As and O to form As_2O_3, N and O to form NO_2, NH_3, and HCl to form NH_4Cl?

153. Phosphoreted hydrogen is decomposed by chlorine, so as to yield hydrochloric acid and pentachloride of phosphorus. How many volumes of chlorine are required by 100 volumes of phosphoreted hydrogen, and how many volumes of hydrochloric acid are generated?

154. In what proportions by volume do the follow-

ing elements unite to form the respective compounds: H and S to form H_2S, C and O to form CO_2?*

155. V volumes of sulphureted hydrogen measured at 120° C. are submitted to combustion. State how many volumes of oxygen measured at 120° C. are required, and how many volumes of steam and sulphurous acid gas, both likewise measured at 120° C., are produced.

1330. THE VOLUME-WEIGHTS OF ELEMENTS OR COMPOUNDS.—Dr. Hofmann has selected one cubic decimeter (1 liter†) of hydrogen, at 0° C., and at a pressure of 760 milimeters of mercury as the *unit of volume*, and the weight of this measure of pure hydrogen as the *unit of weight*. The following is Dr. Hofmann's description of the value and applications of this unit:

1331. "The actual weight of this cube of hydrogen, at the standard temperature and pressure mentioned, is 0.0896 gram, a figure which I earnestly beg you to inscribe, as with a sharp graving tool, upon your memory. There is probably no figure in chemical science more important than this one to be borne in

1330. What is Hofmann's unit of volume and weight? 1331. What is the weight of the unit?

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* Carbon and some other elements, which cannot be vaporized in their pure state, form by their union with some of the other elements compounds which are either gaseous or which are capable of being converted into vapor. The density of the vapor and the atomic volume of these non-vaporizable elements are hypothetical, as they can only be inferred from their gaseous compounds. The atom of carbon is taken to occupy the same volume as an atom of hydrogen; some chemists take it as occupying two volumes.

† French weights and measures are employed by scientific men. For a description of them and their equivalent in English weights and measures, see Appendix, p.

mind, and to be kept ever in readiness for use in calculation at a moment's notice. For this liter-weight of hydrogen, = 0.0896 gram (I purposely repeat it), is the standard multiple, or coefficient, by means of which the weight of 1 liter of any other gas, simple or compound, is computed. Again, therefore, I say—Do not let slip this figure—0.0896 gram. So important, indeed, is this standard weight-unit that some name—the simpler and briefer the better—is needed to denote it. For this purpose I venture to suggest the term *crith*, derived from the Greek word *κριθὴ*, signifying a barley-corn, and figuratively employed to imply a small weight. The weight of 1 liter of hydrogen being called 1 crith, the volume-weight of other gases, referred to hydrogen as a standard, may be expressed in terms of this unit.

1332. "For example, the relative volume-weight of chlorine being 35.5, that of oxygen 16, that of nitrogen 14, the actual weight of 1 liter of each of these elementary gases, at 0° C., and 0.76m. pressure, may be called respectively 35.5 *criths*, 16 *criths*, and 14 *criths*.

1333. "So, again, with reference to the compound gases, the relative volume-weight of each is equal to half the weight of its product-volume. Hydrochloric acid (HCl), for example, consists of 1 volume of hydrogen + 1 volume of chlorine = 2 volumes; or by weight, $1+35.5=36.5$ units; whence it follows that the relative volume-weight of hydrochloric acid gas is $\frac{36.5}{2}$ =

What name is given to this unit? 1332. Calculate the weight of one liter of oxygen.

18.25 units, which last figure, therefore, expresses the number of *criths* which 1 liter of hydrochloric acid gas weighs at 0° C. temperature and 0.76m. pressure; and the crith being (as I trust you already bear in mind) 0.0896 gram, we have $18.25 \times 0.0896 = 1.6352$ as the actual weight in grams of 1 liter of hydrochloric acid gas.

1334. "So, once more, as the product-volume of water-gas (H_2O) (taken at the above temperature and pressure) contains two vols. of hydrogen + 1 vol. of oxygen, and therefore weighs $2 + 16 = 18$ units, the single volume of water-gas weighs $\frac{18}{2} = 9$ units; or, substituting as before the concrete for the abstract value, 1 liter of water-gas weighs 9 *criths*, that is to say, 9×0.0896 gram $= 0.8064$ gram.

1335. "In like manner the product-volume of sulphureted hydrogen (H_2S) = 2 liters of hydrogen, weighing 2 criths + 1 liter of sulphur-gas, weighing 32 criths, together $2 + 32 = 34$ criths, which divided by 2 gives $\frac{34}{2} = 17$ criths $= 17 \times 0.0896$ gramme = 1.5232 gramme = the weight of 1 liter of sulphureted hydrogen at standard temperature and pressure.

1336. "And so, lastly, of ammonia (H_3N): it contains in 2 liters 3 liters of hydrogen, weighing 3 criths, and 1 liter of nitrogen, weighing 14 criths; its total product volume weight is therefore $3 + 14 = 17$ criths,

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1333. How is the weight of hydrochloric acid obtained? 1336. Calculate the weight of 1 liter of ammonia vapor.

and its single volume or liter weight is consequently $\frac{17}{2} = 8.5$ criths $= 8.5 \times 0.0896$ gram $= 0.7616$ gram.

1337. "Thus, by aid of the hydrogen liter weight or *crith* = 0.0896 gram, employed as a common multiple, the actual or concrete weight of 1 liter of any gas, simple or compound, at standard temperature and pressure, may be deduced from the mere abstract figure expressing its volume-weight relatively to hydrogen.

1338. "From this knowledge, the weight of one liter of any gas, simple or compound, at any other than standard temperature or pressure, or under any variation both of standard temperature and pressure, may be deduced by the application of the formulæ devised by physicists to express the laws of expansion and contraction for gases under varying conditions of temperature and pressure."

1339. Answers to the following exercises must now be written out.

EXERCISES.

156. The iodine in 100 volumes of hydriodic acid is liberated in succession by chlorine and oxygen. How many volumes of chlorine and how many volumes of oxygen are required?

157. 100 liters of phosphoreted hydrogen (H_3P) at 100° C. are mixed with 300 liters of chlorine at 100° C. How many liters of chloride of phosphorus and

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1337. How far will this method apply?

how many liters of hydrochloric acid, both measured at 100° C. are produced?

CHAPTER VII.

ATOMICITY OF RADICALS.

1340. ABSOLUTE AND ACTUAL COMBINING CAPACITY OF POLYATOMIC RADICALS.—We have already seen that the elements and bodies playing the part of elements (compound radicals) have different powers of combination or atomicities; thus, one atom of some elements and radicals combines with or replaces one atom of hydrogen, whilst one atom of other elements and radicals combines with or replaces two or more atoms of hydrogen; the former represents one unit, the latter two or more units, of chemical force. The student's attention has already been directed (par. 1225) to the fact that the *capacity of combination of the polyatomic elements is variable*, and it is likewise the case with the polyatomic radicals; and this variation of the atomicity, it is found, always takes place by the *non-saturation* or the becoming *latent*, as it were, of an *even number* of units of chemical force; thus, nitrogen is either a pentad, a triad, or a monad; phosphorus and arsenic, either pentads or triads; carbon and tin, either tetrads or dyads; and sulphur and silenium, either hexads, tetrads, or dyads. The absolute or maximum combin-

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1340. What is said of the power of combination of polyatomic elements? What is said of nitrogen, phosphorus, carbon and sulphur?

ing capacity and the actual combining capacity of polyatomic elements and radicals are, therefore, not always identical; the first is invariable, the latter is variable. The absolute or maximum capacity is reached when all the units of force are saturated or satisfied by union with hydrogen or other bodies, and the compound in such cases is incapable of combining directly with any further quantity of hydrogen or other bodies; it is therefore said to be *saturated.* But when the combining powers of an element are not fully satisfied in a compound, the compound is capable of uniting directly with other bodies; nitrogen, for instance, can unite with three atoms of hydrogen, it can also unite with four atoms of hydrogen, and, in addition, one atom of chlorine or some other monad element. Nitrogen is, therefore, triatomic in NH_3 and pentatomic in NH_4Cl. Some chemists term the maximum combining power the *absolute atomicity*, and the actual combining capacity the *active atomicity*, whilst other chemists term the former the *atomicity*, whilst they term the latter the *quantivalence.*

1341. In the compound CH_4 all the units of force of the tetratomic element carbon are satisfied; one can therefore understand why it is that this carbide of hydrogen (hydride of methyl) is incapable of entering into direct combination with any other element, for it is a saturated compound. But it is not at once so apparent why the carbide of hydrogen (hydride of

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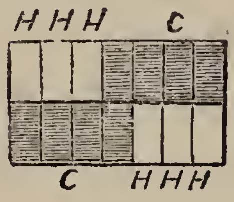
When is a compound said to be saturated? Explain the difference between absolute and active atomicity.

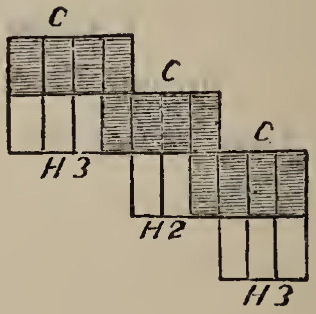
ethyl) C_2H_6, is unable to enter into direct union with another element, for the two atoms of carbon appear at the first inspection to be only triatomic in this body. But in this and similar compounds the two or more atoms of the polyatomic element which exist in a molecule of the compound are themselves united by a portion of the force existing in them. "Thus, in all the saturated combinations which contain two atoms of carbon, one atom of carbon is combined directly with another atom of carbon, and exchanges with it a unit of chemical force in such a way that of the eight units of chemical force which reside in two atoms of carbon two units are satisfied by the combination of carbon with carbon, and there remain only six which are, so to say, disposable. On this account two atoms of carbon can never take more than six atoms of a monatomic element, therefore the body C_2H_6 constitutes the hydrocarbide limit of the series of combinations of carbon and hydrogen which contains two atoms of carbon." We can now understand also why C_3H_8 and C_4H_{10} are saturated compounds, because as all the atoms of carbon, representing them by links in a chain, must be in contact with two others, with the exception of the one at each end, two units of force will be satisfied by this union, whilst the one at each end being in contact with only one atom, only one unit of force will be satisfied; therefore in the compound C_3H_8, out of the twelve units of chemical force which reside in the three atoms of carbon four are satisfied by the union of the three atoms of carbon with each other; and in the compound

C_4H_{10}, out of sixteen units of force residing in the four atoms of carbon, six are satisfied by the union of the four atoms with each other. We can further understand why the family of carbides of hydrogen, of which the four are members, is the richest in hydrogen that is known. The general formula for this family is C_nH_{2n+2}, which means that the hydrogen atoms are twice the sum, and plus two of the carbon atoms.

1342. This partial saturation of carbon by carbon is represented by the following diagrams:*



320



321

1343. We once more impress upon the student the fact that this family of carbides of hydrogen, being saturated compounds, are indifferent; they cannot unite directly with an element; if an element can act upon them, it does so by substitution only, not by direct union. Thus Br acts upon C_3H_8 by taking away some of the hydrogen, an equivalent of bromine entering into the compound in place of the hydrogen which is removed—

1342. Illustrate by diagram the partial saturation of carbon. 1343. Why cannot these carbides unite directly with an element?

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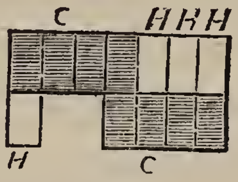
* Wurtz, from whose work on Chemical Philosophy these diagrams have been copied, observes that it is well to point out that these figures do not represent in any manner either the form or the position of the atoms. They simply indicate their mutual relationships, and, to a certain extent, the points of junction of the affinities. Each compartment represents a unit of chemical force or affinity.

$$C_3H_8 + Br_2 = C_3H_7B + HBr.$$

1344. We are now prepared to understand why C_2H_4, or any other member of that family of hydrocarbons whose general formula is C_nH_{2n}, is capable of combining with or replacing two atoms of hydrogen, or generally two atoms of a monad element or radical; in other words, that it and the other members of this family of carbides of hydrogen are diatomic radicals, for two out of the eight units of force are unsatisfied, as shown in the following diagram:



322

1345. The removal of one atom of hydrogen, or one atom of any other monad element or radical, from a saturated compound, converts the residue or remainder into a monatomic radical: Ex.—$H_2O - H = (HO)'$. The removal of two atoms of hydrogen, or two atoms of any other monatomic element or radical, or one atom of a diatomic element or radical, from a saturated compound, converts the residue or remainder into a diatomic radical: Ex.—$C_3H_8 - H_2 = (C_3H_6)''$. The removal of three atoms of monatomic element or radical from a saturated compound converts the residue or remainder into a triatomic radical: Ex.—$C_3H_8 - H_3 = (C_3H_5)'''$, &c.

1344. What is the supposed structure of the diatomic hydrocarbons?
1345. What is the effect of removing one atom of hydrogen from a satu-

1346. In like manner the atomicity of a residue or remainder is diminished one degree by each addition of the atom of a monatomic body.

1347. But the student may ask how it comes to pass that there is such a compound as C_2H_6O, if C_2H_6, as has been stated, is a saturated compound. The formation of this compound C_2H_6O may be supposed to be accomplished either by the monatomic radical $(C_2H_5)'$ combining with the monatomic radical $(HO)'$, or by the diatomic element oxygen, which has two units of force, combining with C_2H_5 by means of one unit, and with H by the other unit; certain it is that one of six atoms of H in this compound, $(C_2H_5)OH$, is less intimately united than the rest, as it can be replaced by potassium, or by a compound radical, whilst the other five atoms can not. From this example it will be seen that *complicated compounds* may be built up by the insertion, as it were, of one or more atoms of a polyatomic radical into a monatomic compound; the student will see that the diammoniums (par. 1300) and several other compounds, which have been given in the preceding pages, are illustrations of this statement.

EXERCISE.

158. Are the following saturated compounds? If not, how many atoms of a monatomic body do they require for their saturation?

$$C_{10}H_{22}, C_8H_{17}, C_{16}H_{32}, CO, PCl_3, C_2O_2, C_2H_3O, C_3H_5.$$

---

rated compound? 1347. Explain the union of a saturated compound with oxygen.

1348. Molecular union or combination.—But according to this atomicity theory, there ought to be no such compounds, yet there are, as ICl_3, and $AgCl,NaCl$. Chemists are therefore compelled to admit an entirely different kind of union to the atomic union, as not unfrequently occurring; it is termed *molecular union*, or *molecular combination*. For the union of compounds by molecular combination no change takes place in the active atomicity of any of the molecules. It is assumed that salts and their water of crystallization are held together by this kind of combination, and that the rational formula of ICl_3 is ICl, Cl_2, the two molecules being held together, not by atomic, but molecular union.

1349. Molecular equations.—If the molecular hypothesis, as regards the elements, be adopted (par. 1311), molecular equations must also be adopted: Examples—

$$\begin{array}{llllllll}
(1) & 2HCl & + & NaNa & = & 2NaCl & + & HH \\
(2) & H_2O & + & NaNa & = & Na_2O & + & HH \\
(3) & H_3N & + & 3NaNa & = & 2Na_3N & + & 3HH
\end{array}$$

1350. Table of Elements, with their Atomic Weights.—In the following table of elements both old and new atomic weights are given:—

Name.	Symbol.	New Atomic weight.	Old Atomic weight.	Name.	Symbol.	New Atomic weight.	Old Atomic weight.
Aluminum	Al	27.5	13.75	Molybdenum	Mo	92	46
Antimony	Sb	122	122	Nickel	Ni	58.8	29.4
Arsenic	As	75	75	Niobium	Nb	97.6	48.8
Barium	Ba	137	68.5	Nitrogen	N	14	14
Bismuth	Bi	208	208	Osmium	Os	199	99.5
Boron	B	11	11	Oxygen	O	16	8
Bromine	Br	80	80	Palladium	Pd	106.5	53
Cadmium	Cd	112	56	Phosphorus	P	31	31
Cæsium	Cs	133	133	Platinum	Pt	197.4	98.7
Calcium	Ca	40	20	Potassium	K	39	39
Carbon	C	12	6	Rhodium	Rh	104	104
Cerium	Ce	92	46	Rubidium	Rb	85.5	85.5
Chlorine	Cl	35.5	35.5	Ruthenium	Ru	104	52
Chromium	Cr	52.5	26	Selenium	Se	79	39.5
Cobalt	Co	58.8	29.5	Silicon	Si	28.5	14
Copper	Cu	63.5	31.75	Silver	Ag	108	108
Didymium	D	96	48	Sodium	Na	23	23
Fluorine	F	19	19	Strontium	Sr	87.5	44
Glucinum	G	14	4.7	Sulphur	S	32	16
Gold	Au	196.7	196.7	Tantalum	Ta	137.5	68.8
Hydrogen	H	1	1	Tellurium	Te	128	64
Indium	In	74		Thallium	Tl	204	204
Iodine	I	127	127	Thorium	Th	231.5	59.6
Iridium	Ir	198	99	Tin	Sn	118	59
Iron	Fe	56	28	Titanium	Ti	50	25
Lanthanium	L	92	46.4	Tungsten	W	184	92
Lead	Pb	207	103.5	Uranium	U	120	60
Lithium	Li	7	7	Vanadium	V	137	68.5
Magnesium	Mg	24	12	Yttrium	Y	68	
Manganese	Mn	55	27.5	Zinc	Zn	65	32.5
Mercury	Hg	200	100	Zirconium	Zr	90	44.8

APPENDIX.

FRENCH WEIGHTS AND MEASURES.

The Metrical System.—"The French meter is equal to 39.370788 English inches. The *meter* is, in France, the integer of the measure of *length*, and from it all measures of surface, capacity and weight, are derived. The integer of the measure of capacity is the *liter*, which is the cubed decimeter, and is equal to 35.275 fluid ounces, or 1.763 imperial pints. The integer of the measure of weight is the *gram* = 15.434 English grains. It is exactly equal to the weight of a *cubic centimeter* of water, weighed in *vacuo* at its maximum density (39.38°). The cubic centimeter is employed by French chemists in all measurements of gases, in place of our cubic inch. It is equal to 0.061 of a cubic inch. The weight of the cubic centimeter of water is to the cubic inch of water as 15.434 to 252.468; hence there are 16.34 cubic centimeters to an English cubic inch.

"This rule is sufficiently correct for practical purposes. It is to be observed, however, that the French take the weight of the cubic centimeter of water at 39.38 in *vacuo*. The English take the weight of the cubic inch (252.458 grains) at 62° in air. Assuming the specific gravity of water at 32° to be 1.000000, the specific gravity at 39.38 is to the specific gravity at 62° as 1.000099 to 0.999000.

"The French measures increase and decrease in decimal proportions. For the *increase*, a prefix is used derived from the Greek *deca*, *hecto*, *kilo*, and *myria ;* the integer, whether meter, liter, or gram, being multiplied by 10, 100, 1000, and 10,000 respectively. To indicate the *decrease*, the prefixes *deci*, *centi*, *milli*, derived from the Latin, are employed. In this case, the integer is supposed to be divided by 10, 100, or 1000.

"Various plans have been devised for converting the French weights and measures into their English equivalents. The following tables will be found useful for this purpose :

MEASURES OF LENGTH.

		English inches.			English inches.
Millimeter	=	.03937	Decameter	=	393.70790
Centimeter	=	.39371	Hectometer	=	3,937.07900
Decimeter	=	3.93708	Kilometer	=	39,370.79000
Meter	=	39.37079	Myriameter	=	393,707.90000

MEASURES OF VOLUME.

		Cubic inches.
Millimeter, or cubic centimeter . .	=	.06103
Centiliter, or 10 cubic centimeters . .	=	.61027
Deciliter, or 100 cubic centimeters . .	=	6.10271
Liter, or cubic decimeter, or 1000 cubic centimeters	=	61.02705
Decaliter	=	610.27052
Hectoliter	=	6,102.70515
Kiloliter	=	61,027.05152
Myrialiter	=	610,270.51519

MEASURES OF WEIGHT.

		English grains.			English grains.
Milligram	=	.01543	Decagram	=	153.32349
Centigram	=	.15432	Hectogram	=	1,543.23488
Decigram	=	1.54323	Kilogram	=	15,432.34880
Gram	=	15.43235	Myriagram	=	154,323.4880

"A kilogram is equal to 2.2046213 pounds avoirdupois, and 1000 kilograms are equal to an English ton. The quintal, or 50 kilogram, is equal to the English cwt. With respect to the equivalents of English and French weights and measures, some slight differences will be found among English writers. These arise from the calculations being based on the employment of a larger or smaller number of decimal figures."

THE following equations express by symbols the chemical changes described in Part III. The numbers refer to the paragraphs:

§ 343. $KO, ClO_5 = KCl + 6O$.

§ 347. $3Fe + 4O + Fe_3\,O_4$.

§ 351. $P + 5O = PO_5$.

§ 353. $C + 2O = CO_2$.

§ 365. $2HCl + MnO_2 = 2HO + MnCl + Cl$.

§ 368. $(CaCl + CaO,\ ClO) + 2SO_3 = 2(CaO,\ SO_3) + 2Cl$.

§ 371. $Sb + 5Cl = SbCl_5$.

§ 375. It will be observed, on comparing § 375 with those which precede, that chlorine sometimes expels oxygen, and is sometimes expelled by it. In relation to the apparent inconsistency of these facts, little more can be said than that chemical affinities are modified by circumstances, the action of which is not perfectly understood.

§ 378. $HO+Cl=HCl+O$.

§ 388. $NaI+2SO_3+MnO_2=NaO,\ SO_3+MnO,\ SO_3+I$.

§ 399. $S+2O=SO_2$.

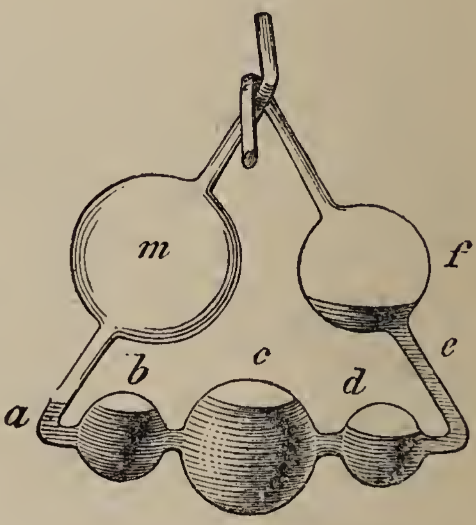
§ 422. $Zn+HO,\ SO_3=ZnO,\ SO_3+H$.
$Cu+2SO_3=CuO,\ SO_3+SO_2$.

§ 429. $P+5O=PO_5$.

§ 430. $Cu+O=CuO$.

§ 437. Liebeg's Potash Bulbs shown at *B*, Figure 117, are shown on a larger scale in Figure 323. They are partly filled with a solution of caustic potash. As the air is driven through the apparatus the first bulb, *m*, is emptied, but it remains at *a*, *b*, *c*, *d*, *e*, and *f*, and as the air passes from bulb to bulb it is entirely deprived of carbonic acid.

323



§ 440. $KO,\ NO_5 + HO,\ SO_3 = KO,\ SO_3 + HO,\ NO_5$.

§ 441. $3Cu + 4NO_5 = 3(CuO,\ NO_5 + NO_2$.

§ 442. $3Sn+2NO_5=3SNO_2+2NO_2$.

§ 443. $NO_2+2O=NO_4$.

§ 447. $3P+5NO_5=3PO_5+5NO_2$.

§ 450. $5C+PO_5=5CO+P$.

§ 466. $AsCl_3 + 6Zn + 6(HO,\ SO = 6ZnO,\ SO_3) + 3HCl+AsH_3$.

§ 485. $C+2O=CO_2$.

§ 486. $HCl+CaO,\ CO_2=HO+CaCl+CO_2$.

§ 501. $CO_2+C=2CO$.

§ 504. $C_2O_3,\ HO+SO_3=HO'SO_3+CO_2+CO$.

§ 514. $Zn+SO_3+HO=ZnO,\ SO_3+H$.

§ 516. $3Fe+4HO=Fe_3O_4+4H$.

§ 522. $H+O=HO$.

§ 528. $Na+HO=NaO+H$.

§ 550. $H+Cl=HCl$.

§ 552. $HO,\ SO_3+NaCl=NaO,\ SO_3+HCl$.

§ 561. $SiO_3+3HF=3HO+SiF_3$.

§ 568. $N+3H_3=NH_3$

§ 570. $CaO+NH_4Cl=HO+CaCl+NH_3$.

§ 574. $NH_3+HCl=NH_4Cl$.

§ 577. $KO+3HO+2P=KO,\ PO_3+PH_3$.

§ 584. $2SO_3+C_4H_5O_2=2(HO,\ SO_3)+C_4H_4$.

§ 624. $2C+KO,\ CO_2=3CO+K$.

§ 635. $Na+NH_4Cl+Hg=NaCl+NH\ +Hg$.

§ 682. $Sb+5Cl=SbCl_5$.

§ 698. $\left\{\begin{array}{l}\text{Litharge}=PbO.\\ \text{Red Lead}=Pb_3O_4.\end{array}\right.$

§ 739. The other elements not mentioned in the text are lithium, cæsium, rubidium, thallium, ilmenium, glucinum, cadmium, cerium, columbium or tantalum, didymium, erbium, iridium, lanthanum, molybdenum, niobium, norium, osmium, palladium, pelopium, rhodium, ruthenium, selenium, tellurium, terbium, thorium, titanium, tungsten or wolframium, vanadium, yttrium, and zirconium. With the exception of selenium and tellurium, which are analogous in their properties to sulphur, they may be classed with the metals. They are of rare occurrence, and may be regarded as sustaining the same relation to the other elements as do the asteroids and satellites to the more important members of the solar system. Cæsium, rubidium and thallium are new metals discovered by the use of the spectroscope.

§ 704. $Zn+PbO, A=ZnO, A+Pb$.

§ 724. $NaCl+AgO, NO_5=NaO, NO_5+AgCl$.

§ 785. $CaO, HO+KO, CO_2=CaO, CO_2+KO\ HO$.

§ 792. $NH_3+HO, SO_3=NH_4O, SO_3$.

§ 793. $CaO, CO_2=CO_2+CaO$.

§ 794. $CaO+HO=CaO, HO$.

§ 808. $HCl+NaO=HO+NaCl$.

§ 809. $NaCl+AgO, NO_5=NaO, NO_5+AgCl$.

§ 815. $(CaCl+CaO, ClO)+2CO_2=2(CaO, CO_2)+2Cl$.

§ 818. $2CaO+2Cl=(CaCl+CaO, ClO)$.

§ 819. $3C+3Cl+Al_2O_3=3CO+Al_2Cl_3$.

§ 827. $HO, SO_3+CaF=CaO, SO_3+HF$.

§ 829. $PbO, A+HS=HO, A+PbS$.

§ 836. $NaO+SO_3=NaO, SO_3$. *Vide* § 422.

§ 837. $(CaO, SO_3+2HO)=2HO+CaO, SO_3$.

§ 838. $2HO+CaO, SO_3=(CaO, SO_3+2HO.)$

§ 840. $HO, SO_3+NaCl=HCl+NaO, SO_3$.

§ 844. $(KO, SO_3+Al_2O_3, 3SO_3+24HO)=24HO+$
$(KO, SO_3+Al_2O_3, 3SO_3.)$

$$\S\ 847.\ \begin{cases} \text{Sulphate of Zinc}=(ZnO, SO_3+7HO). \\ \text{Sulphate of Copper}=(CuO, SO_3+5HO). \\ \text{Sulphate of Iron}=(FeO, SO_3+7HO). \end{cases}$$

§ 851. $CaO, NO_5 + KO, CO_2 = CaO, CO_2 + KO, NO_5$.

§ 853. $S + KO, NO_5 + 3C = KS + N + 3CO_2$

§ 855. $NH_4O, NO_5 = 4HO + 2NO$.

§ 859. $KO, CO_2 + CaO, NO_5 = KO, NO_5 + CaO, CO_2$.

§ 862. $CaO, CO_2 + NaS = CaS + NaO, CO_2$.

§ 871. $CaO + CO_2 = CaO, CO_2$.

§ 876. $(2NaO, HO, PO_5 + 24HO) + 3(AgO, NO_5) = 2(NaO, NO_5) + HO, NO_5 + 24HO + 3(AgO, PO_5)$.

§ 902. $KO, CO_2 + 2(PbO, CrO_3) = KO, CrO_3 + CO_2 + 2(PbO, CrO_3)$.

§ 906. $3(KO, MnO_3) + 2SO_3 = 2(KO, SO_3) + MnO_2 + KO, Mn_2O_7$.

INDEX.

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