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ABSTRACT

This publication is a syllabus for a senior high school chemistry course designed for the average ability, nonscience major. The content of the syllabus is divided into three basic core areas: Area I: Similarities and Dissimilarities of Matter (9 weeks); Area II: Preparation and Separation of Substances (10 weeks); Area III: Structure and Properties of Simple Organic Compounds (2 weeks). A minimum of two optional areas, each lasting for 6 weeks, are to be selected from these topics: Further Study of Organic Compounds; Chemistry in the Home; Water and Air Pollution; and Some Modern Materials and their Uses. It is recommended that there be a minimum of five 45-minute periods per week, with an average of three periods per week devoted to laboratory activities. The syllabus organization includes a listing of topics, an outline of basic concepts to be introduced, suggestions and references for laboratory activities, and supplementary information including amplification and explanation of the basic concepts. The use of this syllabus does not mandate the selection of any particular textbook or laboratory manual. First year algebra is a prerequisite for this course. The appendices include descriptions of the suggested laboratory activities, a bibliography of chemistry references, and a listing of films and filmstrips. (PR)

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# *general chemistry*

**1970 Edition**

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***chemistry***

**The University of the State of New York  
THE STATE EDUCATION DEPARTMENT  
Bureau of Secondary Curriculum Development Albany**

*2*

GENERAL CHEMISTRY

-- A State course of study for credit  
as a Group 3 elective toward a  
State Regents High School Diploma

1970 Edition

The University of the State of New York/The State Education Department  
Bureau of Secondary Curriculum Development/Albany, New York 12224

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## FOREWORD

This tentative syllabus represents an attempt to develop a suggested State chemistry. As indicated on the cover, this course is intended for nonscientists as a senior high school course in chemistry. The Regents course in chemistry, 3-unit, Group 2, major sequence or as an elective, serves the needs of the high school student. This course in general chemistry is mainly for the average student and will be different from those who take the Regents chemistry course.

The past decade has seen many important changes in the science courses. There is greater depth of treatment in the new science 7-8-9 program. As a result, science syllabuses have been revised to limit the range of content to permit better understanding. Obsolete content has been eliminated from the new courses. A basic core of required material with optional extended areas has provided for better treatment. New and more appropriate laboratory experiences have been introduced, including quantitative and analytical investigations.

At the same time the holding power of the secondary school has continued to attract a larger pupil population with an ever widening range of interests and abilities. Therefore, a significant percentage of students take no chemistry beyond the ninth year. Parents, counselors, and administrators have recommended that the Department develop a course with an optional State examination. These recommendations were adopted by the State Board of Regents and this office, and have led to this publication.

A committee was appointed and convened in May 1966 to consider the problem of the nature and framework of such a course. This committee consisted of representatives from diverse areas of the State who were experienced with local and national science courses. The members of the committee were: Daniel Beckett - Hempstead High School; Joseph Bovano - Westchester Central High School; Howard Facklam - Amherst Central High School, Snyder; Milton Goodman - Westchester Central High School; Ellis Katzman - Erasmus Hall High School, New York City; William Kelley - The Bronx High School of Science; Joan Leonard - Bay Ridge High School, New York City; Joseph Marcelli - Hudson High School; Leonora Pugh - Cochran School of Nursing, Yonkers; and Robert Wiechman - New York University.

During the spring of 1967, a committee of high school chemistry teachers developed a tentative syllabus. The members of this committee are: Anthony Anacreonte - Plainedge High School; Citriniti - Sauquoit Valley Central School; Harold Dorf - Midwood High School; Amherst Central School, Snyder; Elizabeth Lamphere - Norwich Central School; Anthony A. Henninger High School, Syracuse. The framework developed at the University of the State of New York, Miss Lamphere, reviewed by the members of the committee, and served as the basis for a new syllabus.

## FOREWORD

presents an attempt to develop a suggested State course of study for general cover, this course is intended for nonscience majors who would benefit from chemistry. The Regents course in chemistry, used for credit as part of the major or as an elective, serves the needs of the high average and above average student. This course of study is mainly for the average student whose interests and goals may be served by the Regents chemistry course.

Many important changes in the science courses offered in secondary schools have resulted in the new science 7-8-9 program. As a result senior high school Regents courses have been limited to limit the range of content to permit a greater depth of treatment and to permit more time to be spent on each topic. Some new content has been added. The new program with optional extended areas has provided teachers with time for depth of study. Laboratory experiences have been introduced to permit extensive investigations.

As the power of the secondary school has continued to increase, there has emerged a widening range of interests and abilities. Then, too, there is the fact that many students take no chemistry beyond the ninth year. As a result, many teachers have recommended that the Department develop a general course in chemistry for the secondary school. These recommendations were adopted by the Bureau of Science Education and are the basis for this publication.

The committee convened in May 1966 to consider the problem and make recommendations as to the content of such a course. This committee consisted of teachers and supervisors from schools where they were experienced with local and national science curriculum programs. Members of the committee are: Joseph Bectett - Hempstead High School; Joseph Bovan - Vestal Central School; Joseph Bectett - High School, Snyder; Milton Goodman - Westchester Community College, Valhalla; Joseph Bectett - High School, New York City; William Kelley - The Fox Lane School, Bedford; Joseph Bectett - High School, New York City; Joseph Marcelli - Hudson Valley Community College, Troy; Joseph Bectett - School of Nursing, Yonkers; and Robert Wiechman - New Rochelle Hospital-Nursing.

The committee of high school chemistry teachers met to develop this chemistry course. The members of the committee are: Anthony Anacreonte - Plainedge Public Schools; Vincent Bectett - High School; Harold Dorf - Midwood High School, New York City; Howard Facklam - High School; Elizabeth Lamphere - Norwich Central School; and E. Dorothy Swindells - School of Nursing, Syracuse. The framework developed at the first meeting was expanded by the members of the committee, and served as the basis for the experimental draft.

During the summer of 1967, Miss Lamphere, serving as a consultant to the Development, worked under the direction of John V. Favitta, Associate in Science, to develop a new course. Robert G. MacGregor, formerly Associate in Science Education and Curriculum Development, reviewed the manuscript and made valuable suggestions. This experiment was conducted in a small number of schools in the State during the 1967-68 school year.

This draft was revised during the summer of 1968 on the basis of the experience in the experimentation, and on the recommendations made by the syllabus committee prepared by W. Allister Crandall, Pulaski Central School, and Miss Lamphere, and Mr. Favitta. The final edition of the syllabus, reflecting feedback from 3 years, was prepared during the summer of 1970 by Orson W. Dunham, Guilderdale High School, and Douglas C. Franke, Colonie Central High School, working with Mr. Favitta.

It is not the intent of this syllabus to mandate the selection of any particular text or guide. Most teachers will find it desirable to rely on multiple references rather than one.

Reactions to this draft are welcome. They should be addressed to the Bureau of Curriculum Development, one of the Bureaus listed below.

Gordon E. Van Hooft  
Chief, Bureau of Science  
Curriculum Development

William E. Young  
Director, Curriculum  
Development Center

, Miss Lamphere, serving as a consultant to the Bureau of Secondary Curriculum in the direction of John V. Favitta, Associate in Science Education, to prepare the draft, formerly Associate in Science Education and now Supervisor of Secondary Curriculum, kept and made valuable suggestions. This experimental draft was used in a number of schools in the State during the 1967-68 school year.

During the summer of 1968 on the basis of the experience of teachers participating in the recommendations made by the syllabus committee. The 1968 edition was prepared by Mr. J. L. Pulaski, Pulaski Central School, and Miss Lamphere, working under the direction of the syllabus, reflecting feedback from the field over a period of time. The summer of 1970 by Orson W. Dunham, Guilderland Central High School, and Mr. J. L. Pulaski, working with Mr. Favitta.

This syllabus to mandate the selection of any particular textbook or laboratory equipment is desirable to rely on multiple references rather than on any one textbook.

Comments are welcome. They should be addressed to the Bureau of Science Education, or to the Bureau of Secondary Curriculum Development.

Gordon E. Van Hooft  
*Chief, Bureau of Secondary  
Curriculum Development*

## OVERVIEW

### Aims and content of the general chemistry course

This course of study presents an approach to the study of chemistry which may be more useful to some pupils than the Regents chemistry course. An effort has been made to provide pupils, not majoring in high school science, with a course of study that may better prepare them to meet their special goals in life. In addition, the course helps to provide pupils with an increased understanding of the work of the chemist.

The objectives of this course in chemistry should extend beyond a minimal comprehension of the basic facts and principles outlined in this syllabus. *The laboratory approach should be stressed and understandings should come out of laboratory experiences whenever possible.* The appreciation of scientific methods, the ability and willingness to change beliefs and opinions after careful weighing of new evidence, and the development of the habit of critical thinking are the intangible, but important, outcomes of this course.

### State diploma credit

This course may be used as one unit of Group III credit as an elective toward a New York State Regents high school diploma. *This course may not be used as one unit of credit for the Group II major science sequence toward a New York State Regents high school diploma.*

### Sequence and scheduling

In an attempt to introduce some degree of flexibility in the course, and at the same time provide for an adequate coverage of basic areas, the

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### Core Area

Area I Similarities  
and Dissimilarities  
of Matter  
Area II Preparation  
and Separation of  
Substances  
Area III Structure  
and Properties of  
Simple Organic  
Compounds

Evaluation-Laborato

## OVERVIEW

course content of the proposed syllabus has been divided into three basic core areas and five optional areas. The minimum requirements of the course include the basic core (Areas I, II, and III) and any *two* of the optional areas. In addition, provision must be made at the local level to evaluate proficiency in laboratory skills. (See under "Final Examination.")

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 chemist.

The guide below may help to establish a basic frame of reference for the course:

	<u>Core Area</u>	<u>Optional Areas</u> (2 are required)	<u>Suggested Time Allotment</u>
Chemistry should be the basic syllabus. and under- experiences scientific range of new of important,	Area I Similarities and Dissimilarities of Matter		9 weeks
	Area II Preparation and Separation of Substances		10 weeks
	Area III Structure and Properties of Simple Organic Compounds		2 weeks
of Group III ate Regents be used as science high school		Area IV Further Study of Organic Compounds	6 weeks
		Area V Chemistry in the Home	6 weeks
		Area VI Water and Air Pollution	6 weeks
		Area VII Some Modern Materials and their Uses	6 weeks
		Area VIII Chemical Analysis	6 weeks
e of time pro- as, the	Evaluation-Laboratory Skills		1 week

### Final examination

A final examination will be prepared by the Department for optional use by the local school system.

The final examination based on the course will consist of:

- 60 points (Basic core - Areas I, II, and III. Required by all.)
- 30 points (Fifteen points based on *each* optional area. Pupils must select *two* of the five areas.)
- 10 points (A laboratory-centered activity developed at the local level.) Teachers should complete this part of the evaluation before the date of the written examination.

Feedback necessary for the preparation and improvement of the examination will require random sampling of the General Chemistry answer sheets. Schools using the final examination should be prepared, upon request, to send the completed answer sheets to the Department for an item analysis.

The minimum time required for this course is five 45-minute periods per week. The course should be taught in a laboratory-classroom suitable for chemistry instruction, and *the laboratory approach to instruction should be used whenever possible*. It is recommended that pupils engage in laboratory-type activity an average of *three* periods per week.

### Prerequisites

The successful completion of Ninth Year Mathematics, Course I - Algebra, is a prerequisite for this course in chemistry.

### Organization of syllabus

The material in the syllabus is organized under four headings:

### Topical Outline

of topics  
Understanding a  
the basic  
course.

### Laboratory Expe

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The coding is a

1. "A" followe  
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For example  
activity in
2. "J" followe  
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7-8-9, Bloc
3. "CH" follow  
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### Supplementary I

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Appendix A - a listi

Appendix B - a bibli  
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Appendix C - a listi

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Ninth Year Mathematics,  
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Topical Outline - This column contains a listing of topics for quick reference by the teacher.

Understanding and Concepts - This column outlines the basic concepts to be introduced in the course.

Laboratory Experiences - This column contains suggestions and references for laboratory activities to be used in the course. These are coded to enable the teacher to locate them readily. Specific references by code are made to this publication, the *Science 7-8-9, Block J, The Chemistry of Matter*, and to the *Chemistry Handbook*.

The coding is as follows:

1. "A" followed by three digits indicates activities in Appendix A of this publication. For example, A 1.03 refers to the third activity in Area I.
2. "J" followed by one or two digits indicates the activity in the Appendix of *Science 7-8-9, Block J*.
3. "CH" followed by three digits indicates the activity in the *Chemistry Handbook*.

Supplementary Information - This column includes amplification and explanations of the basic concepts with examples to illustrate the depth of treatment intended. Material in this column will be subject to examination unless otherwise stated. Statements which delimit the material subject to examination, and specific suggestions to teachers are printed in italics in this column.

Cautions referring to laboratory activities are boxed in this column.

- Appendix A - a listing of laboratory activities  
Appendix B - a bibliography of chemistry reference materials  
Appendix C - a listing of films and filmstrips

## TOPICAL OUTLINE

- AREA 1 - SIMILARITIES AND DISSIMILARITIES OF MATTER
  - I. Substances
  - II. Similarities and Dissimilarities Among Substances
    - A. Phase
      - 1. Gases
      - 2. Liquids
      - 3. Solids
      - 4. Change of phase
    - B. Density
    - C. Solubility
    - D. Other properties
      - 1. Luster
      - 2. Malleability
      - 3. Ductility
      - 4. Tenacity
      - 5. Brittleness
      - 6. Electrical conductivity
  - III. Classes of Matter
    - A. Elements
      - 1. Metals
      - 2. Nonmetals
      - 3. Metalloids
    - B. Compounds
      - 1. Acids
      - 2. Bases
      - 3. Salts
      - 4. Organic compounds
    - C. Mixtures
      - 1. Suspensions
      - 2. Solutions
      - 3. Colloidal suspensions (colloids)
  - IV. Reasons for Similarities and Dissimilarities
    - A. Atomic structure
      - 1. Protons
      - 2. Neutrons
      - 3. Electrons
- B. Bond
  - 1. C
  - 2. I
- V. Periodi
  - A. Purp
  - B. Arra
  - C. Prop
    - 1. M
    - 2. N

## AREA 2 - T

### I. Prepara

#### A. Ener

1. A

2. E

3. E

4. H

#### B. Type

1. D

2. E

3. S

4. D

5. G

### II. Quantit

#### A. Mole

#### B. Chem

1. S

2. F

3. E

#### C. Mass

1. F

2. F

3. F

#### D. Volu

1. M

2. C

## TOPICAL OUTLINE

S OF MATTER

- B. Bonding
  - 1. Covalent bonding
  - 2. Ionic bonding

g Substances

- V. Periodic Table
  - A. Purpose
  - B. Arrangement
  - C. Properties
    - 1. Metals
    - 2. Nonmetals

## AREA 2 - THE PREPARATION AND SEPARATION OF SUBSTANCES

- I. Preparation of Substances
  - A. Energy and reactions
    - 1. Activation energy
    - 2. Exothermic reactions
    - 3. Endothermic reactions
    - 4. Heat of formation
  - B. Types of reactions
    - 1. Direct union or synthesis
    - 2. Exchange of ions
    - 3. Single replacement
    - 4. Decomposition
    - 5. Gain and loss of electrons
- II. Quantitative Relationships
  - A. Mole concept
  - B. Chemical shorthand
    - 1. Symbols
    - 2. Formulas
    - 3. Equations
  - C. Mass relationships
    - 1. From symbols
    - 2. From formulas
    - 3. From equations
  - D. Volume relationships
    - 1. Mole volume
    - 2. Combining volumes

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### III. Preparation of Solutions

- A. Rate of dissolving
- B. Solubility
  - 1. Nature of solute and solvent
  - 2. Temperature
  - 3. Pressure
- C. Concentration
  - 1. Concentrated and dilute solutions
  - 2. Saturated, unsaturated, and supersaturated solutions
  - 3. Mass/volume
  - 4. Molarity

### IV. Separation of Substances

- A. Separation by solubility
  - 1. Filtration
  - 2. Crystallization
- B. Separation by boiling points

## AREA 3 - STRUCTURE AND PROPERTIES OF SIMPLE ORGANIC COMPOUNDS

### I. Organic Compounds

- A. Definition
- B. General properties

### II. Bonding in Organic Compounds

- A. Isomers
- B. Structural formulas
- C. Saturated and unsaturated compounds
- D. Homologous series

### III. Some Classes of Organic Compounds

- A. Hydrocarbons
  - 1. Alkane series
  - 2. Unsaturated hydrocarbons
  - 3. Cyclic hydrocarbons
- B. Other organic compounds
  - 1. Alcohols
  - 2. Aldehydes
  - 3. Ketones
  - 4. Ethers
  - 5. Organic acids

- 6. Esters
- 7. Amine group
- 8. Amino acids

## AREA 4 - FURTHER STUDY OF ORGANIC COMPOUNDS

### I. Hydrocarbons

- A. Series of hydrocarbons
  - 1. Alkanes
  - 2. Alkenes
  - 3. Alkynes
  - 4. Alkadienes
  - 5. Benzene series
- B. Reactions of hydrocarbons
  - 1. Substitution
  - 2. Addition
  - 3. Polymerization
  - 4. Cracking

### II. Alcohols

- A. Classes of alcohols
- B. Properties of alcohols
- C. Some reactions of alcohols
  - 1. Oxidation
  - 2. Esterification

### III. Aldehydes

### IV. Organic Acids

### V. Carbohydrates

- A. Monosaccharides
- B. Disaccharides
- C. Polysaccharides

### VI. Proteins

- A. Formation from amino acids
- B. Hydrolysis

### VII. Lipids

## AREA 5 - CHEMISTRY IN THE HOME

### I. Foods

- A. Preservation of foods
- B. Some food nutrients

- 1. Carbohydrates
- 2. Proteins
- 3. Lipids
- C. Changing structure of nutrients
  - 1. Hydrolysis
  - 2. Oxidation
  - 3. Coagulation
- D. Changing texture or particle size
  - 1. Colloidal dispersions
  - 2. Forming gels
  - 3. Forming emulsions
  - 4. Leavening action
  - 5. Crystallization
- II. Home Cleaning and Sanitation
  - A. Soaps and detergents
    - 1. Soaps
    - 2. Detergents
  - B. Bleaching
  - C. Disinfectants

## AREA 6 - ENVIRONMENTAL POLLUTION

- I. Introduction
- II. Water
  - A. Water supply
  - B. Naturally occurring substances in the water supply
    - 1. Rain water
    - 2. Ground water
  - C. Water pollutants
    - 1. Sewage
    - 2. Infectious agents
    - 3. Heat
    - 4. Sediments
    - 5. Radioactive substances
    - 6. Minerals and chemical substances
      - a. Plant nutrients
      - b. Pesticides
      - c. Industrial chemicals
      - d. Salt water
      - e. Detergents
      - f. Oil

- D. Self-purification
  - 1. Degradation
  - 2. Decomposition
  - 3. Recovery
  - 4. Clean water
- E. Water treatment
  - 1. Aeration
  - 2. Adsorption of gases
  - 3. Coagulation and sedimentation
  - 4. Chlorination
  - 5. Water softening

## III. Air

- A. Composition of the air
- B. Causes of air pollution
- C. Some major air pollutants
  - 1. Industry
  - 2. Internal combustion engines
  - 3. Furnaces and incinerators
- D. Air pollutants
  - 1. Solids
  - 2. Liquids
  - 3. Gases
    - a. Carbon monoxide
    - b. Oxides of nitrogen
    - c. Gaseous sulfur compounds
    - d. Hydrocarbons

- E. Prevention of air pollution

## IV. Land

- A. Refuse disposal
  - 1. Open dumps
  - 2. Sanitary landfills
  - 3. Incineration
- B. Prevention of land pollution

## AREA 7 - SOME MODERN MATERIALS

- I. Polymers
  - A. Formation of polymers
    - 1. Condensation
    - 2. Addition

- B. Some representative polymers
  - 1. Polyamides
    - a. Proteins
    - b. Nylons
  - 2. Phenolic plastics
  - 3. Polyesters
  - 4. Vinyl plastics
  - 5. Silicones
    - a. Synthesis
    - b. Properties
- C. Some types of polymers
  - 1. Elastomers
  - 2. Fibers
  - 3. Thermoplastic polymers
  - 4. Thermosetting and cold-setting plastics
- II. Industrial Metals
  - A. "Natural" impurities
    - 1. Concentration of ore
    - 2. Reduction
  - B. "Artificial" impurities - alloying
  - C. Properties and uses of alloys
- III. Radioisotopes
  - A. Nature of radioactivity
    - 1. Stability of nuclei
    - 2. Nuclear energy
      - a. Fission reactors
      - b. Fusion reactors
    - 3. Major types of nuclear radiation
      - a. Alpha particles
      - b. Beta particles
      - c. Gamma rays
      - c. Neutrons
  - B. Some properties and uses of radioisotopes
    - 1. Uses based on chemical reactivity
    - 2. Uses based on radioactivity
    - 3. Uses based on rate of decay and half-life
  - C. Detection of nuclear radiation
    - 1. Film
    - 2. Electroscope
    - 3. Geiger counter
    - 4. Scintillation counter

D. Radiation and human safety

## AREA 8 - CHEMICAL ANALYSIS

- I. Qualitative Analysis
  - A. Precipitation
  - B. Spectroscopy
  - C. Chromatography
    - 1. Phases
    - 2. Rate of flow
    - 3. Identification
    - 4. Adsorption
    - 5. Thin layer
  - D. Gas evolution
- II. Quantitative Analysis
  - A. Gravimetric methods
  - B. Volumetric methods
    - 1. Gas measurement
    - 2. Titrating normal solutions
  - C. Instrumental analysis
    - 1. pH meters
    - 2. Colorimeters and spectrometers

Area 1 - Similarities and Dissimilarities

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory</u>
I. Substances	<p>A substance is a variety of matter, all specimens of which have identical properties and composition.</p> <p>A substance is homogeneous.</p>	<p>In all areas of course, particularly in an increase of the complexity of the laboratory</p>
II. Similarities and Dissimilarities Among Substances	<p>Each substance has characteristic properties by which it can be recognized.</p> <p>Dissimilar substances may have some properties in common but will have some properties which differ.</p> <p>Some properties that may be used in classifying and identifying substances are color, luster, odor, density, phase at room temperature, melting</p>	<p>Laboratory should enable students to sort out a number of substances on the basis of their properties and obtain data from charts in the <i>Tables, Charts, and Textbook</i></p>

## 1 - Similarities and Dissimilarities of Matter

### Understandings and Concepts

### Laboratory Experiences

### Supplementary Information

Substance is a variety of matter, all specimens of which have identical properties and compositions.

Substance is homogeneous.

Each substance has characteristic properties by which it can be recognized.

Similar substances may have some properties in common but will have some properties which differ.

Properties that may be used in classifying and identifying substances are color, luster, odor, density, phase at room temperature, melting

In all areas of this course, pupils should gain an increased understanding of the concepts through laboratory experience.

Laboratory experiences should enable pupils to sort out and classify a number of substances on the basis of their properties and on information obtained from tables and charts in the *Reference Tables, Chemistry Handbook*, and textbooks.

*Material in this column will be subject to examination unless otherwise stated.*

*The concepts shown in column II at the left for this area should have been covered to some extent in earlier science courses. Teachers should become acquainted with Science 7-8-9, Block J, The Chemistry of Matter, and review pertinent material with pupils when necessary.*

Some properties which can be determined by the use of tables are density, melting point, boiling point, solubility, and phase at room temperature.

*For purposes of examination, pupils will be held responsible for the definitions and interpretation from tables and charts for density, melting point, boiling point, solubility, and phase.*

Topical Outline

Understandings  
and Concepts

Laboratory

point, boiling point, hardness, brittleness, ductility, malleability, tenacity, electrical conductivity, and solubility.

A. Phase

The term "phase" is used to refer to the gas, liquid, or solid form of matter.

The phase in which matter exists depends on the attractive forces between its particles.

1. Gases

Gases have neither a definite shape nor a definite volume. They assume the shape and volume of the container.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

t, boiling point,  
ness, brittleness,  
ility, malleability,  
city, electrical con-  
vity, and solubility.

term "phase" is used  
refer to the gas,  
id, or solid form of  
er.

phase in which matter  
s depends on the  
active forces between  
particles.

s have neither a def-  
e shape nor a definite  
ne. They assume the  
e and volume of the  
ainer.

*Pupils are not expected to  
memorize tables of phys-  
ical constants.*

The magnitude of the  
attractive forces between  
the particles of a sub-  
stance increases as the  
distance between the par-  
ticles decreases.

The effectiveness of the  
attractive forces in  
holding the particles of a  
substance together depends  
on the magnitude of the  
forces and on the kinetic  
energy of the particles.  
The greater the kinetic  
energy of the particles,  
the greater the force  
required to hold them  
together.

The kinetic energy of the  
particles of a substance  
increases with increasing  
temperature.

The particles of a sub-  
stance in the gaseous  
phase are relatively far  
apart (as shown by the  
compressibility of gases)

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

2. Liquids

A liquid has a definite volume, but takes the shape of the container.

Pour liquids into containers of various shapes

3. Solids

A solid has a definite shape and volume.

Find the volume of regularly shaped objects using linear measurements

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

liquid has a definite shape, but takes the shape of the container.

Pour liquids into containers of various shapes.

and the attractive forces have little effect on their behavior.

In the gaseous phase the particles are moving faster (have more kinetic energy) than when the substance is in the liquid or solid phase.

The particles in a liquid are relatively close together (as shown by the fact that liquids are not easily compressed). The particles are moving more slowly than in the corresponding gaseous phase, but more rapidly than when the substance is in the solid phase.

The attractive forces are sufficiently strong to hold the particles together, but not strong enough to hold the particles in a fixed position relative to other particles.

liquid has a definite shape and volume.

Find the volume of regularly shaped objects by using linear measurements.

In the solid phase the attractive forces are sufficiently strong to hold

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

4. Change of  
phase

The particles of a solid resist a change of position.

Change of phase of a substance is accompanied by the absorption or release of heat.

Energy is absorbed when a solid becomes a liquid and when a liquid becomes a gas.

Energy is released when a gas condenses to a liquid and when a liquid becomes a solid.

The volume of an irregularly shaped object can be measured by finding the volume of water displaced by the object.

A 1.01 in the appendix can be used to show changes between liquid and gaseous phases.

The melting and freezing of water or of a low melting point substance such as naphthalene or paradichlorobenzene can be used to illustrate the change between solid and liquid phases.

ings  
ots

Laboratory Experiences

Supplementary Information

F a solid  
of posi-

The volume of an irregularly shaped object can be measured by finding the volume of water displaced by the object.

the particles in a regular geometric pattern. All true solids have a crystalline structure.

of a sub-  
panied by  
or release

A 1.01 in the appendix can be used to show changes between liquid and gaseous phases.

The energy absorbed or released during a change of phase represents a change in potential energy. Thus the energy

ed when a  
liquid  
d becomes

The melting and freezing of water or of a low melting point substance such as naphthalene or paradichlorobenzene can be used to illustrate the change between solid and liquid phases.

absorbed when a solid changes to a liquid or a liquid to a gas does work in separating the particles, resulting in a higher potential energy content. For example, steam can cause more serious burns than boiling water at the same temperature because of its greater heat content.

ed when a  
a liquid  
d becomes

During a change of phase, the energy absorbed or released does not affect the speed (therefore the kinetic energy) of the particles. Thus, there is no temperature change during a phase change.

Topical Outline

Understandings  
and Concepts

Laboratory

a. Melting  
point

A pure solid has a definite temperature, called the melting point, at which it turns into a liquid.

A liquid changes into a solid at a temperature called its freezing point.

The melting and freezing points are the same temperature for the same substance.

It is possible for a substance to exist as a solid and a liquid at the same temperature.

b. Evaporation

Evaporation occurs whenever a liquid substance changes to a gas.

Evaporation tends to take place at all temperatures.

Evaporation rate is affected by temperature.

In a closed system, the vapor (gas) produced exerts a pressure which increases as the temperature of the liquid is raised.

Determine  
of a solid  
Direction  
melting p  
found in  
manuals.

See CH 8.  
comparison  
point of

Findings  
Concepts

Laboratory Experiences

Supplementary Information

It has a definite  
temperature, called  
melting point, at  
which it turns into a

Determine the melting point  
of a solid such as ice.  
Directions for determining  
melting points can be  
found in most laboratory  
manuals.

The melting points and/or  
boiling points of sub-  
stances can be found in  
reference tables, text-  
books, and handbooks of  
chemistry.

It changes into a  
liquid at a certain  
temperature called the  
freezing point.

See CH 8.06 b, c, for a  
comparison of the melting  
point of two metals.

The melting and freezing  
points are the same tem-  
perature for the same sub-

stances. It is possible for a sub-  
stance to exist as a  
solid, liquid at the  
same temperature.

Freezing occurs when-  
ever a liquid substance  
loses heat and becomes  
a solid.

The rate at which it  
tends to take place  
depends on the tempera-  
tures.

The rate is  
faster at higher  
temperatures.

In a closed system, the  
vapor pressure produced  
depends on the tempera-  
ture. The pressure which  
the vapor exerts is  
called the vapor pressure.  
The vapor pressure of a  
liquid is

The term "vapor" is fre-  
quently used to refer to  
the gas phase of a sub-  
stance that is normally a  
liquid or a solid at room  
temperature.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

c. Boiling  
point

This vapor pressure is specific for each substance.

A liquid will boil at a temperature at which the vapor pressure equals the pressure on the liquid.

The normal boiling point is the temperature at which the vapor pressure of the liquid equals one atmosphere (760 mm. of mercury).

Measure the boiling point of water. Air pressure and accuracy of the thermometer may account for possible differences in readings.

B. Density

Density is the mass per unit volume of a substance.

Density can easily be determined in the laboratory. A variety of methods of determining density are given in most laboratory manuals or high school physics textbooks.

Understandings

Concepts

For pressure is  
for each sub-

will boil at a  
temperature at which the  
pressure equals the  
vapor pressure of the liquid.

Normal boiling point  
temperature at  
which the vapor pressure  
of the liquid equals one  
atmosphere (760 mm. of

is the mass per  
unit volume of a substance.

Laboratory Experiences

Measure the boiling point  
of water. Air pressure  
and accuracy of the ther-  
mometer may account for  
possible differences in  
readings.

Density can easily be  
determined in the labora-  
tory. A variety of ways  
of determining density  
are given in most labora-  
tory manuals or high  
school physics textbooks.

Supplementary Information

"Boiling point is the tem-  
perature at which a liquid  
changes to a gas" is an  
inaccurate definition  
often used. A liquid will  
change to a gas at any  
temperature. The boiling  
point depends on the pres-  
sure on the liquid.

Autoclaves used for ster-  
ilizing materials and  
pressure cookers operate  
on the principle that the  
boiling point is increased  
when the pressure on the  
liquid is increased.

Figures given for boiling  
points of liquids in ref-  
erence tables are "normal  
boiling points."

Density should be  
expressed in metric (cgs)  
units.

The density of solids and  
liquids is usually  
expressed in grams per  
milliliter (g/ml). The  
density of gases is

Topical Outline

Understandings  
and Concepts

Laboratory Ex

When the density of a substance is compared with the density of water, the resulting value is called the specific gravity.

The specific gravity of various liquids is determined in the laboratory using hydrometers.

C. Solubility

Solubility is the ability to dissolve in another substance called a solvent.

Compare the amount of undissolved solid after equal quantities of different solvents have been added to equal volumes of water.

D. Other properties

1. Luster

The silvery shine of many substances is called luster.

See CH 8.02 for activities dealing with luster.

Sandpaper dulls metal. Observe their luster.

dings  
epts

Laboratory Experiences

Supplementary Information

ty of a sub-  
ared with  
water, the  
e is called  
ravity.

The specific gravity of various liquids can be determined in the laboratory using hydrometers.

usually expressed in grams per liter.

The density of water is considered to be 1 g/ml.

Density = sp.gr. x 1 g/ml.

In the metric system, specific gravity and density have the same numerical value. Specific gravity is also known as relative density.

the ability  
another  
ed a sol-

Compare the amounts of undissolved solid left after equal quantities of different solutes have been added to equal volumes of water.

*Pupils should have studied the property of solubility in Section V-B-2 of Block J (pp. 60-63).*

*Further details on solutions will be studied in Section III C of this Area and in Area 2.*

ine of many  
called lus-

See CH 8.02 for suggested activities dealing with luster.

*Pupils should have some firsthand experience with the properties of luster, malleability, ductility, tenacity, brittleness, and electrical conductivity.*

Sandpaper dull metals to observe their luster.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laborator</u>
2. Malleability	Malleability is the ability to be pounded into thin sheets.	Zinc and c be hammere new shapes
3. Ductility	Ductility is the ability to be drawn into a wire.	Experiment tility are of this co pupils can of differe compositio the term.
4. Tenacity	Tenacity (tensile strength) is the ability to resist being pulled apart.	Activity J the differ strength b metals. T can be use tensile st ent fibers
5. Brittleness	Brittleness is the tendency to shatter when struck with a sharp blow.	Compare th sulfur w by hitting with a ham
6. Electrical conductivity	Electrical conductivity is the ability of a substance to pass an electric current.	See CH 8.04 for activit trate elect tivity.

Understandings

Concepts

Laboratory Experiences

Supplementary Information

ductility is the ability of a substance to be pounded into sheets.

Zinc and copper sheets can be hammered or worked into new shapes.

ductility is the ability of a substance to be drawn into a wire.

Experiments involving ductility are beyond the scope of this course. However, pupils can inspect wires of different gauges and composition to understand the term.

ductility (tensile strength) is the ability of a substance to resist being pulled apart.

Activity J-15 illustrates the difference in tensile strength between two metals. The same method can be used to compare the tensile strength of different fibers.

brittleness is the tendency of a substance to fracture when struck with a hammer.

Compare the brittleness of sulfur with lead or copper by hitting a piece of each with a hammer.

There are several other properties, such as fracture, streak, cleavage, and hardness which pupils may have encountered in earth science courses.

electrical conductivity is the ability of a substance to conduct an electric current.

See CH 8.04 a(1) and b for activities to illustrate electrical conductivity.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experi</u>
III. Classes of Matter		
A. Elements	An element is a substance which cannot be decomposed by a chemical change.	A collection of elements can be sorted into metal or nonmetal groups on the basis of luster and conductivity.
1. Metals	The majority of the elements are metals; they have luster, are malleable and ductile, and are good conductors of heat and electricity.	
	All metals except mercury are solids at room temperature.	
2. Nonmetals	Nonmetals, except bromine, are gases or brittle solids; they lack luster and are poor conductors of heat and electricity.	
3. Metalloids	Metalloids are those elements which have certain properties characteristic of metals and other properties characteristic of nonmetals.	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Element is a substance  
cannot be decomposed  
chemical change.

A collection of elements  
can be sorted into metal  
or nonmetal groups on the  
basis of luster and con-  
ductivity.

*Teachers may wish to  
introduce the symbols of  
some of the common ele-  
ments at this point.  
Review the use of symbols  
as covered in Section IV  
of Block J.*

Majority of the ele-  
are metals; they  
luster, are malleable  
ductile, and are good  
conductors of heat and  
electricity.

*The quantitative signif-  
icance of symbols will be  
treated in Area 2, Section  
II C.*

Metals except mercury  
are solids at room tem-  
perature.

*Atomic structure is  
treated in Section IV of  
this Area.*

Nonmetals, except bromine,  
are gases or brittle  
solids; they lack luster  
and are poor conductors  
of heat and electricity.

Many nonmetals can cause  
skin burns or are poison-  
ous.

Metalloids are those ele-  
ments which have certain  
properties characteristic  
of metals and other prop-  
erties characteristic of  
nonmetals.

Examples of metalloids are  
boron, silicon, arsenic,  
and tellurium.

Topical Outline

Understandings  
and Concepts

Laboratory

B. Compounds

A compound is a substance which can be decomposed by a chemical change. A compound is composed of two or more elements chemically united.

All samples of a compound have identical composition and properties.

The components of a compound are present in a definite mass ratio which cannot be varied.

Compounds may be classified according to their structure, composition, or properties.

Heating  
burning  
activities  
used for  
the defini  
*do not s*  
*magnesi*

1. Acids

The properties of a compound may be used to classify it as an acid:

- . An acid is a compound which produces hydrogen ions when dissolved in water.
- . Acids affect the color of acid-base indicators.
- . Acids neutralize the effect of bases.
- . Acids react with many metals to liberate hydrogen gas.

The chemi  
contains  
concerni

CH 5.14

CH 5.15

CH 5.16

CH 5.17

CH 5.18

## Understandings and Concepts

Compound is a substance which can be decomposed by a chemical change. A compound is composed of two or more elements chemically united.

Samples of a compound have identical composition and properties.

The components of a compound are present in a definite mass ratio which cannot be varied.

Compounds may be classified according to their structure, composition, or properties.

The properties of a compound may be used to classify it as an acid:

An acid is a compound which produces hydrogen ions when dissolved in water.

Acids affect the color of acid-base indicators.

Acids neutralize the effect of bases.

Acids react with many metals to liberate hydrogen gas.

## Laboratory Experiences

Heating mercuric oxide and burning magnesium are activities which can be used for understanding of the definition. *Caution: do not stare at burning magnesium.*

The chemistry handbook contains several activities concerning pH.

CH 5.14 - pH of distilled water

CH 5.15 - Preparation of solutions of known pH

CH 5.16 - Color change of indicators

CH 5.17 - pH of some common substances

CH 5.18 - Neutralization

## Supplementary Information

The decomposition of mercuric oxide should be carried out in a fume hood, preferably as a teacher demonstration. Both mercury and mercury vapor are extremely toxic. Pupils should not be allowed to handle mercury.

The classification of compounds greatly simplifies the study of chemistry.

Acids can be defined in a number of ways.

*Pupils should be familiar with the pH scale and should understand that each whole number on the scale represents a difference of 10 times in the concentration of hydrogen ions per liter of solution.*

*Pupils are not expected to know that the pH number is the logarithm of the reciprocal of the hydrogen ion concentration.*

Topical Outline

Understandings  
and Concepts

Laboratory Exp

- . Acids have a sour taste. The sour taste of many foods is due to the presence of naturally-occurring acids.
- . Acids react with carbonates to liberate carbon dioxide gas.

2. Bases

The properties of a compound may be used to classify it as a base:

Properties of bases shown by use of and 5.12.

- . Bases affect the color of acid-base indicators.
- . The solution of a base feels slippery.
- . Bases neutralize the effect of acids.

3. Salts

A salt can be considered as a product of the neutralizing of an acid with a base. Most salt compounds are found in the minerals of the earth and in sea water, or are produced by other chemical reactions.

Compare the colorability of several

Laboratory Experiences

Supplementary Information

taste.  
many  
he  
ally-

Pupils should not be allowed to taste laboratory acids or other chemicals.

carbon-  
carbon

Pupils should be warned that strong acid solutions are caustic to the skin.

a com- Properties of bases may be  
to shown by use of CH 5.11 b  
ase: and 5.12.

*Bases can also be defined in a number of ways. In this syllabus only a definition based on the properties of bases will be required.*

color  
icators.

a base

Pupils should be warned that strong basic solutions are caustic to the skin.

e the

sidered as Compare the color and solu-  
neutraliz- bility of several salts.

Although salts have a salty taste, many of them are poisonous, so the property should not be tested.

h a base.  
is are  
rals of  
sea water,  
y other  
s.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

4. Organic  
compounds

The properties of salts  
vary widely.

Organic compounds are com-  
pounds of carbon.

C. Mixtures

A mixture consists of two  
or more distinct sub-  
stances differing in prop-  
erties and composition.

The composition of a mix-  
ture can be varied.

Mixtures may be homoge-  
neous (e.g., solutions or  
mixtures of gases) or  
heterogeneous (e.g., a  
mixture of iron and sul-  
fur).

The separation of mix-  
tures can provide experiential  
learning. Numerous techniques  
exist for separating a  
mixture of salt, pre-  
cipitated chalk, sand, and  
iron filings might be used.

Microscopic study of  
sediments from a river bed will  
reveal some interesting com-  
ponents.

1. Suspensions

Suspensions are mixtures  
containing particles of  
one substance (usually a  
solid) suspended in  
another substance (usually  
a liquid).

standings  
Concepts

Laboratory Experiences

Supplementary Information

ties of salts  
y.

mpounds are com-  
carbon.

There are other defi-  
nitions of organic com-  
pounds which will not be  
used in this course.

*Organic compounds are  
treated more fully in Area  
3 and optional Area 4.*

consists of two  
distinct sub-  
ffering in prop-  
composition.

The separation of mixtures  
can provide experience in  
numerous techniques. A  
mixture of salt, precipi-  
tated chalk, sand, and  
iron filings might be used.

In a mixture, as opposed  
to a compound, the com-  
ponents retain their own  
properties.

ition of a mix-  
e varied.

ay be homoge-  
, solutions or  
f gases) or  
ous (e.g., a  
iron and sul-

Microscopic study of sand  
from a river bed will show  
some interesting compo-  
nents.

s are mixtures  
particles of  
nce (usually a  
pended in  
bstance (usually

Suspensions are opaque to  
the passage of light. The  
particles are visible and  
can be removed by filtra-  
tion.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Ex</u>
2. Solutions	A suspension can be made in varying proportions.	
	A solution is a homogeneous mixture.	
	A solution can be made in varying proportions.	
a. Solute	The solute is the substance which is dissolved.	
	Solutes vary in their solubility.	
b. Solvent	A solvent is the dissolving substance.	

Understandings

Concepts

Laboratory Experiences

Supplementary Information

tion can be made  
g proportions.

a is a homoge-  
ure.

can be made in  
oportions.

is the sub-  
h is dissolved.

y in their

s the dis-  
stance.

*Material on solutions  
should have been covered  
in Block J and only a  
brief review should be  
necessary.*

The dissolved particles in  
a solution are not vis-  
ible, do not interfere  
with the passage of light,  
do not settle out on  
standing, and cannot be  
removed by filtration.

The solute may be a solid,  
a liquid, or a gas.

In a strict sense, no sub-  
stance is absolutely  
insoluble.

The solvent may be a  
solid, a liquid, or a gas.

The most common solutions  
are those in which the  
solvent is a liquid.  
Solutions referred to in  
this syllabus are under-  
stood to be solutions in  
liquid solvents unless  
otherwise specified.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Solvents vary in their ability to dissolve solutes.

Water is the most common solvent.

Tinctures are solutions in which ethanol is used as a solvent.

The difference in solubility of iodine in water and in ethanol can be demonstrated.

3. Colloidal suspensions (colloids)

A colloid is a mixture containing particles which are larger than those in a solution but smaller than those in a suspension.

See CH 3.46 for the preparation of a colloid.

Colloids have some properties of a solution and some properties of a suspension.

Colloidal suspensions show the Tyndall effect.

The Tyndall effect is demonstrated by the experiment in CH 3.53.

a. Dispersing medium

The medium in which the colloidal particles are suspended is known as the dispersing medium.

Standings  
Concepts

Laboratory Experiences

Supplementary Information

ry in their  
dissolve sol-

*Factors affecting solubility and methods of expressing concentrations of solutions are treated in Area 2.*

e most common

re solutions in  
ol is used as

The difference in solubility of iodine in water and in ethanol can be demonstrated.

s a mixture  
particles which  
than those in a  
t smaller than  
suspension.

See CH 3.46 for the preparation of a colloid.

ve some proper-  
olution and  
ties of a sus-

suspensions show  
effect.

The Tyndall effect can be demonstrated by the use of CH 3.53.

Colloidal particles do interfere with the passage of light.

in which the  
articles are  
s known as the  
medium.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory</u>
b. Dispersed substance	The suspended colloidal particles form the dispersed substance.	
IV. Reasons for Similarities and Dissimilarities		
A. Atomic structure	An atom is the smallest particle of an element that can exist separately or enter into combination with other atoms.	
	All atoms of the same element are chemically alike.	
	Atoms of different elements are chemically different.	
	The atomic mass of an atom is the relative mass in comparison to the mass of the carbon-12 atom, which is assigned an arbitrary value of exactly 12 units, called atomic mass units.	
	An atom is composed of protons, neutrons, and electrons.	
	The protons and neutrons are concentrated in the central part of the atom called the nucleus. Col-	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

suspended colloidal  
particles form the dis-  
persed substance.

Atom is the smallest  
particle of an element  
which can exist separately  
or enter into combination  
with other atoms.

Atoms of the same ele-  
ment are chemically alike.

Atoms of different elements  
are chemically different.

Atomic mass of an atom  
is the relative mass in  
comparison to the mass of  
carbon-12 atom, which  
is assigned an arbitrary  
value of exactly 12 units,  
called atomic mass units.

Atom is composed of  
protons, neutrons, and  
electrons.

Protons and neutrons  
are concentrated in the  
central part of the atom  
called the nucleus. Col-

*This material is treated  
in Sections III a-III B2c  
of Block J, and only a  
brief review should be  
necessary.*

An atomic mass unit (amu)  
is defined to be 1/12 the  
mass of the carbon-12  
atom.

The common isotope of  
hydrogen contains no neu-  
trons.

*Although protons and neu-  
trons are the only nuclear  
particles that have been  
identified in an intact*

Topical Outline

Understandings  
and Concepts

Laboratory Ex

lectively they are called nucleons.

An atom consists of a nucleus in association with one or more electrons.

For most practical purposes, the entire mass of an atom may be considered to be in the nucleus.

Electrons are located outside the nucleus and are distributed in the space which makes up most of the atom.

1. Protons

a. Charge

A proton has a single positive charge.

Electrical ch demonstrated rubber or gla an electrosco from the phys tory.

## Laboratory Experiences

## Supplementary Information

*nucleus, other particles have been identified among the break-down products of certain nuclear disintegrations. The relationship of these particles to the structure and stability of the nucleus is the subject of much current research and is beyond the scope of this course.*

Electrical charges can be demonstrated with charged rubber or glass rods and an electroscope borrowed from the physics laboratory.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experi</u>
b. Mass	A proton has a mass of approximately one atomic mass unit.	
c. Symbol	The symbols used to represent a proton are p, and ${}^1_1\text{H}$ .	
d. Atomic number	The atomic number indicates the number of protons in the nucleus of an atom.	
	All atoms of the same element contain the same number of protons, and hence have the same atomic number.	
	Atoms do not gain or lose protons in any chemical reaction.	
2. Neutrons		
a. Charge	The neutron has no electrical charge.	
b. Mass	The neutron has a mass similar to that of the proton.	

ings  
ots

Laboratory Experiences

Supplementary Information

mass of  
the atomic

The actual mass of the  
proton is 1.007267 atomic  
mass units.

l to rep-  
are p, and

er indicates  
protons in  
an atom.

The atomic number may be  
indicated by a subscript  
number placed on the left  
of the symbol, e.g.,  $C_6$ .

e same ele-  
e same num-  
and hence  
atomic num-

The atomic number iden-  
tifies the element.

in or lose  
chemical

no elec-

a mass  
of the pro-

The actual mass of the  
neutron is 1.008665 atomic  
mass units; that of the  
proton is 1.007267 amu.

Topical Outline

Understandings  
and Concepts

Laboratory E

c. Symbol

A symbol often used for a neutron is  $n$ , or  ${}^1_0n$ .

d. Mass  
number

The mass number of an atom is the total of the number of protons and neutrons in the nucleus.

e. Number of  
neutrons

The number of neutrons in a nucleus can be found by subtracting the atomic number from the mass number of the atom.

f. Isotopes

Isotopes are atoms of the same element (therefore having the same number of protons) which differ in the number of neutrons.

### Understandings and Concepts

A symbol often used for a neutron is  $n$ , or  ${}^1_0n$ .

The mass number of an atom is the total of the number of protons and neutrons in the nucleus.

The number of neutrons in a nucleus can be found by subtracting the atomic number from the mass number of the atom.

Isotopes are atoms of the same element (therefore having the same number of protons) which differ in the number of neutrons.

### Laboratory Experiences

### Supplementary Information

The mass number may be indicated by a superscript number placed on the left of the symbol, e.g.,  ${}^{12}C$ .

Distinguish between mass number and atomic mass. The mass number indicates the total of the number of protons and neutrons of an atom and is always a whole number. The atomic mass of an element is the weighted average mass of the naturally occurring isotopes of that element and is usually a fractional number.

Isotopes are usually named by affixing the mass number to the name of the element, as carbon-12. An exception is frequently made in naming the three isotopes of hydrogen. The most abundant isotope  ${}^1_1H$ ,

is usually referred to as hydrogen, but has been

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Isotopes of the same element are chemically the same, but differ in mass.

3. Electrons

a. Charge

The electron has a single negative charge.

b. Mass

The mass of an electron is 1/1836 that of a proton. Electrons do not contribute significantly to the total mass of the atom.

c. Symbol

The symbols used to represent an electron are  $e^-$  and  ${}_{-1}^0e$ .

d. Number of electrons

In any neutral atom there are the same number of electrons as protons.

Laboratory Experiences

Supplementary Information

called "protium." The isotope  ${}^2_1\text{H}$ , is frequently called "deuterium," and  ${}^3_1\text{H}$  is called "tritium."

The atomic mass of an element, as given in atomic "weight" tables, is the average mass of the naturally occurring isotopes of the element.

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Topical Outline

e. Energy levels

Understandings  
and Concepts

The electrons are outside the nucleus at various energy levels.

In the Bohr model of the atom, electrons are considered to revolve around the nucleus in one of several concentric circular orbits.

The orbits are called shells, rings, or principal energy levels and can be denoted by the letters K, L, M, N, O, P, Q, or by the numbers 1, 2, 3, 4, 5, 6, 7.

Electrons in orbits near the nucleus have less energy than those in orbits farther from the nucleus.

Laboratory

Activities for models of atoms may be found 2.08 and in

Understandings  
and Concepts

Electrons are outside the nucleus at various energy levels.

In the Bohr model of the atom, electrons are considered to revolve around the nucleus in one of several concentric circular orbits.

These orbits are called shells, rings, or principal energy levels and can be denoted by the letters K, L, M, N, O, P, Q, or by the numbers 1, 2, 3, 4, 5, 6, 7.

Electrons in orbits near the nucleus have less energy than those in orbits further from the nucleus.

Laboratory Experiences

Activities for illustrating models of atomic structure may be found in CH 2.07-2.08 and in J-25.

Supplementary Information

*Teachers should stress that the Bohr model is one of several models used to explain the behavior of atoms which are too small to be seen or isolated. A model represents an approximation of atomic structure and does not picture the actual atom.*

It should be pointed out that the electrons do not actually travel in regular circular orbits. Their actual motion more closely resembles the random motion of bees around a hive. However, the principal energy level or shell represents the energy associated with a definite average distance from the nucleus.

Topical Outline

Understandings  
and Concepts

Laboratory

f. Electron  
distribu-  
tion

There is a maximum number  
of electrons which each  
orbit can hold.

The first (K) energy level  
can hold no more than 2  
electrons.

The second (L) energy level  
can hold no more than 8  
electrons.

Atoms with atomic numbers  
1-20 can have no more than  
8 electrons in the third  
(M) energy level.

g. Excited  
atoms -  
spectral  
lines

When atoms absorb energy,  
electrons may shift to  
higher energy levels. The  
atom is then said to be in  
the excited state.

The excited state is unsta-  
ble, and the electrons fall  
back to a lower energy  
level.

When elements are suffi-  
ciently excited in the  
vapor phase, they yield  
radiant energy in the form

CH 2.17 is  
dealing with  
lines.

Understandings  
and Concepts

... a maximum number  
... electrons which each  
... can hold.

... highest (K) energy level  
... contains no more than 2  
... electrons.

... second (L) energy level  
... contains no more than 8  
... electrons.

... elements with atomic numbers  
... less than 20 have no more than  
... three electrons in the third  
... energy level.

... atoms absorb energy,  
... and electrons may shift to  
... higher energy levels. The  
... energy then said to be in  
... an excited state.

... an excited state is unsta-  
... ble and the electrons fall  
... to a lower energy

... elements are suffi-  
... ciently excited in the  
... ground state, they yield  
... energy in the form

Laboratory Experiences

CH 2.17 is an activity  
dealing with spectral  
lines.

Supplementary Information

*Pupils should be able to  
use the Bohr model to rep-  
resent the probable struc-  
ture of atoms and ions and  
to indicate electric  
charge.*

*For purposes of examina-  
tion, models will be lim-  
ited to the first 20 ele-  
ments, and the necessary  
information may be  
obtained from Reference  
Tables.*

Representations of atoms  
with numbers greater than  
20 are complicated by  
exceptions to the simple  
rules stated.

The use of spectroscopy in  
identifying elements is  
treated in optional Area  
8.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Exp</u>
h. Valence electrons	of characteristic spectral lines which can identify the element.	
	The electrons in the outermost shell of an atom are called the valence electrons.	
	The valence shell of an atom is complete with 8 electrons. (The K-shell, which is complete with 2 electrons, is an exception.)	
	The chemical behavior of an element depends largely on the number of valence electrons.	
B. Bonding	Atoms with incomplete valence shells tend to combine with other atoms to complete their valence shells.	
	Atoms may achieve a complete valence shell by losing, gaining, or sharing electrons.	
	The number of electrons transferred or shared between atoms is such that each atom acquires a	Pupils can use board or other material to show how can be transfer

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Laboratory Experiences

Supplementary Information

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Stress the peculiar sta-  
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Pupils can use the felt  
board or other model mate-  
rial to show how electrons  
can be transferred to form

The number of electrons  
transferred or shared  
between atoms in forming  
compounds determines the

Topical Outline

Understandings  
and Concepts

Laboratory E

complete valence shell.

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dation number  
Directions for  
ing a felt boa  
on p. 354 of t  
*Handbook.*

Elements may be classified according to their tendency to lose, gain, or share electrons in combining with other elements.

Metals tend to lose electrons when combining with other elements.

In general, atoms with 1, 2, or 3 valence electrons tend to lose electrons and are classified as metals.

When an atom loses electrons, the resulting particle is no longer electrically neutral but has an excess positive charge. Such a particle is called a positive ion.

CH 8.08 shows t  
form positive i

Understandings  
and Concepts

the valence shell.

atoms may be classified according to their tendency to lose, gain, or share electrons in combination with other elements.

Atoms tend to lose electrons when combining with nonmetals.

Generally, atoms with 1, 2, or 3 valence electrons tend to lose electrons and are classified as metals.

When an atom loses electrons, the resulting particle is no longer electrically neutral but has a net positive charge. This particle is called a positive ion.

Laboratory Experiences

Students should identify compounds and relate the "transfer number" to oxidation number values. Directions for constructing a felt board are found on p. 354 of the *Chemistry Handbook*.

CH 8.08 shows that metals form positive ions.

Supplementary Information

Students should determine the oxidation state of the atoms in the compound. Have pupils refer to the oxidation states listed in the *Reference Tables*.

*Teachers should introduce formula writing at this point. Review the writing of formulas as covered in Section IV of Block J.*

*The quantitative significance of formulas will be treated in Area 2, Section II C.*

The positive charge on a metal ion is equal to the number of electrons lost. Thus, sodium with one valence electron forms a +1 ion, and calcium with two valence electrons forms a +2 ion. The

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

The relatively "free" electrons of metallic atoms account for several properties of metals such as electrical conductivity and luster.

Nonmetals tend to gain electrons when combining with metals or to share electrons when combining with other nonmetals.

Display a number of compounds labeled with their formulas. Show compounds on the board, those containing nonmetals and both metals

Understandings  
and Concepts

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her nonmetals.

Laboratory Experiences

Display a number of binary  
compounds labeled with  
their formulas. Sort the  
compounds on the basis of  
those containing only non-  
metals and both metals

Supplementary Information

oxidation number of a  
metal ion is equal to the  
charge on the ion.

A metal consists of an  
arrangement of positive  
ions which are located at  
the crystal lattice sites  
and immersed in a "sea" of  
mobile electrons. These  
mobile electrons can be  
considered as belonging to  
the whole crystal rather  
than to individual atoms.

As light strikes the sur-  
face of the metal, it  
affects the mobile elec-  
trons. The net result is  
that the electrons in  
"reflecting back" the  
light cause a lustrous  
appearance.

The mobile electrons are  
responsible for the  
ability of the metallic  
solid to conduct electric-  
ity.

Topical Outline

Understandings  
and Concepts

Laboratory Experi-

and nonmetals.

In general, atoms with 5, 6, or 7 valence electrons are classified as nonmetals.

Use the conductivity of aqueous metallic solutions to illustrate the presence of ions.

When a nonmetal atom gains electrons it becomes a negative ion.

Atoms with complete valence shells are classified as inert elements since they seldom enter into any chemical action.

Display neon, krypton, and argon light bulbs. The color of the light given off by the bulb is one way of identifying the gas.

Pupils who like to do library research may enjoy reading about the discovery of the noble gases.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

and nonmetals.

It is recommended that films be used to show reactions involving nonmetals other than oxygen. The poisonous nature of the elements or their products makes them generally unsuitable for pupil use in this course.

al, atoms with 5,  
valence electrons  
classified as non-

Use the conductivity of aqueous metallic salt solutions to illustrate the presence of ions.

nonmetal atom gains  
as it becomes a  
ion.

The negative charge on a nonmetal ion is equal to the number of electrons gained. The oxidation number is equal to the charge on the ion.

th complete valence  
re classified as  
elements since they  
ntr into any  
action.

Display neon, krypton, and argon light bulbs. The color of the light emitted by the bulb is one way of identifying the gas.

Other names for the inert gases are noble gases or rare gases.

Pupils who like to do library research might enjoy reading about the discovery of the noble gases.

The term, inert, is no longer strictly applicable to these elements since it has been possible to form compounds of krypton, xenon, and radon with fluorine and oxygen. However, the term is still in

Topical Outline

Understandings  
and Concepts

Laboratory Exper

1. Covalent  
bonding

A covalent bond is formed  
when two atoms share elec-  
trons.

The number of electrons  
shared is such that each  
atom attains a complete  
valence shell.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

covalent bond is formed  
as two atoms share elec-  
trons.

number of electrons  
shared is such that each  
atom attains a complete  
valence shell.

general use, and the elec-  
tron configuration is  
quite generally referred  
to as the "inert gas  
structure."

The electrons shared in a  
covalent bond are con-  
sidered as occupying the  
valence shells of both  
atoms.

Chlorine atoms, with 7  
valence electrons, can  
complete their valence  
shells by sharing one pair  
of electrons with another  
atom; nitrogen atoms, with  
5 valence electrons, must  
share 3 pairs of electrons  
in order to complete the  
valence shell.

The oxidation numbers  
assigned to atoms sharing  
electrons are governed by  
arbitrary rules. *Pupils  
will not be required to  
learn these rules.* How-  
ever, for purposes of  
formula writing the  
following generalizations  
are useful: (1) atoms of  
uncombined elements are  
assigned an oxidation  
number of 0; (2) in binary

Topical Outline

Understandings  
and Concepts

Laboratory E

a. Nonpolar  
bonds

When two atoms of the same element share electrons, the electrons are shared equally between the two atoms, forming a non-polar covalent bond.

b. Polar  
bonds

When two atoms of different elements share electrons, the shared electrons may be more strongly attracted to one of the atoms. As a result, one end of the bond may be somewhat more negative than the other. Such a bond is called a polar covalent bond.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

compounds of nonmetals, the oxidation number of each atom represents the number of shared electrons, with the more electronegative element assigned a negative oxidation number and the less electronegative element a positive oxidation number.

Since oxygen is a strongly electronegative element (second only to fluorine), oxygen has an oxidation number of -2 in most oxides.

Most uncombined nonmetallic elements achieve the stability of a complete valence shell by nonpolar covalent bonding.

The measure of the ability of an element to attract shared electrons is known as its electronegativity.

*Pupils should be able to use an electronegativity table to predict the nature of a bond. Assume that an electronegativity difference of 1.7 or greater indicates an ionic bond.*

atoms of the same element share electrons are formed by between the atoms forming a nonpolar covalent bond.

atoms of different electronegativity share electrons, the more electronegative atoms may attract electrons more strongly. As a result, the bond is somewhat more polar than the other. This is called a polar covalent bond.

Topical Outline

c. Molecules

Understandings  
and Concepts

Laboratory Exper

A molecule may be defined as the smallest particle of any substance that can exist free and still exhibit all of the properties of the original substance.

When a molecule contains atoms of different elements, the number of each kind of atom is such that every atom attains a complete valence shell.

A molecule in which the electrons are evenly distributed is said to be a nonpolar molecule.

Understandings  
Concepts

Laboratory Experiences

Supplementary Information

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...molecule.

Nonmetallic elements that are gases at room temperature have diatomic molecules.

When carbon, needing 4 valence electrons, combines with hydrogen, needing 1 valence electron, one carbon atom can share one pair of electrons with each of four hydrogen atoms to form a molecule having the formula  $\text{CH}_4$ . When carbon

combines with oxygen, which needs 2 valence electrons, one carbon atom can combine with two oxygen atoms to form a molecule having the formula  $\text{CO}_2$ .

A molecule may be nonpolar (1) if the bonds in the molecule are nonpolar, or (2) if the geometry of the molecule results in a symmetrical arrangement of polar bonds. A molecule of an element is nonpolar, since only nonpolar bonds are present; a molecule of methane,  $\text{CH}_4$ , is nonpolar

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

d. Forces  
between  
molecules

A molecule in which the electron density is greater at one end of the molecule than the other is said to be a polar molecule, or a dipole.

In general, the forces of attraction between molecules are weak forces.

The attractive forces between molecules increase as the size of the molecules increases.

The attractive forces between polar molecules are greater than between nonpolar molecules of comparable size.

The properties of covalent substances depend on the attractive forces between the individual

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Laboratory Experiences

Supplementary Information

because of the symmetrical arrangement of the polar carbon-hydrogen bonds around the carbon atom.

A diatomic molecule composed of two unlike atoms is polar. For example, the hydrogen chloride molecule, HCl, is polar. Water is an example of a polar molecule containing more than two atoms.

While the covalent bonds holding the atoms together to form the molecule may be strong, the attractive forces between the molecules are relatively weak.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experi</u>
e. Properties of covalent substances	molecules.	
(1) Melting and boiling points	Covalent substances gen- erally have low melting and boiling points.	Illustrate the low point of paraffin heating the wax on bath. Compare the with those obtaine an ionic substance heated in a simila
(2) Conduc- tivity	Covalent substances gen- erally are poor conduc- tors of electricity.	Show that sulfur d have any mobile el or ions by using t ductivity test.
(3) Solu- bility	Nonpolar substances tend to dissolve in nonpolar solvents.	Compare the solubi of iodine and sodi chloride crystals water and nonpolar

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

es.

at substances gen-  
have low melting  
ing points.

Illustrate the low melting point of paraffin wax by heating the wax on a water bath. Compare the results with those obtained when an ionic substance is heated in a similar manner.

Covalent substances exist as gases, liquids, or low melting point solids at room temperature.

at substances gen-  
are poor conduc-  
E electricity.

Show that sulfur does not have any mobile electrons or ions by using the conductivity test.

Covalent substances lack ions or mobile electrons needed to conduct electricity. The valence electrons are "tied up" in covalent bonds.

It should be pointed out that acids in water solution react with water molecules to produce ions. Thus water solutions of acids will conduct an electrical current.

ar substances tend  
solve in nonpolar  
ts.

Compare the solubilities of iodine and sodium chloride crystals in polar water and nonpolar benzene.

Organic solvents in general are nonpolar.

Topical Outline

Understandings  
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Polar substances tend to dissolve in polar solvents.

2. Ionic bonding

When metal atoms, which lose electrons readily, react with nonmetal atoms with a strong tendency to gain electrons, the valence electrons of the metal atoms may be transferred completely to nonmetal atoms. The electrostatic attraction between the oppositely charged ions so formed is called an ionic bond.

a. Structure of ionic compounds

The electrostatic forces between oppositely charged ions are sufficiently strong to hold the ions in relatively fixed sites, forming a crystal lattice.

Some pupils might build a styrofoam model of a sodium crystal. Directions be found in most manuals.

Findings  
Experiments

Laboratory Experiences

Supplementary Information

Benzene should be used only under the hood since its vapors are toxic and flammable.

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Water is the most common polar solvent.

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A general rule of solubility is "like dissolves like."

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Some pupils might like to build a styrofoam ball model of a sodium chloride crystal. Directions can be found in most laboratory manuals.

The salt cube model can be quickly drawn on the blackboard to illustrate lattice sites.

In an ionic crystal there are no discrete neutral units that could be called molecules.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

b. Properties  
of ionic  
compounds

(1) Melting  
and  
boiling  
points

Ionic compounds have high melting and boiling points, and are solids at room temperature.

That sodium chloride and other ionic crystals do not be easily melted in the laboratory is a direct indication of their high melting and boiling points.

(2) Conduc-  
tivity

In the solid phase, ionic compounds are poor conductors of electricity.

Test the electrical conductivity of hypo (sodium thiosulfate) crystals in the solid, "melted," and dissolved form. When the "melted form" is a true liquid phase, it can be used as an analog for ionic compounds with melting points too high to be obtained easily or conveniently in the laboratory.

Electrical conductivity can occur only after the destruction of the lattice structure of an ionic solid and the release of the ions. Melting, and dissolving the crystal in water are ways of destroying the lattice structure.

(3) Solu-  
bility

In general, ionic compounds tend to dissolve in polar solvents and are insoluble in nonpolar solvents.

Use small round magnets to represent the "dipole" action of water in the thumbtack "ions" from some prearranged or

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Compounds have high melting points and boiling points and are solids at room temperature.

That sodium chloride and other ionic crystals cannot be easily melted in the laboratory is an indirect indication of their high melting and boiling points.

The high melting and boiling points of ionic compounds are due to the strength of the ionic bonds and the high energy required to permit ions to escape from the crystal lattice.

In the solid phase, ionic compounds are poor conductors of electricity.

Test the electrical conductivity of hypo (sodium thiosulfate) crystals in the solid, "melted," and dissolved form. While the "melted form" is not a true liquid phase, it can be used as an analogy for compounds with melting points too high to be obtained easily or safely in the laboratory.

Electrical conductivity is observed only after the disruption of the lattice structure of an ionic compound and the release of ions. Melting, and dissolving the crystal in water are ways of destroying the lattice structure.

Nonpolar solvents, ionic compounds tend to dissolve in polar solvents and are insoluble in nonpolar sol-

Use small round magnets to represent the "dipole" action of water in pulling thumbtack "ions" from some prearranged order.

Electrostatic forces between the dipole solvent molecules and the ions of the crystalline solid result in the weakening of the lattice structure, and ions are pulled from their sites.

Topical Outline

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Laboratory

The degree of solubility of a substance depends upon the solvent's ability to pull ions from the lattice structure.

Water is the most common solvent for ionic substances.

V. Periodic Table

A. Purpose

The periodic table is used to organize and classify a large body of information about the elements.

Derive a 10  
"strip" of  
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The similarities and dissimilarities of properties are the basis for classifying substances.

B. Arrangement

In the present form of the periodic table, the elements are arranged on the basis of atomic number.

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Laboratory Experiences

Supplementary Information

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Derive a long form from a  
"strip" of elements. See  
A 1.02 in the appendix.

Finding other arrangements  
for the periodic table  
makes an interesting  
assignment requiring the  
use of the library.

By learning how to use and  
interpret the periodic  
table, one can avoid mem-  
orizing a great mass of  
details.

Early periodic tables  
based upon atomic "weights"  
led to predictions of  
properties of elements  
that were not known at the  
time. These predictions  
led to the discovery of  
many elements.

Topical Outline

Understandings  
and Concepts

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C. Properties

The horizontal rows of the periodic table are called periods or rows.

The vertical columns of the periodic table are called groups or families.

The properties of the elements depend on the structure of the atom and vary with the atomic number in a systematic way.

The properties of elements change systematically through a period.

The elements of a group exhibit similar or related properties.

Metallic properties are most pronounced in those elements on the left-hand side of the periodic table; nonmetallic, in the upper right-hand side.

Appropriate activities based upon the periodic table can be found in sections 1, 2, and 3 of 2.22 (Melting point, boiling points and densities).

Generalizations based on the periodic table are listed in CH 2.21.

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Laboratory Experiences

Supplementary Information

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Appropriate activities based upon the periodic table can be found in Sections 1, 2, and 3 of CH 2.22 (Melting points, boiling points and densities).

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Generalizations based upon the periodic table are listed in CH 2.21.

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*Pupils will be expected to know that metals in groups on the extreme left of the table, when combined with nonmetals on the right, tend to form ionic compounds. Likewise, they will be expected to anticipate that elements relatively "near" each other on the table tend to form covalent bonds.*

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

1. Metals

Generally, the larger the atom of a metal, the less firmly it holds its valence electrons, and the more active it is.

The activity series of metals can be developed through the use of CH 8.09.

2. Nonmetals

Generally, the smaller the atom of a nonmetal, the more strongly it attracts electrons and the more "electronegative" it is.

Generally, the smaller the nonmetallic atom is, the more active it is.

Generally, the fewer the electrons needed to complete the valence shell of a nonmetal, the more active the nonmetallic atom is.

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Laboratory Experiences

Supplementary Information

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The activity series of  
metals can be developed by  
the use of CH 8.09.

While some general predic-  
tions regarding the activ-  
ity of a metal can be made  
on the basis of its posi-  
tion in the periodic  
table, factors other than  
the atomic size and number  
of valence electrons  
result in many exceptions.  
Pupils should refer to the  
Electromotive Series in  
the *Reference Tables* to  
find the relative activity  
of metals.

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## AREA 2 - THE PREPARATION AND SEPARATION OF

Pupils should have a wide latitude of laboratory ing a variety of techniques. Area 2 adapts its oratory approach so there may be more activities done in the allotted time. Teachers should sele iences that are most suitable to their teaching

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory E</u>
<p>I. Preparation of Substances</p> <p style="padding-left: 20px;">A. Energy and reactions</p> <p style="padding-left: 40px;">1. Activation energy</p> <p style="padding-left: 40px;">2. Exothermic reactions</p>	<p>Substances may be made by chemical reactions.</p> <p style="padding-top: 20px;">A reaction requires "starting energy" called activation energy.</p> <p style="padding-top: 20px;">When energy is released during any reaction, the reaction is said to be exothermic.</p>	<p>Activation en illustrated b of wood. The to reach the perature is a activation en</p> <p style="padding-top: 20px;">Burning wood examples of e reactions pro and light.</p> <p style="padding-top: 20px;">Activities ti to show exoti tions are li 1.25-b. A 1 or candle wi trate an exo tion.</p>

## THE PREPARATION AND SEPARATION OF SUBSTANCES

ve a wide latitude of laboratory experiences require techniques. Area 2 adapts itself well to the lab- so there may be more activities listed than can be tted time. Teachers should select laboratory exper- most suitable to their teaching situations.

### standings

#### Concepts

#### Laboratory Experiences

#### Supplementary Information

may be made by reactions.

requires "start-  
" called activa-  
y.

Activation energy may be illustrated by the burning of wood. The energy needed to reach the kindling temperature is an example of activation energy.

y is released  
reaction, the  
s said to be

Burning wood or carbon are examples of exothermic reactions producing heat and light.

The energy released during an exothermic reaction may be in the form of heat, light, and/or electrical energy.

Activities that can be used to show exothermic reactions are listed in CH 1.25-b. A lighted burner or candle will also illustrate an exothermic reaction.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Ex</u>
3. Endothermic reactions	Reactions requiring the continued application of energy are called endothermic reactions.	CH 1.22-b shows energy resulting from chemical action. 0-6 volt voltaic lamp.  Endothermic reactions can be illustrated by electrolysis of water by CH 1.24.
4. Heat of formation	The energy released or absorbed during the formation of a compound from its elements is known as the heat of formation of the compound.  When energy is released during the formation of a compound from its elements, the compound is said to have a negative heat of formation. The greater the amount of energy released, the more stable the compound.  When energy is absorbed during the formation of a compound from its elements, the compound is said to	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

CH 1.22-b shows electrical energy resulting from chemical action. Substitute a 0-6 volt voltmeter for the lamp.

Endothermic reactions can be illustrated by the electrolysis of water and by CH 1.24.

If CH 1.24-a is used, the decomposition of mercuric oxide should be carried out in a fume hood, preferably as a teacher demonstration. Both mercury and mercury vapor are extremely toxic.

*Refer pupils to the Reference Tables for some heats of formation. Other values of heats of formation can be found in textbook tables.*

tions requiring the continued application of energy are called endothermic reactions.

energy released or absorbed during the formation of a compound from its elements is known as the heat of formation of the compound.

energy is released during the formation of a compound from its elements, the compound is said to have a negative heat of formation. The greater the amount of energy released, the more stable the compound.

energy is absorbed during the formation of a compound from its elements, the compound is said to

Topical Outline

Understandings  
and Concepts

Laboratory Expe

have a positive heat of formation. The greater the amount of energy absorbed, the less stable the compound.

B. Types of reactions

1. Direct union or synthesis

Elements may combine to form a compound by a reaction called Direct union or synthesis.

Burning carbon can be used to direct union reaction. *Pupils should not directly at burn sium.*

Two compounds may react to form a single compound.

The slaking of reaction between and hydrogen chloride gases can be used two compounds to form another compound. Use the fume hood case.

2. Exchange of ions

Two ionic compounds in aqueous solution may interact by exchanging ions.

An activity involving interaction between compounds in aqueous solution is listed in A. 2.

A reaction will occur only if at least one of the products is a precipitate, a gas, or water.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

have a positive heat of formation. The greater the amount of energy absorbed, the less stable the compound.

Elements may combine to form a compound by a reaction called direct union or synthesis.

Two compounds may react to form a single compound.

Two ionic compounds in aqueous solution may interact by exchanging ions.

A reaction will occur only if at least one of the products is a precipitate, a gas, or water.

Burning carbon or magnesium can be used to illustrate a direct union reaction.  
*Pupils should not look directly at burning magnesium.*

The slaking of lime or the reaction between ammonia and hydrogen chloride gases can be used to show two compounds uniting to form another compound. Use the fume hood in either case.

An activity involving the interaction between compounds in aqueous solutions is listed in A 2.01.

Synthesis can also mean a series of reactions which eventually results in the formation of a desired substance.

During the slaking of lime, spattering may occur. USE CAUTION.

*Pupils should be able to use solubility tables to predict the formation of precipitates or to identify a precipitate.*

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory E</u>
	If no reaction occurs when two aqueous solutions are mixed, a state of equilibrium exists.	
3. Single replacement	An element may replace a less active element in a compound. The reaction is called a single replacement.	Most laboratory list exercise single replacements.
4. Decomposition	A reaction in which a compound is broken up to form two or more simpler substances is called a decomposition.	Activities in decomposition compounds were in Section I Area.
	Binary compounds (compounds composed of only two elements) may be decomposed to free the two elements.	The electrolysis of sodium chloride solution is carried out using carbon electrodes. Do not operate for long enough to produce visible amounts. Pupils will be able to detect the smell of $\text{Cl}_2$ by the odor.

standings  
Concepts

Laboratory Experiences

Supplementary Information

tion occurs when  
s solutions are  
state of equilib-  
s.

may replace a  
e element in a  
The reaction is  
single replace-

in which a com-  
broken up to form  
e simpler sub-  
called a decom-

pounds (compounds  
f only two ele-  
be decomposed  
e two elements.

Most laboratory manuals  
list exercises involving  
single replacement reac-  
tions.

Activities involving the  
decomposition of binary  
compounds were indicated  
in Section I A 3 of this  
Area.

The electrolysis of copper  
chloride solution may be  
carried out in a U-tube  
using carbon electrodes.  
Do not operate the cell  
long enough to collect vis-  
ible amounts of chlorine.  
Pupils will be able to  
detect the small quantity  
of  $\text{Cl}_2$  by the "Clorox"  
odor.

The relative activities of  
the metals and of the hal-  
ogens is given in the  
Electromotive Series in  
the *Reference Tables*.

Most decomposition reac-  
tions are endothermic.  
The energy is generally  
supplied in the form of  
heat or electrical energy.

Most binary compounds are  
quite stable to decomposi-  
tion by heat. Binary  
ionic compounds may be  
decomposed by electrolysis  
in the liquid phase or in  
aqueous solution. The  
very active metals may be  
produced by electrolysis  
of their fused (melted)  
compounds only.

Topical Outline

Understandings  
and Concepts

Laboratory

Pupils should  
through laboratory  
experience that during  
electrolysis of  
a compound, the negative  
electrode is the negative  
and the nonmetallic  
positive.

Some compounds can be  
decomposed into two or  
more compounds.

Copper (II)  
oxide readily be decomposed  
by heat to give  
copper and  $\text{CO}_2$ .

2

5. Gain and  
loss of  
electrons

Many reactions involve a  
gain of electrons by one  
species and a loss of  
electrons by another.

A 2.02 describes the  
position of carbonate.

As an aid to understanding  
oxidation, reduction,  
redox reactions,  
"transfer" electrons  
using models shown  
listed in CH 1.08  
and CH 2.08.

Understandings  
and Concepts

Some compounds can be decomposed into two or more compounds.

Many reactions involve a gain of electrons by one species and a loss of electrons by another.

Laboratory Experiences

Pupils should learn through laboratory experience that during the electrolysis of a binary compound, the metal is formed at the negative electrode and the nonmetal at the positive.

Copper (II) carbonate can readily be decomposed by heat to give copper oxides and CO<sub>2</sub>.

A 2.02 describes the decomposition of calcium carbonate.

As an aid to understanding oxidation, reduction, and redox reactions, pupils can "transfer" electrons by using models such as are listed in CH 1.18, CH 2.07, and CH 2.08.

Supplementary Information

A metal carbonate  $\xrightarrow{\text{heat}}$  a metal oxide + CO<sub>2</sub>.

A metal chlorate  $\xrightarrow{\text{heat}}$  a metal chloride + oxygen.

Because of their explosive nature, the decomposition of chlorates is not recommended as a laboratory activity.

Topical Outline

Understandings  
and Concepts

Laboratory

a. Oxidation

Oxidation is defined as the loss of electrons by an atom or ion.

To release nonmetals from ionic compounds, the non-metal ion must undergo oxidation.

Metals are oxidized to metal ions in combining with nonmetals.

b. Reduction

Reduction is defined as a gain of electrons by an atom or ion.

Nonmetals are reduced to nonmetal ions in combining with metals.

To release metals from their compounds, the metal ion must be reduced.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

idation is defined as  
e loss of electrons by  
atom or ion.

Originally the term "oxi-  
dation" was applied only  
to reactions involving  
combination with oxygen.  
Because of the high elec-  
tronegativity of oxygen,  
elements combining with it  
appear to lose electrons  
to the oxygen. It has  
been found useful to  
expand the definition of  
oxidation to include any  
loss of electrons.

y release nonmetals from  
nic compounds, the non-  
tal ion must undergo  
idation.

Nonmetals tend to gain  
electrons in forming ionic  
compounds with metals. To  
decompose the compound  
into its elements, the  
nonmetal ion must lose the  
electrons it has gained.

tals are oxidized to  
tal ions in combining  
th nonmetals.

duction is defined as a  
in of electrons by an  
om or ion.

nmetals are reduced to  
nmetal ions in combin-  
g with metals.

release metals from  
eir compounds, the metal  
n must be reduced.

Topical Outline

Understandings  
and Concepts

Laboratory Ex

c. Redox  
reactions

A reaction involving oxidation and reduction is called a redox reaction. Oxidation must be accompanied by reduction.

Use the electrochemical cell with copper chloride to illustrate a redox reaction. Oxidation occurs at the anode and reduction at the cathode.

III. Quantitative  
Relationships

A. Mole  
concept

The mole is a convenient unit for use with large numbers of small particles.

A mole is  $6.02 \times 10^{23}$  particles.

Compare the weight of a mole of light with a mole of heavy as a convenient way of comparing the masses of individual substances.

### Understandings and Concepts

A reaction involving oxidation and reduction is called a redox reaction. Oxidation must be accompanied by reduction.

The mole is a convenient unit for use with large numbers of small particles.

A mole is  $6.02 \times 10^{23}$  particles.

### Laboratory Experiences

Use the electrolysis of copper chloride solution to illustrate a redox reaction. Oxidation will occur at the positive pole and reduction at the negative pole.

Compare the weight of a ream of light weight paper with a ream of heavy bond as a convenient method of comparing the weights of individual sheets of paper.

### Supplementary Information

Oxidation and reduction occur simultaneously; one cannot occur without the other.

*Pupils will be required to recognize redox reactions only in cases of direct union of elements, decomposition of binary compounds, and single replacement reactions.*

Small particles such as atoms, molecules, ions, electrons, etc., cannot be isolated, weighed, or counted as individual units. For practical purposes it is necessary to work with large numbers of these particles. If the same number of particles is taken as a group (unit), comparison of groups will show the same ratios as comparisons of individual particles.

Topical Outline

Understandings  
and Concepts

Laboratory Expe

B. Chemical shorthand

1. Symbols

A chemical symbol represents one atom of an element or one mole of atoms of the element.

2. Formulas

A formula is composed of symbols and subscripts and indicates the composition of a substance. A formula also represents one mole of the substance.

Point out the need for carefully reading formulas on reagent labels by using A 2.03.

Suggestions for a laboratory experiment are found in CH 1.17 for pupils during formula writing. See also A 2.03.

3. Equations

An equation consists of formulas which indicate the reactants and products of a chemical reaction.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

Symbol repre-  
sents an ele-  
ment of atoms  
present.

is composed of  
subscripts and  
the composition  
of the formula.  
The formula  
represents one mole  
of the substance.

Point out the need for  
carefully reading the for-  
mulas on reagent bottles  
by using A 2.03.

Suggestions for adapting  
CH 1.17 for pupil's use  
during formula writing can  
be found in A 2.04.

Illustrations using other  
number units familiar  
to the pupil, such as a  
dozen eggs or a ream of  
paper, may help to clarify  
the mole concept.

The formula of a molecular  
substance represents the  
atoms forming the mole-  
cule and is called a  
molecular formula.

The formula of an ionic  
compound represents the  
ratio of the elements  
present and is called an  
empirical formula.

*Pupils will not be  
required to distinguish  
between molecular and  
empirical formulas.*

consists of  
which indicate  
reactants and products  
of a chemical reaction.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory</u>
a. Conserva- tion of mass	Mass is conserved during a chemical reaction.	Compare the mass as expr equation, $K_2CrO_4 + Pb$ $2KNO_3 + PbO$ with CH 1.23
b. Balancing equations	To indicate that mass is conserved, an equation is balanced by the use of appropriate coefficients.	Adapting CH use in writi can be done similar to t found in A 2
c. Writing equations	The formulas of the reac- tants are shown on the left of the arrow or equal sign and those of products on the right. Balance the equation by inserting coef- ficients that will result in conservation of mass.	The felt boa effective to for the pres equation wri CH 1.18.
d. Redox equations	In a redox reaction there is an oxidation and a reduction. Separate half- reaction equations may be written to show the gain and loss of electrons.	

Understandings  
and Concepts

is conserved during a  
chemical reaction.

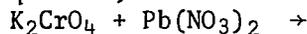
Indicate that mass is  
conserved, an equation is  
balanced by the use of  
appropriate coefficients.

Formulas of the reac-  
tants are shown on the  
left of the arrow or equal  
sign and those of products  
on the right. Balance the  
equation by inserting coef-  
ficients that will result  
in conservation of mass.

In a redox reaction there  
is oxidation and a  
reduction. Separate half-  
reaction equations may be  
written to show the gain  
and loss of electrons.

Laboratory Experiences

Compare the conservation of  
mass as expressed in the  
equation,



$2\text{KNO}_3 + \text{PbCrO}_4,$   
with CH 1.23.

Adapting CH 1.18 for pupil  
use in writing equations  
can be done in a manner  
similar to the adaptations  
found in A 2.04.

The felt board is a very  
effective teaching device  
for the presentation of  
equation writing. See  
CH 1.18.

Supplementary Information

*Although equation writing  
is listed as a separate  
section, teachers should  
feel free to introduce  
equation writing at any  
point in the course.*

*Pupils should be able to  
write simple reduction and  
oxidation equations to  
show the gain or loss of  
electrons. In writing  
simple reduction and oxi-  
dation equations, pupils  
should show the electrons  
as a reactant in reduction  
and as a product in oxi-  
dation.*

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

C. Mass relationships

1. From symbols

Atomic mass is the mass of one atom of an element measured in atomic mass units.

Gram atomic mass is the mass of one mole of atoms of an element measured in grams.

The atomic mass in amu is numerically equal to the gram atomic mass in grams.

Compare the ability of a balance scale to measure the mass of 1 grain of sand and the mass of 1 tablespoon or scoopful of sand. Relate the size of the sand to atomic mass and gram atomic mass.

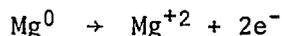
## Laboratory Experiences

## Supplementary Information

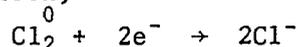
For example, the equation for the combination of magnesium and chlorine,



can be written as an oxidation half-reaction,



and a reduction half-reaction,



*The basis for relative atomic mass and the definition of an atomic mass unit were treated in Area I, Section IV A.*

1 amu  $\times (6.02 \times 10^{23}) =$   
1 gram. The number in a mole ( $6.02 \times 10^{23}$ ) was chosen to provide this relationship.

Chemists prefer to use the gram atomic mass since it can be measured on laboratory scales.

*Pupils may round off atomic masses to the nearest whole number for the solution of*

Compare the ability of a balance scale to measure the mass of 1 grain of sand and the mass of a tablespoon or scoopful of sand. Relate the situation to atomic mass and gram atomic mass.

mass of  
ent  
mass

the  
atoms  
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amu is  
o the  
grams.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

2. From  
formulas

a. Mole mass

The mole mass of a substance is the mass in grams of one mole of the substance.

The mole mass can be calculated from the formula by adding the gram atomic masses represented by the symbols making up the formula.

The number of moles in a given sample of a substance can be calculated by dividing the mass of the sample by the mole mass of the substance.

Find the number of in given samples stances such as chunks, galena pi a "pile" of copper crystals.

b. Percentage  
composition

The percentage composition of a compound can be determined experimentally or calculated from its formula.

Most laboratory include exercise the percentage of a compound can mined experiment

Standings  
Concepts

Mass of a sub-  
the mass in grams  
of the sub-

Mass can be cal-  
om the formula  
the gram atomic  
represented by the  
aking up the

of moles in a  
e of a sub-  
be calculated  
g the mass of  
by the mole  
e substance.

age composition  
and can be deter-  
perimentally or  
from its

Laboratory Experiences

Find the number of moles  
in given samples of sub-  
stances such as calcite  
chunks, galena pieces, or  
a "pile" of copper sulfate  
crystals.

Most laboratory manuals  
include exercises in which  
the percentage composition  
of a compound can be deter-  
mined experimentally.

Supplementary Information

*problems.*

*The mole mass of a molec-  
ular substance is some-  
times called the gram  
molecular mass. The mole  
mass of an ionic substance  
is sometimes called the  
gram formula mass. Since  
the term "mole mass"  
applies to both, it is not  
necessary for pupils to  
distinguish between them.*

Sample problem:

How many moles are there  
in 200 grams of calcite  
(CaCO<sub>3</sub>)?

Solution:

Mole mass of CaCO<sub>3</sub> (from  
formula) = 100g.

$$200\text{g. CaCO}_3 \times \frac{1 \text{ mole CaCO}_3}{100\text{g. CaCO}_3}$$

$$= 2 \text{ moles CaCO}_3$$

Topical Outline

Understandings  
and Concepts

Laboratory Expe

The percentage composition of a compound can be calculated from the ratio of the mass of the element represented in the formula to the mole mass of the compound, or

$$\frac{\text{mass of the element}}{\text{mole mass of the compound}} \times 100\%$$

Some examples of

a. Calculate water ( $\text{H}_2\text{O}$ )

Solution:

Mass of hydrogen  
Mass of oxygen  
Mole mass

% hydrogen

% oxygen

b. Find the percentage mass in gypsum

Solution:

Mole mass of  
Total mass of

dings  
epts

Laboratory Experiences      Supplementary Information

composition  
can be cal-  
the ratio of  
e element  
the formula  
ss of the

Some examples of percentage problems are:

- a. Calculate the percentage composition by mass of water ( $H_2O$ ).

Solution:

$$\begin{aligned} \text{Mass of hydrogen, } 2 \times 1.0\text{g.} &= 2\text{g.} \\ \text{Mass of oxygen, } 1 \times 16\text{g.} &= 16\text{g.} \\ \text{Mole mass of water} &= 18\text{g.} \end{aligned}$$

$$\% \text{ hydrogen} = \frac{\text{mass of hydrogen}}{\text{mole mass of water}} \times 100\%$$

$$= \frac{2.0\text{g.}}{18\text{g.}} \times 100\%$$

$$= 11\%$$

$$\% \text{ oxygen} = \frac{\text{mass of oxygen}}{\text{mole mass of water}} \times 100\%$$

$$= \frac{16\text{g.}}{18\text{g.}} \times 100\%$$

$$= 89\%$$

- b. Find the percentage of water of hydration by mass in gypsum ( $CaSO_4 \cdot 2H_2O$ ).

Solution:

$$\begin{aligned} \text{Mole mass of gypsum} &= 172\text{g.} \\ \text{Total mass of water in formula} &= 36\text{g.} \end{aligned}$$

$$\frac{\text{element}}{\text{compound}} \times 100\%$$

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

3. From  
equations

The reactants and products of a reaction are in a definite mole ratio.

The relative numbers of moles of reactants and products are indicated by the coefficients of the formulas represented in a balanced equation.

It is possible to predict the mass of a product that will be formed from a specific mass of reactant.

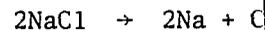
The mass of a reactant needed to combine with a specific mass of another reactant to make a specified mass of a product can also be calculated.

$$\begin{aligned} \% \text{ water} &= \frac{\text{total}}{\text{mole}} \\ &= \frac{36\text{g}}{172\text{g}} \\ &= 21\% \end{aligned}$$

The combining mole ratio is shown by A 2.05.

Sample problem:

How many grams of produce 350 grams solution is:



Step 1: Change mass

$$350\text{g. Cl}_2 \times \frac{1\text{ mole}}{71\text{g}}$$

Step 2: From moles of Cl<sub>2</sub> to moles of NaCl

$$5 \text{ moles Cl}_2 \times 2$$

Step 3: Change moles of NaCl to mass

$$10 \text{ moles NaCl}$$

ings  
ts

Laboratory Experiences

Supplementary Information

$$\begin{aligned}\% \text{ water} &= \frac{\text{total mass of water}}{\text{mole mass of gypsum}} \times 100\% \\ &= \frac{36\text{g.}}{172\text{g.}} \times 100\% \\ &= 21\%\end{aligned}$$

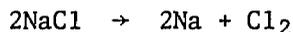
d products  
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tio.

The combining mole ratio  
is shown by A 2.05.

Sample problem:

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icated by  
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nted in a  
n.

How many grams of sodium chloride are needed to  
produce 350 grams of chlorine gas? One method of  
solution is:



o predict  
oduct that  
rom a  
reactant.

Step 1: Change problem data to moles:

$$350\text{g. Cl}_2 \times \frac{1 \text{ mole Cl}_2}{70\text{g. Cl}_2} = 5 \text{ moles Cl}_2$$

actant  
e with a  
another  
a speci-  
oduct can  
ed.

Step 2: From moles of Cl<sub>2</sub> calculate moles of NaCl  
from mole ratio in equation:

$$5 \text{ moles Cl}_2 \times \frac{2 \text{ moles NaCl}}{1 \text{ mole Cl}_2} = 10 \text{ moles NaCl}$$

Step 3: Change moles NaCl to grams

$$10 \text{ moles NaCl} \times \frac{58\text{g. NaCl}}{1 \text{ mole NaCl}} = 580\text{g. NaCl}$$

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory</u>
D. Volume relationships	Equal volumes of gases under the same conditions of temperature and pressure contain an equal number of particles.	Students mathematical m in one ed  Mass of M  350g.  = 580g  Mole-volume apply only t phase.
1. Mole volume	A mole of any gas contains $6.02 \times 10^{23}$ particles. Therefore a mole of any gas will have the same volume as a mole of any other gas at the same temperature and pressure. The volume of a mole of gas at S.T.P. is 22.4 liters.	Sample pr  In the re volume of NH <sub>3</sub> .
2. Combining volumes	In a reaction involving gases, the coefficients in the balanced equation indicate the volume ratios of the gases in the reaction.	Sample pr  In the re volume of NH <sub>3</sub> .

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Students who are sufficiently proficient in mathematical manipulations can combine the three steps in one equation:

Mass of NaCl needed =

$$350\text{g. Cl}_2 \times \frac{1 \text{ mole Cl}_2}{70\text{g. Cl}_2} \times \frac{2 \text{ moles NaCl}}{1 \text{ mole Cl}_2} \times \frac{58\text{g. NaCl}}{1 \text{ mole NaCl}}$$

= 580g. NaCl

Volumes of gases at the same conditions of temperature and pressure contain an equal number of particles.

Mole-volume relationships apply only to the gaseous phase.

One mole of any gas contains  $6.02 \times 10^{23}$  particles. All gases at the same temperature and pressure have the same volume of a mole of gas at S.T.P. is 22.4 liters.

In a balanced chemical equation involving gases, the coefficients indicate the volume ratios of the gases in the reaction.

Sample problem:

In the reaction  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ , calculate the volume of hydrogen required to form 100 liters of  $\text{NH}_3$ .

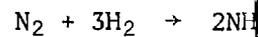
Topical Outline

Understandings  
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Laboratory Experience

Solution:

Equation:



Mole ratio:

1            3            2

When reacting gases at the same temperature and pressure, the volume ratio is the same as the mole ratio.

Since the mole ratio is 1 mole of  $\text{N}_2$  to 3 moles of  $\text{H}_2$ , the volume ratio is 1 volume of  $\text{N}_2$  to 3 volumes of  $\text{H}_2$ . Therefore:

$$\begin{aligned} \text{volume of H}_2 \text{ needed} &= \left( \frac{\text{mole H}_2}{\text{mole N}_2} \right) \times \text{volume of N}_2 \\ &= \left( \frac{3 \text{ moles H}_2}{1 \text{ mole N}_2} \right) \times 100 \text{ L} \\ &= 150 \text{ L} \end{aligned}$$

An alternate solution is to use the mole ratio. From the equation, 1 mole of  $\text{N}_2$  reacts with 3 moles of  $\text{H}_2$ .

$$\frac{x \text{ liters}}{3 \text{ moles}} = \frac{100 \text{ L}}{1 \text{ mole}}$$

(150 liters of  $\text{H}_2$ )

Laboratory Experiences

Supplementary Information

Solution:

Equation:



Mole ratio:

1        3        2

When reacting gases are at the same temperature and pressure, the volume ratio is equal to the mole ratio.

Since the mole ratio between  $\text{H}_2$  and  $\text{NH}_3$  is 3:2, the volumes of the gases are in the same ratio.

Therefore:

$$\begin{aligned} \text{volume of H}_2 \text{ needed} &= \left( \frac{\text{moles H}_2}{\text{moles NH}_3} \right) \left( \text{volume of NH}_3 \text{ produced} \right) \\ &= \left( \frac{3 \text{ moles H}_2}{2 \text{ moles NH}_3} \right) (100 \text{ liters NH}_3) \\ &= 150 \text{ liters H}_2 \end{aligned}$$

An alternate solution:

From the equation, the proportion:

$$\frac{x \text{ liters}}{3 \text{ moles}} = \frac{100 \text{ liters}}{2 \text{ moles}} \text{ will yield the same answer}$$

(150 liters of  $\text{H}_2$ )

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
III. Preparation of Solutions	Many chemical reactions are carried out in aqueous solutions.	
A. Rate of dissolving	The rate of dissolving is the quantity of solute dissolving per unit of time.	Ask pupils to find the quickest way to dissolve large pieces of solid such as sugar cubes, large crystals of soluble salt.
	The process of dissolving occurs only at the surface of the solid.	
	The rate of dissolving is affected by such factors as surface area, agitation, and temperature.	
B. Solubility	The solubility of a substance is defined as the quantity of the substance that can be dissolved in a stated amount of solvent at a specified temperature.	
1. Nature of solute and solvent	Polar solvents tend to dissolve only polar and ionic solutes; nonpolar solvents tend to dissolve only nonpolar solutes.	

Laboratory Experiences

Ask pupils to find the quickest way to dissolve large pieces of solids such as sugar cubes or large crystals of some soluble salt.

Supplementary Information

*Material on solutions is treated in Block J, pp. 60-65, and in Area I, Section III C of this syllabus.*

*Review the dipole action of water on a crystal lattice in Area 1, Section IV B 2.*

*Pupils should be able to read and use the solubility charts on the Reference Tables.*

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experi</u>
2. Temperature	<p>Most solids become more soluble as the temperature increases.</p> <p>Gases become less soluble as the temperature increases.</p>	
3. Pressure	<p>The solubility of gases varies directly with the pressure on the gas.</p>	
C. Concentration	<p>The concentration of a solution may be expressed in a variety of ways.</p>	
1. Concentrated and dilute solutions	<p>A concentrated solution contains a relatively large amount of solute.</p> <p>A dilute solution contains a relatively small amount of solute.</p>	<p>Make a series of d of copper sulfate and compare the de color of the solut</p> <p>Evaporate some of vent from a copper solution and notice depth of color.</p>
2. Saturated, unsaturated, and supersaturated solutions	<p>A saturated solution is a solution containing all the solute that can be dissolved at the temperature of the solution.</p> <p>An unsaturated solution is one in which more solute can be dissolved without changing the temperature</p>	<p>Sodium thiosulfate is a suitable solv making solutions c degrees of saturat</p>

Understandings  
Concepts

Laboratory Experiences

Supplementary Information

solubilities become more  
soluble as the temperature

solubility of some less soluble  
solutes increases with temperature

solubility of gases  
decreases directly with the  
increase in temperature on the gas.

Concentration of a solution  
can be expressed in  
many different ways.

Concentration of a saturated solution  
is a function of a relatively  
small amount of solute.

A saturated solution contains  
the maximum amount of solute

A saturated solution is  
one containing all  
the solute that can be dissolved  
at a given temperature and pressure.

A saturated solution is  
one in which more solute  
cannot be dissolved without  
changing the temperature

Make a series of dilutions  
of a copper sulfate solution,  
and compare the depth of  
color of the solutions.

Evaporate some of the solvent  
from a copper sulfate  
solution and notice the  
depth of color.

Sodium thiosulfate (hypo)  
is a suitable solute for  
making solutions of varying  
degrees of saturation.

Because the definitions of  
concentrated and dilute  
solutions are vague, they  
are useful only in comparing  
different solutions  
of the same solute. The  
terms listed below have a  
more common usage.

Topical Outline

Understandings  
and Concepts

Laboratory

of the solution.

A supersaturated solution is one which contains more dissolved solute than it normally would have at that temperature.

3. Mass/volume

The concentration of a solution may be expressed in a mass/volume ratio.

Common units used to express concentration are g./liter, g./ml., and mg./ml.

The mass of a solute in a given solution can be found:  $\text{volume} \times \text{mass/volume} = \text{mass of solute}$ . The two volume units must be the same.

4. Molarity

The molarity of a solution indicates the number of moles of solute per liter of solution.

Pupils should be encouraged to find evidence in previous laboratory exercises. Use CH 3. Laboratory exercises found in manuals.

standings  
concepts

Laboratory Experiences

Supplementary Information

ation.

aturated solution  
ch contains more  
olute than it  
ould have at that

A supersaturated solution  
is prepared by cooling a  
saturated solution.

ration of a  
y be expressed  
olume ratio.

Many recent laboratory  
manuals express concentra-  
tion in a mass/volume  
ratio.

s used to  
centration are  
./ml., and

Nursing students will  
encounter percentage solu-  
tions. Percentage solu-  
tions = parts solute/100  
parts solution.

a solute in a  
ion can be  
ume x mass/vol-  
of solute. The  
units must be

Small quantities of solute  
are sometimes expressed as  
parts of solute per mil-  
lion parts of solvent, or  
parts per million (ppm).

y of a solution  
he number of  
olute per liter

Pupils should have experi-  
ence in preparing solutions  
of different molarities.  
Use CH 3.26 or the labora-  
tory exercises on molarity  
found in most laboratory  
manuals.

The prepared standard solu-  
tions may be saved for uses  
in other experiments.

Topical Outline

Understandings  
and Concepts

Laboratory

The mass of solute in a given volume of molar solutions can be computed:

mass of solute =

molarity x  $\frac{\text{mole mass}}{\text{mole}}$

x volume (in liters).

A standard solution is one in which the molarity is known.

IV. Separation of Substances

Mixtures of substances can be separated on the basis of differences in properties of the components. Two common methods are based on differences in solubility and boiling points.

Understandings  
and Concepts

of solute in a  
volume of molar  
solution can be computed:

$$\text{moles of solute} = \text{volume} \times \frac{\text{mole mass}}{\text{molar mass}}$$

(in liters).

of a solution is one  
the molarity is

of substances can  
be determined on the basis  
of differences in proper-  
ties of the components.  
Different methods are  
used to determine differences in  
melting point and boiling

Laboratory Experiences

Supplementary Information

The quantities used must  
be expressed in proper  
units. For example:

$$\text{grams} = \frac{\text{moles}}{\text{liter}} \times \frac{\text{gram(s)}}{\text{mole}}$$

x liter(s).

The allowable amounts of  
impurities present in a  
reagent are set by various  
agencies.

Work in the laboratory  
requires a degree of pur-  
ity found in CP, USP, or  
reagent grades.

Technical grade contains  
the highest amounts of  
impurities and is used  
only in industrial  
processes where the impur-  
ities do not affect the  
process.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Exper</u>
A. Separation by solubility	Soluble substances can be separated from insoluble ones by dissolving the soluble ones.	
1. Filtration	Undissolved materials may be isolated by filtration.	Ask pupils to isolate many substances as can from an unknown mixture. Such a mixture might include sand, stone or chalk, and sodium chloride.
2. Crystallization	Since most solutes are more soluble in hot water than cold, cooling a solution (or filtrate) generally causes some of the solute to crystallize out.	Pupils should be able to use decanting and filtering techniques. These techniques are in connection with separation of crystals.
	Crystals suspended in a solution can be isolated by filtration.	Pupils should be able to recover solutes by filtration of filtrate. (Spattering during filtration can be decreased using a heat lamp above the evaporator as the heat source).
B. Separation by boiling points	Distillation is a process by which a liquid is vaporized and recondensed.	Use a distillation to find the percent water in vinegar. Pupils plan their experiment, some work up with a percent

## Laboratory Experiences

## Supplementary Information

Ask pupils to isolate as many substances as they can from an unknown solid mixture. Such a mixture might include sand, limestone or chalk, and sodium chloride.

Pupils should be able to use decanting and vacuum filtering techniques. These techniques are used in connection with the separation of crystals.

Pupils should be able to recover solutes by evaporation of filtrates. (Spattering during evaporation can be decreased by using a heat lamp mounted above the evaporating dish as the heat source.)

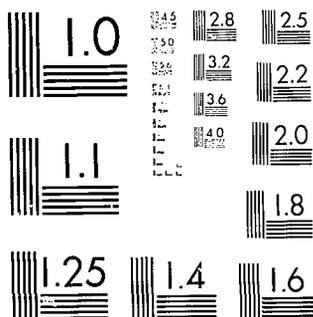
Use a distillation process to find the percent of water in vinegar. If pupils plan their own experiment, some will end up with a percent by volume

No sample can be 100% pure. There are always traces of other substances.

The process by which the amount of contamination components is significantly reduced is called purification.

When contaminating materials have been reduced to such an extent that their effect is no longer significant, the substance is considered to be "pure."

OF 7  
ED  
52 009



MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

## Topical Outline

## Understandings and Concepts

## Laboratory Experi-

The recondensed liquid which is collected is called the distillate.

A liquid may be isolated from high boiling point (nonvolatile) impurities by distillation.

Volatile components can often be separated by the use of fractional distillation.

Successive samples or fractions contain decreasing amounts of low boiling point components and increasing amounts of higher boiling point components.

Repeated fractional distillation of a specific fraction can be used for further separation.

and others, with by mass. Since v about 95 percent some teachers may concentrate it be for quicker and m accurate results.

Ask pupils to find amount of alcohol fraction collected the fractional distillation of an ethanol-water mixture. Specific gravity ethanol solutions found in chemical books.

Understandings  
and Concepts

Condensed liquid  
is collected in  
the distillate.

It may be isolated  
high boiling point  
(volatile) impurities  
distillation.

The components can  
be separated by the  
fractional distil-

secutive samples or frac-  
tion contain decreasing  
amounts of low boiling  
components and  
increasing amounts of  
high boiling point com-

Fractional distil-  
lation of a specific  
mixture can be used for  
separation.

Laboratory Experiences

and others, with a percent  
by mass. Since vinegar is  
about 95 percent water,  
some teachers may prefer to  
concentrate it beforehand  
for quicker and more  
accurate results.

Ask pupils to find the  
amount of alcohol in each  
fraction collected during  
the fractional distillation  
of an ethanol-water mix-  
ture. Specific gravity of  
ethanol solutions can be  
found in chemical hand-  
books.

Supplementary Information

There is a U.S. tax on  
ethanol used in intoxicat-  
ing beverages. To avoid  
the high tax, industry  
uses a denatured ethanol  
solvent which contains  
"impurities" which are  
very difficult to remove  
and which make the alcohol  
poisonous.

### AREA 3 - STRUCTURE AND PROPERTIES OF SIMPLE ORGANIC

In some areas, working with models provides greater understanding than working with the actual substances. In this unit suggested laboratory experiences will emphasize the use of models. It is recommended that each pupil have a set of models.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
I. Organic Compounds		
A. Definition	Organic compounds are compounds of carbon.	
B. General properties	<p>Organic compounds tend to be soft, low-boiling point solids, or gases.</p> <p>Organic compounds are more easily decomposed by heat than inorganic compounds.</p> <p>Organic compounds usually are nonconductors of electricity.</p>	<p>Arrange a display of organic materials among which might be paraffin wax, an alcohol, propyl turpentine, and an ester such as amyl acetate.</p> <p>Show that glycerol, sugar and alcohol solutions are not conductors of electricity.</p>

## AND PROPERTIES OF SIMPLE ORGANIC COMPOUNDS

Working with models provides greater than working with the actual substance. It suggested laboratory experiences the use of models. It is recommended to have a set of models.

s

### Laboratory Experiences

### Supplementary Information

are com-

*Pupils will have encountered some of the concepts listed at the left in Science 7, 8, 9, Block L (pp. 62-75).*

Other definitions of organic compounds will not be treated in this course.

tend to  
ng point

Arrange a display of organic materials among which might be paraffin wax, an alcohol, propane, turpentine, and an ester such as amyl acetate.

An odor indicates a low boiling point.

are more  
by heat  
mpounds.

Organic compounds tend to char when heated.

usually  
of elec-

Show that glycerol, sugar, and alcohol solutions are not conductors of electricity.

Topical Outline

Understandings  
and Concepts

Laboratory Experi-

The solubility of organic compounds depends upon the nature of the solvent used.

Since many organic compounds are nonpolar, they are not soluble in water. They are soluble in nonpolar solvents such as petroleum ether, carbon tetrachloride, and cyclohexane.

Organic compounds tend to react more slowly than inorganic compounds.

There are many more organic compounds than inorganic compounds.

ings  
epts

Laboratory Experiences

Supplementary Information

of organic  
nds upon the  
solvent used.

Oil or kerosene will not  
dissolve in water, but  
will dissolve in nonpolar  
organic solvents.

enic com-  
polar, they  
in water.  
e in non-  
such as  
, carbon  
and cyclo-

Oil contains nonpolar mole-  
cules, while water has  
polar molecules. Gener-  
ally, "like tends to dis-  
solve like."

The toxic nature and flam-  
mability of most organic  
solvents make them  
unsuitable for use in high  
schools.

nds tend to  
ly than  
unds.

A notable exception is the  
speed with which some  
organic reactions occur in  
living things.

more organic  
inorganic

Known inorganic compounds  
number about 50,000 com-  
pared to some 1,000,000 or  
more organic compounds.  
More impressive than the  
relative numbers is the  
fact that virtually all  
new chemical compounds  
being discovered can be  
classified as organic com-  
pounds. The number of new

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

II. Bonding in  
Organic  
Compounds

Generally, molecules of organic compounds are covalently bonded.

The carbon atom has four valence electrons, each of which can be used in forming a covalent bond.

The carbon atom tends to form four covalent bonds to achieve a complete eight-electron valence ring.

The carbon atom is considered to have a tetrahedral structure.

A satisfactory device to illustrate the arrangement of covalent bonds in a variety of organic compounds is a set of molecular models. The models consist of wooden spheres with one to five holes in them and dowels or springs to represent the covalent bonds. Prices range from \$3. to over \$75. A set costing less than \$10. is usually satisfactory for use at this level. These sets may also be constructed of styrofoam spheres and dowels.

Directions for constructing a regular tetrahedron are given in A 3.01.

Use the ball-and-stick model to show the bond angles. Insert four sticks into the ball representing the carbon atom. Show that the "ends" of any three sticks represent the vertices of an equilateral triangle.

## Laboratory Experiences

## Supplementary Information

compounds averages at  
least 30,000 per year.

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A satisfactory device to illustrate the arrangement of covalent bonds in a variety of organic compounds is a set of molecular models. The models consist of wooden spheres with one to five holes in them and dowels or springs to represent the covalent bonds. Prices range from \$3. to over \$75. A set costing less than \$10. is usually satisfactory for use at this level. These sets may also be constructed of styrofoam spheres and dowels.

consid-  
ahedral

Directions for constructing a regular tetrahedron are given in A 3.01.

The angle between adjacent bonds tends to be  $109^{\circ}28'$ .

Use the ball-and-stick model to show the bond angles. Insert four sticks into the ball representing the carbon atom. Show that the "ends" of any three sticks represent the vertices of an equilateral triangle.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

A. Isomers

Carbon atoms have the ability to produce long chains or rings by forming covalent bonds with other carbon atoms.

"Build" carbon chains by hooking 20 to 40 paper clips together. Each clip represents a carbon atom.

The same atoms may often be bonded in more than one spatial arrangement to form compounds having different structures and properties.

To develop the concept of isomers, ask pupils to "bond" 6 carbon and 12 hydrogen "atoms" from a molecular model kit into identical arrangements. These are made by the pupils. Ask them to find other possible ways of putting the atoms together.

Compounds having the same molecular formulas (thus the same number of each kind of atom) but different structures and properties are called isomers.

As the number of atoms in a molecule increases, the possibility of more spatial arrangements (isomers) increases.

B. Structural formulas

Structural formulas can be written by the use of a short line or dash between symbols to represent each covalent bond.

Have pupils write structural formulas for the model arrangements of carbon and hydrogen atoms constructed in the activity above.

Display a number of ball-and-stick models of molecules and ask pupils to write a structural formula for each "molecule".

standings  
concepts

Laboratory Experiences

Supplementary Information

atoms have the ability to form long chains by forming covalent bonds with other carbon atoms.

"Build" carbon chains by hooking 20 to 40 paper clips together. Each clip represents a carbon atom.

The ability of carbon atoms to form chains and rings accounts for the large number of possible compounds.

Carbon atoms may often form more than one arrangement to form molecules having different shapes and properties.

To develop the concept of isomers, ask pupils to "bond" 6 carbon and 14 hydrogen "atoms" from their molecular model kits. If identical arrangements are made by the pupils, ask them to find other possible ways of putting the atoms together.

*Pupils should be able to recognize isomers by comparing molecular formulas. For example,  $C_2H_5OH$  and  $CH_3OCH_3$  have the same molecular formula,  $C_2H_6O$ , and hence are isomers.*

Molecules having the same molecular formula (thus same number of each atom) but different shapes and properties are called isomers.

As the number of atoms in a molecule increases, the number of possible spatial arrangements (isomers) also increases.

Structural formulas can be written using the use of a solid line or dash between atoms to represent each bond.

Have pupils write structural formulas for the model arrangements of carbon and hydrogen "atoms" constructed in the activity above.

A structural formula is a two-dimensional representation of a three-dimensional molecule.

Display a number of "models" of molecules and ask pupils to write a structural formula for each "molecule."

Topical Outline

C. Saturated and  
unsaturated  
compounds

Understandings  
and Concepts

Each carbon atom in a compound may be joined to another carbon atom by sharing one pair of electrons (one covalent bond). This compound is considered saturated.

Two carbon atoms in a compound may be joined by sharing two or three pairs of electrons. This compound is considered unsaturated.

Laboratory Experiences

Standings  
Concepts

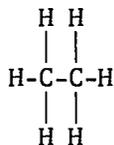
n atom in a com-  
be joined to  
arbon atom by  
e pair of elec-  
e covalent bond).  
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ated.

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be joined by  
wo or three pairs  
ons. This com-  
considered unsat-

Laboratory Experiences

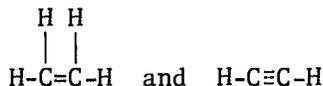
Supplementary Information

A bond formed between atoms by the sharing of one pair of electrons is called a single bond. An example of a saturated compound is ethane ( $C_2H_6$ ) represented as:



A bond formed between atoms by the sharing of two pairs of electrons is called a double bond; a bond formed by the sharing of three pairs of electrons is called a triple bond.

Examples of unsaturated compounds are  $C_2H_4$  and  $C_2H_2$ . Their structural formulas are:



<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
D. Homologous series	Organic compounds can be classified into groups having related structures and properties. Such groups are called homologous series.	The use of models will illustrate that the increment is $\text{CH}_2$ for the series covered in this unit.
III. Some Classes of Organic Compounds	Classes of organic compounds may be recognized by the numbers and arrangements of certain atoms or groups of atoms in their structural formulas.	
A. Hydrocarbons	Hydrocarbons are compounds containing only atoms of hydrogen and carbon.	Ask pupils to build models of hydrocarbons represented by structural formulas. This activity will help develop an understanding of the spatial relationships involved.
	Hydrocarbons may be in the form of straight chains or rings, and may contain from 1 to over 40 carbon atoms.	
	Hydrocarbons may be gases, liquids with a low boiling point, or solids with a low melting point.	Handbooks can be used for a comparison of melting points and boiling points of hydrocarbons.

<u>Findings</u> <u>Concepts</u>	<u>Laboratory Experiences</u>	<u>Supplementary Information</u>
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oms in their  
ormulas.

are compounds  
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carbon.

may be in the  
ight chains or  
ay contain  
er 40 carbon

may be gases,  
a low boiling  
lids with a  
point.

The use of models will help  
illustrate that the incre-  
ment is  $\text{CH}_2$  for the series  
covered in this unit.

Ask pupils to build models  
of hydrocarbons represented  
by structural formulas.  
This activity will help  
develop an understanding of  
the spatial relationships  
involved.

Handbooks can be used for  
a comparison of melting  
points and boiling points  
of hydrocarbons.

The major sources of raw  
materials from which  
organic chemicals are  
obtained are petroleum,  
coal, wood and other plant  
products, and animals.

The most abundant sources  
of hydrocarbons are petro-  
leum and natural gas.

Topical Outline

Understandings  
and Concepts

Laboratory Ex

The nonpolar nature of the hydrocarbon molecules make them relatively insoluble in water.

When burned, hydrocarbons form water and products such as carbon, carbon monoxide, and carbon dioxide.

Most chemistry manuals describe reactions involving (methane gas) in Bunsen

1. Alkane series

The alkane series consists of hydrocarbons having the general formula,  $C_nH_{2n+2}$ .

Build ball-and-stick models for the first four members of the alkane series.

The alkanes are saturated hydrocarbons since only single bonds exist between adjacent carbon atoms.

Isomerism is shown beginning with the fourth member, butane, of the alkane series.

Build models of butane and its isomers.

There is a systematic way of naming organic compounds based upon the number of carbon atoms in the alkane chain.

Standings  
Concepts

Laboratory Experiences

Supplementary Information

lar nature of the  
on molecules make  
ivley insoluble

d, hydrocarbons  
and products  
arbon, carbon mon-  
carbon dioxide.

Most chemistry laboratory  
manuals describe activi-  
ties involving the combus-  
tion of methane (natural  
gas) in Bunsen burners.

The products of combustion  
are determined by the  
amount of oxygen present  
and by the temperature.

Complete combustion results  
in the formation of  $\text{CO}_2$   
and  $\text{H}_2\text{O}$ . Incomplete com-  
bustion may result in the  
formation of  $\text{H}_2\text{O}$ ,  $\text{CO}$ ,  
and/or C.

series consists  
rbons having the  
rmula,  $\text{C}_n\text{H}_{2n+2}$ .

Build ball-and-stick models  
for the first five members  
of the alkane series.

The alkane series is also  
called the methane series,  
or the paraffin series.

s are saturated  
ns since only  
ds exist between  
arbon atoms.

Build models of the isomers  
of butane and pentane.

is shown begin-  
the fourth mem-  
e, of the alkane

systematic way  
organic compounds  
the number of  
ms in the alkane

*For purposes of examina-  
tion, pupils will be held  
responsible for the names  
and formulas of the first  
ten normal (unbranched)*

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

The number of carbon atoms is indicated by the first part of a name. For example,

meth - 1 carbon atom  
eth - 2 carbon atoms  
prop - 3 carbon atoms  
but - 4 carbon atoms

The letters "-ane" are used for the ending of an alkane's name.

2. Unsaturated hydrocarbons

There are several homologous series of unsaturated hydrocarbons.

Unsaturated hydrocarbons are named from the corresponding alkane, with the ending "-ane" changed to indicate the series to which the compound belongs.

The alkene series contains one double bond in the hydrocarbon chain. The alkyne series contains one triple bond in the hydrocarbon chain.

3. Cyclic hydrocarbons

Some series of hydrocarbons contain carbon atoms arranged to form a ring structure.

Ball-and-stick models will be built to illustrate the structure of alkenes, alkynes. Spring connections will be necessary for double and triple bond connections. Pupils will cover how the number of hydrocarbons in these series compares with corresponding alkanes.

In building models of benzene, spring connections will be necessary for double bond connections.

standings  
Concepts

Laboratory Experiences

Supplementary Information

of carbon atoms  
ed by the first  
name. For

carbon atom  
carbon atoms  
carbon atoms  
carbon atoms

s "-ane" are used  
ding of an  
ame.

Several homolo-  
s of unsaturated  
ns.

l hydrocarbons  
from the corres-  
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series contains  
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ies contains one  
d in the hydro-  
in.

of hydrocarbons  
bon atoms  
form a ring

Ball-and-stick models can  
be built to illustrate the  
structure of alkenes and  
alkynes. Spring connectors  
will be necessary for  
double and triple bond con-  
nections. Pupils will dis-  
cover how the number of  
hydrocarbons in these  
series compares with the  
corresponding alkanes.

In building models of ben-  
zene, spring connectors  
will be necessary for  
double bond connections.

*members of the alkane  
series, and for recognizing  
isomers of butane and pen-  
tane from their structural  
formulas. In this area  
pupils will not be respon-  
sible for the I.U.C naming  
of these isomers. The  
naming of hydrocarbon iso-  
mers will be treated in  
optional Area 4.*

*Pupils will not be held  
responsible for the names  
or formulas of individual  
alkenes or alkynes in Area  
3. Unsaturated hydrocar-  
bons will be treated in  
greater detail in optional  
Area 4.*

While alternate double and  
single bonds are shown in  
the structural formula of  
benzene to satisfy the  
valence requirements of

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

The most important series of cyclic hydrocarbons is the benzene series.

Benzene, the first member of the series, has the molecular formula  $C_6H_6$ , with the six carbon atoms forming a ring structure.

B. Other organic compounds

In some homologous series of organic compounds one or more hydrogen atoms of a hydrocarbon have been replaced by other elements.

Organic compounds often can be considered as being composed of one or more functional groups attached to a hydrocarbon molecule.

A functional group is a particular arrangement of a few atoms which gives characteristic properties to an organic molecule.

The use of ball-and-stick models can provide an opportunity for developing an understanding of the function of the functional group.

Standings  
Concepts

Important series  
hydrocarbons is  
the series.

The first member  
series, has the  
formula  $C_6H_6$ ,  
six carbon atoms  
ring structure.

Homologous series  
of compounds one  
hydrogen atoms of  
carbon have been  
replaced by other elements.

Compounds often can  
be considered as being com-  
posed of one or more func-  
tional groups attached to  
the carbon molecule.

A functional group is a  
specific arrangement of  
atoms which gives  
characteristic properties  
to an organic molecule.

Laboratory Experiences

The use of ball-and-stick  
models can provide an  
opportunity for developing  
understanding of the role  
of the functional groups.

Supplementary Information

the carbon atoms, all car-  
bon-carbon bonds are the  
same, and the benzene ring  
does not show the reactions  
typical of unsaturated com-  
pounds.

*For purposes of examination  
benzene will be represented  
as:*



The purpose of this section  
is to introduce pupils to  
a few classes of organic  
compounds and to show them  
how to recognize the  
classes from their func-  
tional groups. Naming of  
the compounds will not be  
stressed.

*More detailed treatment of  
organic compounds and an  
introduction to some of  
their reactions may be  
found in optional Area 4.*

Topical Outline

Understandings  
and Concepts

Laboratory Exper

Organic compounds are usually named from their corresponding hydrocarbons but are not necessarily prepared from the hydrocarbon.

1. Alcohols

The functional group, -OH, substituted for a hydrogen atom in a hydrocarbon gives the compound properties of an alcohol.

While an alcohol may have more than one -OH group, no more than 1 -OH group can be attached to one carbon atom in the molecule.

In the case of alcohols, the -OH functional group does not form hydroxide ions in aqueous solution.

Alcohols may be named from the corresponding hydrocarbon by replacing the final "e" by "ol."

Change alkane models of alcohol that an homologous of alcohols will from replacing an oxygen atom of successive members of the alkan

Compare the effect of aqueous alcohol solutions on indicators. Account for the different results.

2. Aldehydes

The structural representation of the aldehyde group is



Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

ic compounds are  
ly named from their  
sponding hydrocarbons  
re not necessarily  
red from the hydrocar-

unctional group, -OH,  
ituted for a hydrogen  
in a hydrocarbon gives  
ompound properties of  
cohol.

an alcohol may have  
than one -OH group,  
re than 1 -OH group  
e attached to one car-  
tom in the molecule.

e case of alcohols,  
OH functional group  
not form hydroxide  
in aqueous solution.

ols may be named from  
corresponding hydro-  
n by replacing the  
"e" by "ol."

tructural representa-  
of the aldehyde group



Change alkane models into  
models of alcohols. Show  
that an homologous series  
of alcohols will result  
from replacing an end hydro-  
gen atom of successive mem-  
bers of the alkane series.

Compare the effect of  
aqueous alcohol and base  
solutions on indicators.  
Account for the different  
results.

The general structural  
formula of an alcohol is  
R-OH, where R represents  
any hydrocarbon minus one  
H.

Two common alcohols are  
methanol, CH<sub>3</sub>OH, and eth-  
anol, C<sub>2</sub>H<sub>5</sub>OH.

An aldehyde of primary  
importance is methanal,  
HCHO, which is generally  
referred to by its common  
name, formaldehyde. Pupils  
should be familiar with  
formaldehyde, which is

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experience</u>
3. Ketones	Aldehydes can be named by replacing the final "e" of the corresponding hydrocarbon with the ending "al."  The structural representation of the ketone group is  $\begin{array}{c} \text{O} \\    \\ \text{R}_1\text{-C-R}_2 \end{array}$	Compare models of $\text{C}_2\text{H}_5\text{O}$ an alcohol; $\text{CH}_3\text{CHO}$ , an aldehyde; and $\text{CH}_3\text{OCH}_3$ , ether. The last is the only one where O is bonded to two carbon atoms.
4. Ethers	The structural representation of an ether group is $\text{R}_1\text{-O-R}_2$ .  An ether group has an oxygen atom as part of its chain.	Using a model, derive an organic acid from an aldehyde.
5. Organic acids	Organic acids are characterized by a functional group called the carboxylic group.	

Laboratory Experiences

Supplementary Information

often used to preserve biological specimens.

$R_1$  and  $R_2$  must be from a hydrocarbon.

An important ketone, widely used as a solvent, is propanone,  $CH_3COCH_3$ , generally referred to by its common name, acetone.

The ether used as an anaesthetic has the formula  $C_2H_5OC_2H_5$ .

Compare models of  $C_2H_5OH$ , an alcohol;  $CH_3CHO$ , an aldehyde; and  $CH_3OCH_3$ , an ether. The last is the only one where O is bonded to two carbon atoms.

Using a model, derive an organic acid from an alkane.

There are acids which have other functional groups in addition to a carboxylic group. Amino acids are an example.

Topical Outline

Understandings  
and Concepts

Laboratory Experience

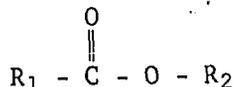
The carboxylic group has the structure



Organic acids are named from their corresponding hydrocarbons by replacing the final "-e" with the ending "-oic" and adding the class name, acid.

6. Esters

The structure of the ester is



7. Amine group

Amine group structure is represented by



See A 4.08-a.

8. Amino acids

An amino acid is an organic compound containing both an amine group (-NH<sub>2</sub>) and an organic acid group (-COOH).

See A 4.08-b.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

ic group has

e

OH

s are named  
corresponding  
by replacing  
" with the  
and adding  
e, acid.

of the ester

O - R<sub>2</sub>

structure is

See A 4.08-a.

is an  
and containing  
group (-NH<sub>2</sub>)  
c acid group

See A 4.08-b.

Organic acids containing  
long hydrocarbon chains  
(often 14-18 carbon atoms)  
are found as constituents  
of fats, and are known as  
fatty acids.

Methanoic acid, HCOOH, and  
ethanoic acid, CH<sub>3</sub>COOH,  
will be familiarly known  
by their common names,  
formic acid and acetic  
acid.

Esters generally have odors  
of fruit or mint.

Esters are often used in  
synthetic flavoring.

*The production of esters  
by condensation reactions  
between an alcohol and an  
acid will be treated in  
optional Area 4.*

Units of amino acids can  
function as an amine, as  
an acid, or as both.

## AREA 4 - FURTHER STUDY OF ORGANIC COMPO

Area 4 is an expansion and continuation of subject matter introduced in Area 3. Teachers electing this optional area may wish to incorporate the material of both areas in a single organic chemistry unit.

### Topical Outline

### Understandings and Concepts

### Laboratory Ex

#### I. Hydrocarbons

##### A. Series of hydrocarbons

There are many homologous series of hydrocarbons. The members of a series have related structures and properties.

##### 1. Alkanes

The alkanes are saturated hydrocarbons having the general formula  $C_nH_{2n+2}$ .

The alkanes range from gases to low-melting point solids.

#### 4 - FURTHER STUDY OF ORGANIC COMPOUNDS

Area 4 is an expansion and continuation of subject matter introduced in Area 3. Teachers electing this optional area may wish to incorporate the material of both areas in a single organic chemistry unit.

##### Understandings and Concepts

##### Laboratory Experiences

##### Supplementary Information

There are many homologous series of hydrocarbons. Each member of a series has related structures and properties.

Alkanes are saturated hydrocarbons having the general formula  $C_nH_{2n+2}$ .

Alkanes range from methane to low-melting point

The IUPAC (International Union of Pure and Applied Chemistry) system of naming will be used in this area. There will be a few exceptions where common usage may be desired. For example, nursing students will need to know that ethanol is also called ethyl alcohol.

There are series of hydrocarbons not included in this area.

The ending "-ane" indicates the saturated series.

The first four members of the alkane series are gases at room temperature; those from  $C_5H_{12}$  to  $C_{16}H_{34}$  are liquids, and those above

Topical Outline

Understandings  
and Concepts

Laboratory Expt

The alkanes show isomerism beginning with butane.

In naming the normal or straight chain isomers, the first part of the name indicates the number of carbon atoms in the molecule.

In naming branched-chain isomers, the longest unbranched chain of carbon atoms in the molecule is used as the basis of the name.

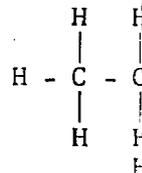


Topical Outline

Understandings  
and Concepts

Laboratory Experi

The branch chains are named as derivatives of alkanes, with the ending "-yl" substituted for "-ane."



The carbon atom to which the branch is attached is indicated by a number preceding the name. The chain is numbered from the end nearest the first attached group.

2 met

2. Alkenes

The alkenes are unsaturated hydrocarbons having 1 pair of carbon atoms with a double bond between them.

Build models of the five members of the series.

The alkene series is represented by the general formula,  $C_nH_{2n}$ .

In naming alkenes, the "-ane" of the corresponding alkane is dropped and the "-ene" ending is substituted to show the



Topical Outline

Understandings  
and Concepts

Laborator

double bonding.

Isomerism is shown beginning with the third member of the series, butene. Isomers of the alkenes are named in the same manner as the alkanes.

3. Alkynes

The alkynes are unsaturated hydrocarbons having one pair of carbon atoms with a triple bond between them. Build models of the first five members of the series.

The alkyne series is represented by the general formula  $C_nH_{2n-2}$ .

Understandings  
and Concepts

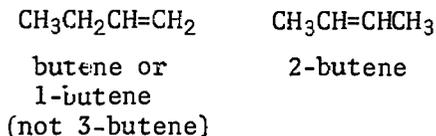
Laboratory Experiences

Supplementary Information

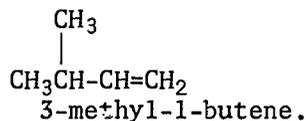
ble bonding.

(The carbon atoms are numbered from the end of the chain nearest the double bond.)

For example:



Example:



*Pupils will be held responsible for the names and formulas of the first four members of the alkene series and any of their isomers.*

omerism is shown beginning with the third member of the series, butene. Members of the alkenes are named in the same manner as the alkanes.

alkynes are unsaturated hydrocarbons having one or more carbon atoms with a triple bond between them.

Build models of the first five members of the alkyne series.

The alkyne series is also known as the acetylene series.

The alkyne series is represented by the general formula  $\text{C}_n\text{H}_{2n-2}$ .

The formula,  $\text{C}_n\text{H}_{2n-2}$ , also represents the alkadienes.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

The alkynes are named by dropping the "-ane" ending of the corresponding alkane and substituting "-yne" to indicate the triple bond.

Isomers of alkynes are named in the same manner as the alkenes.

4. Alkadienes

The alkadienes are unsaturated hydrocarbons having two pairs of carbon atoms with double bonds between them.

Build a model of butadiene

The alkadiene series is represented by the general formula  $C_nH_{2n-2}$ .

The alkadienes are named by dropping the "-ane" ending of the corresponding alkane and substituting "-adiene" to indicate two double bonds.

## Laboratory Experiences

## Supplementary Information

Build a model of butadiene.

The common name for ethyne,  $C_2H_2$ , the first member of the alkyne series, is acetylene. The name is still in use and should be familiar to students.

*Pupils will be held responsible for the names and formulas of the first three alkynes.*

Two double bonds do not occur consecutively in a molecule; that is, one carbon atom cannot form double bonds with two other carbon atoms.

The alkadienes cannot be distinguished from the alkynes on the basis of their molecular formulas. Butadiene and butyne both have the molecular formula  $C_4H_6$ .

*Pupils will be held responsible for the name and formula of the first member of the alkadiene series, butadiene,*  
 $CH_2=CH-CH=CH_2$ .

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
5. Benzene series	<p>The benzene series is a series of cyclic hydrocarbons which have the general formula, <math>C_nH_{2n-6}</math>.</p> <p>The compound, benzene, is the first member of the benzene series. Other members of the series are named by changing the "-ane" ending of the added alkane radical to "-yl", and adding the word "benzene" to complete the name.</p>	<p>In building a model of methylbenzene, start with molecules of benzene and methane. This can be used as an introduction to substitution reactions discussed later.</p>
B. Reactions of hydrocarbons	<p>Hydrocarbons will burn at elevated temperatures.</p> <p>Saturated hydrocarbons are relatively unreactive.</p> <p>Unsaturated compounds are much more reactive than saturated compounds.</p>	

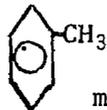
### Laboratory Experiences

In building a model of methylbenzene, start with molecules of benzene and methane. This can be used as an introduction to substitution reactions discussed later.

### Supplementary Information

*Review Area 3, Section IV A 3.*

The second member of the benzene series is:



methylbenzene  
 $C_6H_5CH_3$

The common name for methylbenzene is toluene.

*For purposes of examination, only the names and structures for the first two members of the benzene series will be required.*

Complete combustion results in the formation of  $CO_2$  and  $H_2O$ .

Saturated compounds will react with the halogens (except iodine) to form halogen substitution products.

Topical Outline

1. Substitution

Understandings  
and Concepts

In a substitution reaction a hydrogen atom is replaced by another kind of atom or group.

Substitution reactions are characteristic of saturated hydrocarbons.

Hydrogen atoms of saturated hydrocarbons can be replaced by halogen atoms.

In naming substitution products, use the longest hydrocarbon chain for the alkane's name. Precede this name by prefixes to indicate the kind and number of atoms substituted, and numbers to indicate on what carbons they are located.

Laboratory Experience

Start with a methane molecule and by substitution form

- (1) trichloromethane,  $\text{CCl}_3$  (chloroform)
- (2) difluorodichloromethane,  $\text{CF}_2\text{Cl}_2$  (freon)
- (3) tetrachloromethane,  $\text{CCl}_4$  (carbon tetrachloride)

Findings  
Concepts

Substitution reaction  
Atom is replaced  
Kind of atom or

Laboratory Experiences

Start with a methane mole-  
cule and by substitution  
form

- (1) trichloromethane,  $\text{CHCl}_3$   
(chloroform)
- (2) difluorodichlorometh-  
ane,  $\text{CF}_2\text{Cl}_2$  (freon)
- (3) tetrachloromethane,  
 $\text{CCl}_4$  (carbon tetra-  
chloride)

reactions are  
typical of satu-  
rated carbons.

Reactions of satu-  
rated carbons can be  
substituted with  
halogen atoms.

Substitution prod-  
ucts have the longest  
carbon chain for the  
parent. Precede  
with prefixes to  
indicate kind and num-  
ber of substituted,  
to indicate on  
which carbon they are

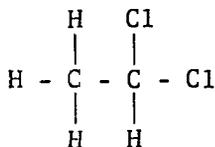
Supplementary Information

In view of the safety  
aspects, it is recommended  
that only models be used  
in working out the organic  
reactions treated in this  
section.

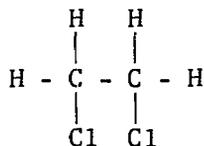
Combustion and thermal  
decomposition are not sub-  
stitution reactions.

The general term for these  
substitutions is halogena-  
tion, and the products are  
called halogen derivatives  
or halogen substitution  
products.

Examples of substitution  
products are:



1, 1-dichloroethane



1, 2-dichloroethane

Topical Outline

2. Addition

Understandings  
and Concepts

Addition reactions are characteristic of unsaturated compounds.

Addition usually involves adding one or more atoms at the double bond, resulting in saturation of the bond.

Generally, addition reactions tend to be faster than substitution reactions.

The addition of chlorine and bromine (iodine does not add) may take place at room temperature. The compounds formed are called halogen derivatives.

At high temperatures and with suitable catalysts hydrogen can be added at the double bonds. This process is called hydrogenation. The products are saturated compounds.

Addition products are named in the same manner as substitution products.

Laboratory Experiences

Start with ethylene and "add" hydrogen and chlorine atoms to saturation reactions. that ethyne (acetylene) can add "more" than

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

reactions are  
characteristic of unsatu-  
rated compounds.

usually involves  
one or more atoms  
of double bond, result-  
ing in saturation of the

addition reac-  
tion is faster  
than substitution reac-

reaction of chlorine  
and bromine (iodine does  
not) may take place at  
room temperature. The com-  
pounds formed are called  
halogen derivatives.

higher temperatures and  
suitable catalysts  
can be added at  
higher temperatures. This  
is called hydro-  
halogenation. The products  
are saturated compounds.

addition products are  
formed in the same manner  
for substitution products.

Start with ethylene models  
and "add" hydrogen or/and  
chlorine atoms to show  
addition reactions. Show  
that ethyne (acetylene)  
can add "more" than ethene.

Bromine in  $\text{CCl}_4$  is used as  
a test for unsaturation.  
If this test is used, it  
should be limited to a  
teacher demonstration.  
Bromine can cause serious  
skin burns. Teachers  
should acquaint themselves  
with first aid for bromine  
burns listed on the  
reagent's label before  
performing the experiment.

*Pupils will be held respon-  
sible for names and struc-  
tural formulas of halogen  
derivatives of hydrocarbons  
containing no more than five  
carbon atoms in a straight*

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory</u>
3. Polymer- ization	Polymerization involves the formation of a large molecule from smaller molecules.	Build a polymer ethylene
	For polymerization to occur, there must be a catalyst and/or increased temperature.	
4. Cracking	Cracking is the process by which long chain molecules can be broken into smaller molecules.	
	Generally, cracking requires the use of a catalyst and increased temperature.	
II. Alcohols		
A. Classes of alcohols	Alcohols can be classified according to the number of -OH functional groups in the molecule:	A 4.01 is used in producing the classes
	. Monohydroxy alcohols have one -OH group.	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Polymerization involves the combination of a large molecule from smaller molecules.

Build a polymer from several ethylene models.

*chain.*

Synthetic rubbers, plastics such as polyethylene, and other large chain molecules synthesized by man are polymers. *These polymers are included in optional Area 7.*

For polymerization to occur, there must be a catalyst and/or increased temperature.

Cracking is the process by which long chain molecules can be broken into smaller molecules.

The cracking process makes possible a greater yield of usable hydrocarbons for gasoline and other products.

Generally, cracking requires the use of a catalyst and increased temperature.

*Use sound films to show cracking, polymerization, and fractional distillation processes applied to the production of gasoline.*

Alcohols can be classified according to the number of functional groups in the molecule:

A 4.01 is useful in introducing the structures of the classes of alcohols.

Methanol (methyl alcohol) and ethanol (ethyl alcohol) are common monohydroxy alcohols.

Monohydroxy alcohols have one -OH group.

In naming monohydroxy alcohols in which the -OH is

Topical Outline

Understandings  
and Concepts

Laboratory Exper

. Dihydroxy alcohols have  
two -OH groups.

. Trihydroxy alcohols have  
three -OH groups.



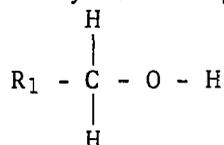
Topical Outline

Understandings  
and Concepts

Laboratory

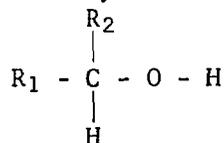
The functional groups of alcohols can be classified as primary, secondary, or tertiary alcohol groups according to the number of carbon chains attached to the carbon having the -OH group.

. Primary alcohol group:



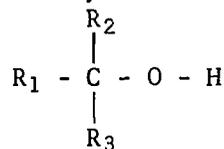
written in condensed structural formulas as -CH<sub>2</sub>OH.

. Secondary alcohol group:



written in condensed structural formulas as -CHOH.

. Tertiary alcohol group:



written in condensed

ings  
ots

Laboratory Experiences

Supplementary Information

groups of  
classified  
secondary, or  
groups  
the number of  
attached to  
the -OH

ol group:

H

condensed  
formulas as

ol group:

H

condensed  
formulas as

ol group:

H

condensed

*Pupils will be held responsible for naming monohydroxy alcohols containing up to five carbon atoms and their straight chain isomers. Pupils will not be expected to name dihydroxy or trihydroxy alcohols except ethylene glycol and glycerol. Pupils will be expected to recognize whether an alcohol is a primary, secondary, or tertiary alcohol from its structural formula.*

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
B. Properties of alcohols	<p>structural formulas as -COH.</p> <p>Alcohols show isomerism.</p> <p>The hydroxyl group gives polarity to some alcohols when H<sub>2</sub>O is the solvent.</p>	<p>The solubilities of alcohols are illustrated in A 4.02.</p>
C. Some reactions of alcohols	<p>As the number of hydroxyl groups increases, the more polar the molecule becomes.</p> <p>The -OH functional group in alcohols does not form a hydroxide ion in aqueous solution.</p> <p>Alcohols are electrical non-conductors, even in aqueous solution.</p>	<p>Compare the effect of aqueous alcohol and base solutions on indicators. Account for the different results.</p> <p>Show the lack of electrical conductivity of alcohols such as ethanol and glycerol.</p>
1. Oxidation	<p>Alcohols will burn at elevated temperatures.</p>	<p>Illustrate with an alcohol lamp.</p>

standings  
Concepts

Laboratory Experiences

Supplementary Information

al formulas as

how isomerism.

yl group gives  
o some alcohols  
s the solvent.

The solubilities of alco-  
hols are illustrated in  
A 4.02.

As the length of a hydro-  
carbon chain increases,  
the polarity and solubil-  
ity effects induced by the  
hydroxyl group are reduced.  
Monohydroxy alcohols con-  
taining a chain of five or  
more carbon atoms tend to  
become insoluble.

ber of hydroxyl  
reases, the more  
molecule becomes.

Ethylene glycol and glyc-  
erol are completely mis-  
cible with water.

unctional group  
s does not form  
e ion in aqueous

Compare the effect of  
aqueous alcohol and base  
solutions on indicators.  
Account for the different  
results.

re electrical non-  
even in aqueous

Show the lack of electrical  
conductivity of alcohols  
such as ethanol and glyc-  
erol.

ill burn at ele-  
peratures.

Illustrate with an alcohol  
lamp.

Complete combustion results  
in the formation of CO<sub>2</sub>  
and H<sub>2</sub>O.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

Primary alcohol groups can be oxidized to aldehydes.

See A 4.03.

Secondary alcohol groups can be oxidized to ketones.

See A 4.04.

Tertiary alcohols are not readily oxidized.

2. Esterification

The hydroxyl group of an alcohol can react with the carboxylic (-COOH) group of an acid to form an ester and water.

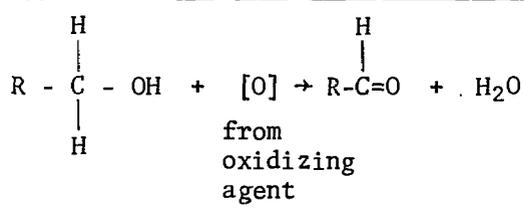
The preparation of oil (an ester) is CH 7.17.

Aldehydes  
Aldehydes

Aldehyde groups can be oxidized to carboxylic acids.

Laboratory Experiences

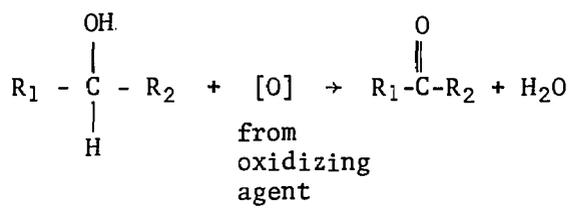
See A 4.03.



Supplementary Information

Alcohol groups can be oxidized to ketones.

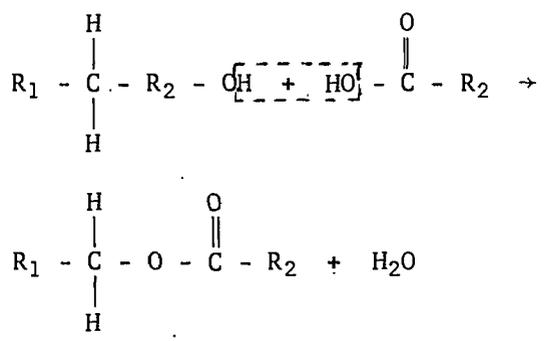
See A 4.04.



Alcohols are not oxidized to aldehydes.

The preparation of banana oil (an ester) is given in CH 7.17.

Alcohol group of an ester reacts with the (COOH) group to form an ester.



Topical Outline

Understandings  
and Concepts

Laboratory Ex

III. Aldehydes

The aldehyde group confers only a moderate polarity to the molecule which tends to make the molecule soluble.

Only aldehydes with a low formula mass are soluble in water.

Aldehyde groups are very easily oxidized to acids.

Aldehydes can be oxidized by air into their respective acids.

Aldehyde groups act as reducing agents.

A 4.07 illustration by the models.

The oxidation of aldehyde to an acid is illustrated in A 4.0

Heat a few drops of aldehyde in Benedict's solution or Fehling's solution to show the effect of an aldehyde. See CH 7.14 (a)

Laboratory Experiences

A 4.07 illustrates esterification by the use of models.

Supplementary Information

As the length of a hydrocarbon chain increases, the tendency to be soluble in water is reduced.

The oxidation of an aldehyde to an acid is illustrated in A 4.05.

Heat a few drops of an aldehyde in Benedict's solution or Fehling's solution to show the reducing effect of an aldehyde. See CH 7.14 (a).

The presence of an aldehyde group is shown by the reduction of the metal ion (usually  $\text{Cu}^{++}$ ) to the metallic state.

Benedict's solution is more stable than Fehling's solution.

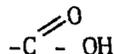
Topical Outline

IV. Organic Acids

Understandings  
and Concepts

Laboratory

Organic acids contain one or more carboxylic groups having the structure



Using a model of an organic acid and an alkane. A

The carboxylic group confers considerable polarity to molecules.

Organic acids containing one to four carbon atoms are soluble in water.

The boiling points of the carboxylic acids are higher than their corresponding hydrocarbons because of the polarity of the molecules.

Organic acids react very much like inorganic acids because both produce hydrogen ions in aqueous solution.

Organic acids are weak acids.

Compare the properties of some organic acids with some inorganic acids. 7.16 a-d.

The carboxylic group of acids is very resistant to oxidation.

Understandings

Concepts

Laboratory Experiences

Supplementary Information

acids contain one  
carboxylic groups  
in their structure

Using a model, derive an  
organic acid from an  
alkane. A 4.06.

OH

carboxylic group con-  
siderable polarity  
exists.

acids containing  
fewer carbon atoms  
are more soluble in water.

As the length of the car-  
bon chain of an organic  
acid increases, the solu-  
bility decreases.

Boiling points of the  
organic acids are higher  
than corresponding  
alcohols because of  
the presence of the mole-

acids react very  
readily with  
inorganic acids  
and both produce hydro-  
gen in aqueous solu-

acids are weak

Compare the properties of  
some organic acids with  
some inorganic acids. CH  
7.16 a-d.

carboxylic group of  
acids is very resistant to  
oxidation.

Topical Outline

Understandings  
and Concepts

Laboratory

Organic acids react with alcohols to form esters.

See A 4.10

V. Carbohydrates

Carbohydrates can be recognized from an empirical formula written as  $C_y(H_2O)_x$ .

Carbohydrates contain hydroxyl groups and aldehyde or ketone groups.

A. Monosaccharides

Carbohydrates that cannot be hydrolyzed (reacted with water) into simpler molecules are called monosaccharides.

Monosaccharides are known as simple sugars and have the general formula  $C_6H_{12}O_6$ .

In naming classes of monosaccharides, the number of carbon atoms is indicated and the presence of an aldehyde or ketone group is shown by the prefix "aldo" or "keto."

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Organic acids react with alcohols to form esters.

See A 4.10.

Esters of long chain organic acids (fatty acids) and the alcohol glycerol are fats.

Carbohydrates can be recognized from an empirical formula written as  $C_x(H_2O)_x$ .

There is no structural significance to this formula.

Carbohydrates contain hydroxyl groups and aldehyde or ketone groups.

Carbohydrates that cannot be hydrolyzed (reacted with water) into simpler molecules are called monosaccharides.

*Pupils are not expected to learn structural formulas of the various carbohydrates but should be acquainted with the functional groups which give rise to the properties of the carbohydrates.*

Monosaccharides are known as simple sugars and have the general formula  $C_6H_{12}O_6$ .

In naming classes of monosaccharides, the number of carbon atoms is indicated and the presence of an aldehyde or ketone group is shown by the prefix "aldo" or "keto."

Example: A 6-carbon sugar containing an aldehyde group would be called an aldohexose.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

Aldose carbohydrates are reducing sugars.

Show the effect of sugars on Benedict's solution. CH 7.19 a (3)

Glucose and fructose are reducing sugars.

B. Disaccharides

Carbohydrates that undergo hydrolysis to form two monosaccharide molecules are classified as disaccharides.

Cane sugar is a disaccharide known chemically as sucrose,  $C_{12}H_{22}O_{11}$ . Maltose and lactose are also examples of disaccharides.

Prenursing students have some experience using a hydrometer to determine the specific gravity of sugar solutions.

The number of polar functional groups present makes the disaccharides soluble in water.

In the presence of an acid or the enzyme, invertase, cane sugar can

For the hydrolysis of refer to CH 7.19 a (3)

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

carbohydrates are  
g sugars.

Show the effect of aldose  
sugars on Benedict's solu-  
tion. CH 7.19 a (3).

Glucose is an important  
aldohexose found in fruits,  
honey, the blood stream,  
and in other fluids of the  
body. It is the chief  
source of energy for the  
operation of muscles,  
glands, and nerve impulses.

and fructose are  
g sugars.

Fructose is the sweetest  
of all sugars. While it  
is a ketohexose, it reacts  
as if it has a "potential"  
aldehyde group.

drates that undergo  
sis to form two  
charide molecules  
ssified as disac-  
s.

gar is a disaccha-  
own chemically as  
,  $C_{12}H_{22}O_{11}$ .  
and lactose are  
amples of disaccha-

Prenursing students should  
have some experiences in  
using a hydrometer to test  
the specific gravity of  
sugar solutions.

ber of polar func-  
groups present  
he disaccharides  
in water.

presence of an  
the enzyme, inver-  
ane sugar can

For the hydrolysis of sugar  
refer to CH 7.19 a (4).

The hydrolysis of cane  
sugar is called inversion  
of sugar since the mixture

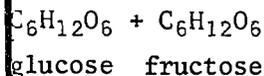
<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Exper</u>
C. Polysaccharides	<p>undergo hydrolysis to produce equal amounts of glucose and fructose. The reaction can be expressed:</p> $C_{12}H_{22}O_{11} + H_2O \rightarrow$ $C_6H_{12}O_6 + C_6H_{12}O_6$ <p>glucose fructose</p> <p>The polysaccharides include starch, glycogen (animal starch), and cellulose.</p> <p>Polysaccharides have the general formula <math>(C_6H_{10}O_5)_x</math>.</p> <p>Polysaccharides yield many monosaccharide molecules when they are hydrolyzed.</p> <p>The large size of the polysaccharide molecule tends to make it insoluble or only slightly soluble in water.</p> <p>The solutions of polysaccharides show colloidal properties.</p>	<p>For the hydrolysis starch see CH 7.1</p> <p>Use A 5.06 to illustrate colloidal starch ties.</p>

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Undergo hydrolysis to produce equal amounts of glucose and fructose. The reaction can be expressed:



Polysaccharides include starch, glycogen (animal starch), and cellulose.

Polysaccharides have the general formula  $(C_6H_{10}O_5)_x$ .

Polysaccharides yield many small saccharide molecules when they are hydrolyzed.

The large size of the polysaccharide molecule tends to make it insoluble or slightly soluble in water.

Solutions of polysaccharides show colloidal properties.

For the hydrolysis of starch see CH 7.19 a (4).

Use A 5.06 to illustrate colloidal starch properties.

The hydrolysis products rotate polarized light in the opposite direction from pure sucrose.

Glucose and fructose are isomers that have different structures and properties.

*The fermentation of sugar is discussed in optional Area 5.*

The complete hydrolysis of starch produces glucose.

*The colloidal properties of starch solution are treated in optional Area 5.*

Topical Outline

Understandings  
and Concepts

Laboratory Experi

VI. Proteins

Proteins are complex nitro-  
gen compounds built up  
from amino acids.

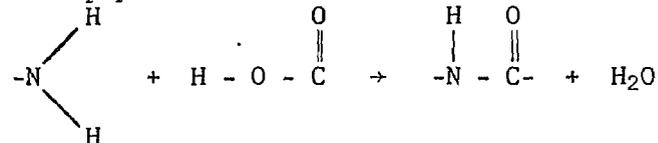
The protein compo  
can be qualitative  
tigated. Refer to  
d (1). CH 7.19 d  
gives a test for p

A. Formation from  
amino acids

An amino acid is an  
organic compound contain-  
ing both an amine group  
(-NH<sub>2</sub>) and an organic  
acid group (-COOH).

By forming amide linkages,  
amino acids polymerize to  
form peptides.

Activity A 4.09 de  
amide linkages.



from  
one  
amino  
acid  
mole-  
cule

from  
another  
amino  
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mole-  
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amide  
linkage

Peptides, in turn, polymer-  
ize to form proteins.

Proteins have very large  
molecules.

Findings  
Experiments

Laboratory Experiences

Supplementary Information

Complex nitro-  
built up  
peptides.

The protein composition  
can be qualitatively inves-  
tigated. Refer to CH 7.19  
d (1). CH 7.19 d (2)  
gives a test for proteins.

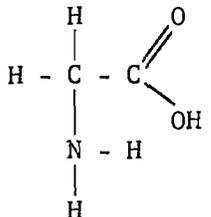
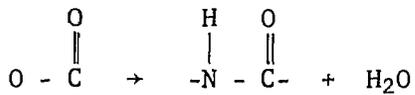
is an  
and contain-  
amine group  
organic  
(COOH).

Units of amino acids can  
function as an amine, as  
an acid, or as both.

peptide linkages,  
polymerize to

Activity A 4.09 deals with  
amide linkages.

An example of an amino  
acid is glycine,  
CH<sub>2</sub>NH<sub>2</sub>COOH, with the  
structural formula



amino  
other  
no  
d  
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e

amide  
linkage

protein, polymer-  
peptides.

*Pupils will be expected to  
recognize an amino acid  
from its structural for-  
mula, and a peptide from  
an amide linkage.*

very large

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
B. Hydrolysis	Boiling with dilute acid or the action of certain enzymes can make proteins undergo hydrolysis.	Refer to A 5.03 for the hydrolysis of proteins food.
	The complete hydrolysis of a protein produces amino acids.	
VII. Lipids	Lipids are constituents of plants and animal tissue that are insoluble in water but are soluble in nonpolar solvents.	
	Lipids are esters formed by the reaction between the trihydroxy alcohol, glycerol, and one or more fatty acids.	
	Fatty acids usually have one carboxyl (-COOH) group per molecule. The hydrocarbon chain of the fatty acid is a straight chain containing an even number of carbon atoms.	
	Fatty acids may be saturated or unsaturated.	

Laboratory Experiences

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Refer to A 5.03 for the hydrolysis of proteins in food.

Supplementary Information

*The hydrolysis of proteins is treated in optional Area 5.*

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The term, lipid, will be used in this Section to mean fat or vegetable oil, although some other plant and animal products are included in the lipid group, since they meet the solubility requirements.

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The esters of glycerol are sometimes called glycerides.

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fatty  
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Some common saturated fatty acids are lauric ( $C_{11}H_{21}COOH$ ), palmitic ( $C_{15}H_{31}COOH$ ), and stearic ( $C_{17}H_{35}COOH$ ).

tu-

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Unsaturated fatty acids react like alkenes since the carbon to carbon double bonds will add bromine or hydrogen.

Lipids are low-melting-point solids or liquids.

The melting point of lipids decreases as the number of double bonds increases.

The degree of unsaturation of a natural fat or oil can be reduced to any stage by hydrogenation in the presence of a nickel catalyst.

In the presence of enzymes, glycerides can undergo hydrolysis to form three fatty acids and glycerol.

The enzymes for the hydrolysis of some glycerides can be furnished by the microorganisms in the air.

Laboratory Experiences

Supplementary Information

Oleic acid ( $C_{17}H_{33}COOH$ ), is an unsaturated fatty acid containing a double bond between the ninth and tenth carbon atoms.

Lipids which are solids at room temperature are called fats; those which are liquids at room temperature are called oils.

*Hydrolysis of lipids is treated in optional Area 5.*

AREA 5 - CHEMISTRY IN THE HOME

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory</u>
I. Foods	<p>Cooking and preservation of foods involve many chemical changes.</p> <p>The preparation of foods changes the structure of their nutrients and/or the texture or particle size of the foods.</p> <p>The most common food nutrients are carbohydrates, proteins, and lipids.</p>	
A. Preservation of food	<p>Preservation of foods is accomplished by preventing the growth of microorganisms which provide the enzymes required for chemical changes in foods.</p> <p>Growth of microorganisms can be controlled by drying, salting, pickling, or irradiation of foods.</p> <p>Heat can be used to destroy microorganisms or to decompose enzymes which bring about changes in foods.</p>	<p>For the effect of the action of the rennin, see A 5.0</p>

## AREA 5 - CHEMISTRY IN THE HOME

### Understandings and Concepts

ing and preservation  
ds involve many  
al changes.

eparation of foods  
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xture or particle  
f the foods.

st common food nu-  
s are carbohydrates,  
ns, and lipids.

vation of foods is  
lished by preventing  
rowth of micro-  
sms which provide  
zymes required for  
al changes in foods.

of microorganisms  
e controlled by  
, salting, pickling,  
adiation of foods.

an be used to  
y microorganisms or  
compose enzymes  
bring about changes  
ods.

### Laboratory Experiences

For the effect of heat on  
the action of the enzyme,  
rennin, see A 5.01.

### Supplementary Information

Two useful resources for  
this section are  
Lowe, Belle. *Experimental  
Cooking*.  
Fitch, N.K. & Francis, C.A.  
*Foods and Principles of  
Cookery*. Prentice-Hall,  
Inc.

*Teachers should not hesitate  
to refer to cookbooks as a  
reference source for this  
area. The use of cookbooks  
will emphasize that there  
is chemistry involved in  
the cooking process. Poor  
cooking results from lack  
of control of the chemical  
processes involved in food  
preparation.*

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
B. Some food nutrients		
1. Carbohydrates	<p>Carbohydrates can be recognized from a molecular formula written as <math>C_y(H_2O)_x</math>.</p> <p>Most carbohydrates found in foods are sugars and starches.</p>	
a. Sugars	<p>Simple sugars are isomers having the molecular formula <math>C_6H_{12}O_6</math>.</p> <p>Glucose and fructose are some examples of simple sugars.</p> <p>A complex sugar is formed by the polymerization of two molecules of simple sugars.</p> <p>Sucrose is a complex sugar having the molecular formula <math>C_{12}H_{22}O_{11}</math>.</p>	<p>Display a collection of different sugars. By referring to the formula on the label have pupils classify each as a simple or a complex sugar.</p>
b. Starches	<p>Starches are polymers of simple sugars.</p>	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Hydrates can be rec-  
ed from a molecular  
la written as  
(O)<sub>x</sub>.

carbohydrates found  
oods are sugars and  
hes.

e sugars are isomers  
g the molecular  
la C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>.

ose and fructose are  
examples of simple  
rs.

mplex sugar is formed  
ne polymerization of  
molecules of simple  
rs.

ose is a complex sugar  
ng the molecular for-  
C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>.

hes are polymers of  
le sugars.

There is no structural sig-  
nificance to this formula.

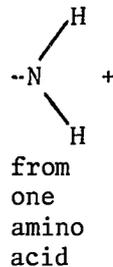
Display a collection of  
different sugars. By re-  
ferring to the formula on  
the label have pupils clas-  
sify each as a simple or a  
complex sugar.

Fructose is much sweeter  
than glucose.

Maltose and lactose are  
examples of complex sugars.

Sucrose is also known as  
cane sugar or table sugar.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>	Su
2. Proteins	<p>The molecular formula for a starch is <math>(C_6H_{10}O_5)_n</math>.</p> <p>Proteins are complex nitrogen compounds built up from amino acids.</p> <p>An amino acid is an organic compound containing both an amine group (<math>-NH_2</math>) and an organic acid group (<math>-COOH</math>).</p> <p>Proteins have very large molecules.</p>	<p>The protein composition can be qualitatively investigated. Refer to CH 7.19 d (1). CH 7.19 d (2) gives a test for proteins. A 4.09 deals with amide linkages.</p>	E a f
3. Lipids	<p>Fats and oils are classified as lipids.</p> <p>Fats and oils are esters of long chain fatty acids and glycerol.</p> <p>If the long chain of the lipid contains only single bonded carbon atoms, the fat is saturated.</p>	<p>Compare the solubility of lipids in different solvents.</p>	C a s s a
a. Saturated			V d a A c v s



Laboratory Experiences

Supplementary Information

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(-NH<sub>2</sub>)

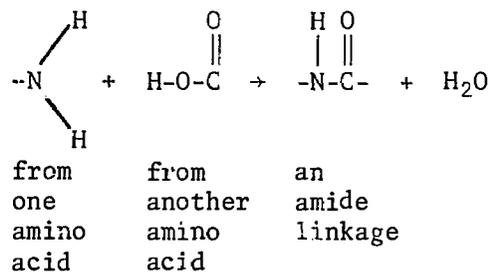
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The protein composition can be qualitatively investigated. Refer to CH 7.19 d (1). CH 7.19 d (2) gives a test for proteins. A 4.09 deals with amide linkages.

By forming amide linkages, amino acids polymerize to form peptides.



Compare the solubility of lipids in different solvents.

Constituents of plant and animal tissues that are insoluble in water but are soluble in nonpolar solvents are known as lipids.

Vegetable oils have a greater degree of unsaturation than animal fats.

At room temperatures, vegetable oils are liquids while animal fats are solids.

Topical Outline

Understandings  
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Laboratory Experiences

b. Unsaturated

Unsaturated lipids contain double bonds between some adjacent carbon atoms.

C. Changing structure of nutrients

1. Hydrolysis

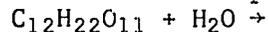
A reaction between a nutrient and water is called hydrolysis.

a. Carbohydrates

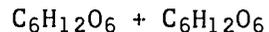
Carbohydrates undergo hydrolysis during the cooking process.

For the hydrolysis of sugar refer to CH 7.19 a(4).

In the presence of an acid or the enzyme, invertase, cane sugar can undergo hydrolysis to produce equal amounts of glucose and fructose. The reaction can be expressed:



sucrose



glucose    fructose

Findings  
Concepts

Laboratory Experiences

Supplementary Information

Lipids contain  
between some  
on atoms.

The degree of unsaturation  
of natural fat or oil can  
be reduced by hydrogenation  
in the presence of a nickel  
catalyst.

Oleomargarines and solid  
vegetable shortenings are  
made by hydrogenating a  
liquid vegetable oil.

Between a nu-  
mer is  
lysis.

Hydrolysis can also be de-  
fined as the reaction of any  
species with water.

s undergo  
during the  
ess.

For the hydrolysis of sugar  
refer to CH 7.19 a(4).

The hydrolysis of cane sugar  
is called inversion of sugar  
since the mixture of products  
rotates the polarized light  
in the opposite direction  
from pure sucrose.

ence of an acid  
e, invertase,  
an undergo  
o produce  
s of glucose  
. The re-  
e expressed:  
 $H_2O \rightarrow$

$H_{12}O_6$   
uctose

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
	As the concentration of the hydrolysis products increases, the boiling point of the solution increases.	The "stages" of boiled syrup can be used to "measure" the amount of sugar. See A 5.02.
	As the concentration of hydrolysis products increases, the density of the solution increases.	
	Starches undergo hydrolysis to form simple sugars.	Benedict's solution is used to detect the presence of a simple sugar in a <i>boiled</i> starch solution.
b. Proteins	Proteins undergo hydrolysis when boiled with dilute acid or when in the presence of certain enzymes.	Use A 5.03 to show hydrolysis of food proteins.
	During hydrolysis a protein molecule breaks up into several smaller molecules.	
	Meat tenderizers contain enzymes that promote hydrolysis.	
c. Lipids	In the presence of enzymes from microorganisms in air, lipids can undergo hydrolysis.	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Concentration of  
hydrolysis products  
decreases, the boiling  
point of the solution in-

The "stages" of boiling  
syrup can be used to "mea-  
sure" the amount of simple  
sugar. See A 5.02.

Prenursing students should  
have some experiences in  
using a hydrometer to test  
the specific gravity of  
sugar solutions.

Concentration of  
hydrolysis products in-  
creases, the density of  
the solution increases.

Simple sugars  
undergo hydrolysis

Benedict's solution can be  
used to detect the presence  
of a simple sugar in a  
*boiled* starch solution.

Simple sugars  
undergo hydrolysis  
when diluted with dilute  
acids in the  
presence of certain en-

Use A 5.03 to show hydrol-  
ysis of food proteins.

Collagen, the protein found  
in connective tissues and  
ligaments, hydrolyzes  
in boiling water to form  
gelatin.

Hydrolysis a pro-  
tein molecule breaks up  
into smaller mol-

The complete hydrolysis of  
a protein produces amino  
acids.

Enzymes contain  
active sites that promote  
reactions.

The presence of enzymes  
in microorganisms in air,  
soil, and water, and  
how they undergo hydrol-

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experi</u>
2. Oxidation	<p>During hydrolysis a lipid molecule may form products which have a disagreeable odor and taste.</p> <p>Atmospheric oxygen reacts with unsaturated lipids to produce malodorous products.</p> <p>The enzymes from microorganisms in the air are catalysts for the oxidation of lipids.</p>	Coagulation of prot illustrated in A 5
3. Coagulation	<p>Heating causes the globular proteins in egg white and milk to coagulate.</p> <p>The enzyme, rennin, and dilute acids can also coagulate the globular proteins in milk.</p>	Coagulation of prot illustrated in A 5
D. Changing texture or particle size	<p>Gluten protein chains are formed when doughs are beaten or kneaded.</p>	A 5.05 is concerned the coagulation of in flours and the affecting gluten ch mation.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Hydrolysis of a lipid may form products with a disagreeable taste.

Free oxygen reacts with saturated lipids to form a colorless and odorless product.

Free radicals from microorganisms in the air are responsible for the oxidation of lipids.

Acid causes the globular proteins in egg white and milk to coagulate.

Heat, rennin, and digestive enzymes can also coagulate globular proteins.

Protein chains are cross-linked when doughs are kneaded.

Coagulation of proteins is illustrated in A 5.04.

A 5.05 is concerned with the coagulation of gluten in flours and the factors affecting gluten chain formation.

One of the hydrolysis products of butter is butyric acid. Very slight amounts of the acid can be detected because of its disagreeable odor.

Lipids become rancid as a result of hydrolysis and/or oxidation.

Keeping butter and other fats and oils covered and in a cool place reduces the possibility of hydrolysis and oxidation and retards the onset of rancidity.

Cottage cheese is made by the coagulation of milk proteins.

Commercial casein glues are made from milk proteins.

By controlling the amount of gluten formation, the texture of the dough can be controlled.

Topical Outline

Understandings  
and Concepts

Laboratory Experience

1. Colloidal  
dispersions

A colloid is a mixture containing particles which are larger than those in a solution but smaller than those in a true suspension.

Use CH 3.46 to illustrate the intermediate position of colloidal particles.

A colloid contains a dispersed substance in a dispersing medium.

The phases of the two parts of a colloid may be alike or different.

a. Kinds of  
colloids

A gel contains a liquid suspended in a solid.

Use CH 3.49 to illustrate types of colloids.

A sol contains a solid suspended in a liquid.

Ask pupils to make a collection or a list of colloids used as food.

An emulsion is a suspension of two immiscible liquids.

A sponge is a gas dispersed in a solid.

A foam is a gas suspended in a liquid.

A fog is a liquid suspended in a gas.

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s

Laboratory Experiences

Supplementary Information

mixture con-  
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suspension.

Use CH 3.46 to illustrate  
the intermediate position  
of colloidal particles.

ns a dis-  
in a dis-

e two parts  
t be alike

A colloid may not be made by  
dispersing a gas in another  
gas. The combination would  
be a gaseous solution.

a liquid  
solid.

Use CH 3.49 to illustrate  
types of colloids.

a solid sus-  
lid.

Ask pupils to make a col-  
lection or a list of some  
colloids used as foods.

a suspension  
le liquids.

The size of the suspended  
particles determines the  
stability of an emulsion.

as dispersed

suspended

id suspended

The "steam" coming from con-  
tainers in which food is  
being cooked is really a fog  
of tiny particles of con-  
densed water suspended in air.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
b. Properties of colloids	Smoke contains a solid dispersed in a gas.	Compare the appearance, settling rate, and ability to pass through a filter of a $\text{FeCl}_3$ solution and a colloidal dispersion. CH 3.46.
2. Forming gels	Colloidal suspensions show the Tyndall effect.	Demonstrate the Tyndall effect by use of CH 3.46.
2. Forming gels	A cooling starch solution sets to a gel.	The colloidal properties of a starch suspension are illustrated by use of CH 3.46. A 5.06.
3. Forming emulsions	The proteins in a gelatin-water dispersion will form a gel upon being chilled.	A 5.07 deals with the solubility of lipid
3. Forming emulsions	The long hydrocarbon chains found in lipid molecules make them insoluble in water.	A 5.07 deals with the solubility of lipid

Findings  
Experiments

Laboratory Experiences

Supplementary Information

is a solid  
or a gas.

Compare some prop-  
erties of a sus-  
pensions show  
effect.

Compare the appearance, set-  
tling rate, and ability to  
pass through a filter of a  
 $\text{FeCl}_3$  solution and a col-  
loidal dispersion. See  
CH 3.46.

starch solution

Demonstrate the Tyndall  
effect by use of CH 3.53.

starch solution

The colloidal properties of  
a starch suspension can be  
illustrated by use of  
A 5.06.

Upon heating, the starch  
granules in a suspension  
swell and form a viscous  
solution with colloidal  
properties.

The starch in flour, corn-  
starch, and tapioca can  
absorb great quantities of  
liquid as the gel is formed;  
these substances are used  
as thickening agents.

gelatin  
will form  
when chilled.

solubility of  
lipids in  
water.

A 5.07 deals with the in-  
solubility of lipids.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Immiscible lipids can be permanently suspended by "coating" the drops with a substance (called an emulsifying agent) that is compatible with both liquids.

A 5.08 illustrates the emulsifying action of egg and starch.

Reducing the size of suspended liquid particles makes an emulsion more stable.

4. Leavening  
action

Leavening agents form a gas which expands upon being heated and changes the texture of the dough.

Finding a combination of chemicals that will produce a leavening effect is the problem in A 5.09.

Baking powder, baking soda, yeast, and steam are common leavening agents.

Understandings  
and Concepts

Emulsifiable lipids can be temporarily suspended by "stirring" the drops with emulsifier (called an emulsifying agent) that is compatible with both

Controlling the size of suspended liquid particles in an emulsion more

Emulsifying agents form a film which expands upon beating and changes the texture of the dough.

Baking powder, baking soda, and steam are common leavening agents.

Laboratory Experiences

A 5.08 illustrates the emulsifying action of eggs and starch.

Finding a combination of chemicals that will produce a leavening effect is the problem in A 5.09.

Supplementary Information

Flour, cornstarch, and egg yolk are emulsifying agents used in the preparation of gravies and salad dressings.

*The role of the emulsifier is similar to the detergent effect discussed in more detail in Section III A of this Area.*

Homogenized milk is made by using ultrasonic waves to break up the butter fat globules into particles small enough to stay dispersed in the skim milk.

Early recipes used brandy for the leavening agent. The steam formed in the dough produced the main leavening effect. The lower boiling point of alcohol allowed it to escape before the dough "cooked."

Dry baking powders contain sodium bicarbonate (baking soda) and tartaric acid, or acid salts such as monocalcium phosphate and disodium phosphate. When water

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

The reaction between an acid or acid salt and sodium bicarbonate is the basis for the leavening action of baking powder and baking soda.

The role of proteins in leavening is shown in A 5.10.

Yeast produces enzymes which cause the fermentation of sugar.  
enzyme



Many laboratory manuals contain directions for experiments on fermentation.

standings  
Concepts

Laboratory Experiences

Supplementary Information

ion between an acid salt and sodium carbonate is the leavening action of baking powder and soda.

The role of proteins in leavening is shown in A 5.10.

Many laboratory manuals contain directions for experiments on fermentation.

is added, the acid or acid salt ionizes and reacts with the sodium bicarbonate to form CO<sub>2</sub> gas.

The lactic acid in sour milk reacts with the baking soda to form CO<sub>2</sub> gas.

Many cakes, biscuits, and breads require the use of baking powder as the leavening agent.

The large number of eggs used in making sponge cake and cream puffs produces strong gluten chains and a "tough" dough which can keep the steam trapped.

The large amount of CO<sub>2</sub> produced from the fermentation process provides a leavening action for breads and rolls.

The spoilage of some foods is caused by undesirable fermentation processes.

produces enzymes  
use the fermenta-  
sugar.  
enzyme  
→ 2CO<sub>2</sub> + 2C<sub>2</sub>H<sub>5</sub>OH

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

5. Crystallization

When a sugar crystal or a piece of foreign matter is introduced into a super-saturated sugar solution, the excess dissolved sugar in the solution begins to crystallize.

The size of sugar crystals determines the texture of a candy.

Controlling crystal growth in candy is treated in A 5.11.

Crystals formed in sugar syrup, honey, or maple syrup can be dissolved by heating the substance.

II. Home Cleaning and Sanitation

Cleansing requires the loosening or dissolving of fats and oils which bind dirt to surfaces.

Sanitation requires the control of bacteria, mold, and virus growth which may endanger the health of the individual.

Water alone is not a good cleaning agent, since it is a polar solvent and grease is nonpolar.

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pts

Laboratory Experiences

Supplementary Information

crystal or a  
gn matter is  
o a super-  
r solution,  
solved sugar  
n begins to

ugar crystals  
e texture of

Controlling crystal growth  
in candy is treated in  
A 5.11.

Candy making depends upon  
(1) hydrolysis of cane  
sugar, and (2) the control  
of crystal growth from the  
resulting supersaturated  
solution.

d in sugar  
or maple  
dissolved by  
bstance.

Generally, supersaturated  
sugar solutions such as  
honey are quite stable.  
When crystallization does  
occur, the solution is re-  
formed easily.

ires the  
dissolving of  
which bind  
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not a good  
, since it is  
t and grease

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

A. Soaps and  
detergents

Soaps and detergents are composed of complex molecules which enable water to mix with oil or grease.

The molecules of a soap or detergent consist of a long hydrocarbon-like "tail" and a very polar, water soluble "head." The "tail" is soluble in the grease films, and the "head" is soluble in water.

Use soap to emulsify a mixture of kerosene "oil" and water.

1. Soaps

Soaps are metallic salts of fatty acids having a chain consisting of 10 to 18 carbon atoms.

CH 7.19-c(4) may be used for an activity involving saponification.

standings  
concepts

detergents are  
of complex mole-  
h enable water  
h oil or grease.

cles of a soap or  
consist of a long  
on-like "tail"  
y polar, water  
head." The "tail"  
e in the grease  
d the "head" is  
n water.

metallic salts  
acids having a  
sisting of 10 to  
atoms.

Laboratory Experiences

Use soap to emulsify a mix-  
ture of kerosene "oil" and  
water.

CH 7.19-c(4) may be used  
for an activity involving  
saponification.

Supplementary Information

When water containing a  
detergent or soap is put  
on a grease film, the  
"tails" of the soap or  
detergent molecules dis-  
solve in the grease. At the  
same time the "heads" are  
attracted to the water.  
As a result, the film is  
loosened, and tiny globules  
of oil, from which the polar  
ends of the soap or deter-  
gent project, are formed.  
The polar ends give the  
surface of the oil globules  
a charge and set up a  
stable emulsion.

Common soaps are sodium or  
potassium salts of stearic  
or palmitic acids. While  
the sodium salts are more  
widely used, the potassium  
soaps are softer and more  
soluble.

Topical Outline

Understandings  
and Concepts

Laboratory Exper

Soaps react with minerals in hard water to form a "scum."

Soaps are made by reacting a fat and aqueous NaOH or KOH.

fat + base → a soap +  
glycerol

The reaction for making a soap is called saponification.

2. Detergents

Detergents are sodium salts of long chain alkyl sulfates (sulfonates).

Understandings  
and Concepts

Soaps react with minerals in hard water to form a "scum."

Soaps are made by reacting a fat and aqueous NaOH or KOH.

fat + base → a soap +  
glycerol

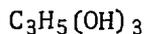
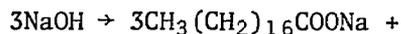
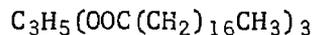
The reaction for making a soap is called saponification.

Detergents are sodium salts of long chain alkyl sulfates (sulfonates).

Laboratory Experiences

Supplementary Information

The reaction for making a typical soap, sodium stearate, from beef fat (glyceryl stearate) and sodium hydroxide is:



*For purposes of examination, pupils will not be held responsible for the formulas for substances involved in saponification.*

Grease that collects in drain pipes can be removed by saponification.

Drain cleansers are very caustic and care must be taken in using them. They can corrode the plumbing pipes and produce serious burns on the skin. Be sure to follow directions listed on the container.

Detergents are also known as syndets.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Detergents which can be decomposed by bacteria are known as biodegradable detergents.

Biodegradable detergents in present use are straight chain alkyl sulfates.

B. Bleaching

Bleaching is accomplished by the oxidation or reduction of coloring agents.

Bleaching by oxidation involves the addition of oxygen to the coloring agent, while bleaching by reduction involves the removal of oxygen from the coloring agent.

Laundry bleaches form hypochlorous acid which decomposes to form oxygen which, in turn, combines with the coloring agent.

Bleaching by oxidation is illustrated by CH 4.24-b

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

agents which can be  
destroyed by bacteria  
known as biodegradable  
agents.

Early detergents such as  
lauryl sulfonate (sulfate)  
created a sewage problem  
because soil bacteria were  
not able to break down the  
detergent molecule and  
destroy its sudsing effect.

Biodegradable detergents  
of recent use are straight  
alkyl sulfates.

Bleaching is accomplished  
by oxidation or reduc-  
tion of coloring agents.

Bleaching by oxidation in-  
volves the addition of  
oxidizing agents to the coloring  
agent while bleaching by  
reduction involves the re-  
lease of oxygen from the  
oxidizing agent.

The composition of the color-  
ing agent determines which  
bleaching action should be  
used.

Chlorine bleaches form hypo-  
chlorous acid which decom-  
poses to form oxygen which,  
in turn, combines with the  
coloring agent.

Bleaching by oxidation is  
illustrated by CH 4.24-b.

*The disinfecting action of  
chlorine bleaches is dis-  
cussed under Section C -  
hypochlorites of this area.*

Pupils should be warned that  
a chlorine bleach in the  
presence of a strong soap,  
household ammonia, or an acid  
such as a vinegar solution  
forms poisonous chlorine

Topical Outline

Understandings  
and Concepts

Laboratory Experience

Peroxide bleaches decompose to form oxygen which reacts with the coloring agent.

Reducing bleaches make use of a combination of sulfur dioxide and moisture which removes oxygen from the coloring agent.

The effect of a reducing bleach is counteracted by prolonged exposure to air.

The type of material to be bleached determines the strength of the bleach to be used:

- . Chlorine bleaches are strong bleaches which tend to destroy fibers.
- . Peroxide bleaches and the sulfur dioxide-water bleach are considered to be mild bleaches.

A reducing bleach can be illustrated by the reaction between oxalic acid and potassium permanganate.

For the effect of bleaching on fibers see A 5.12.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Some bleaches decompose  
oxygen which reacts  
with a coloring agent.

Some bleaches make use  
of a combination of sulfur  
dioxide and moisture which  
reacts with oxygen from the  
air as a coloring agent.

The effect of a reducing  
bleach is counteracted by  
oxidizing exposure to air.

The type of material to be  
bleached determines the  
effectiveness of the bleach to  
be used.

Chlorine bleaches are  
strong bleaches which  
are used to destroy fibers.

Sulfur dioxide bleaches and  
sulfur dioxide-water  
bleaches are considered to  
be mild bleaches.

A reducing bleach can be  
illustrated by the reaction  
between oxalic acid and po-  
tassium permanganate.

For the effect of bleaches  
on fibers see A 5.12.

Chlorine gas. When using a chlorine  
bleach, one should follow  
the directions listed on  
the label.

The 7% H<sub>2</sub>O<sub>2</sub> solution on the  
market is primarily a bleach-  
ing product and too strong  
an oxidizing agent to be  
used as an antiseptic.

Oxalic acid is often used  
to remove stains.

Oxalic acid is poisonous.

The yellowing of white wool  
or straw is caused by oxy-  
gen from the air reacting  
with the material.

Chlorine destroys protein  
fibers.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

C. Disinfectants

Bleaching of yellow materials may be accomplished by the use of a bluing agent.

Compare the appearance under a yellow light of piece of white cloth and a similar piece of white cloth which has been dipped into a weak laundry bluing solution.

A disinfectant is an agent that will destroy the cell structure or enzymes of bacteria.

Discover materials that be used as disinfectants See A 5.13.

A disinfectant used for cleaning should be able to concentrate on, adhere to, and sterilize a surface and keep it resistant to bacterial growth.

Evaluate the effectiveness of disinfectants on bacterial growth. See A 5.

Findings  
Concepts

yellow  
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plished by the use of a  
solution.

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of enzymes of

ant used for  
could be able  
to adhere on, adhere  
to sterilize a sur-  
face to prevent its resis-  
tance to bacterial growth.

Laboratory Experiences

Compare the appearance  
under a yellow light of a  
piece of white cloth and  
a similar piece of white  
cloth which has been dipped  
into a weak laundry bluing  
solution.

Discover materials that can  
be used as disinfectants.  
See A 5.13.

Evaluate the effectiveness  
of disinfectants on bac-  
terial growth. See A 5.18.

Supplementary Information

This illustrates a physics  
principle that a mixture  
of yellow and blue re-  
flected light forms a com-  
plementary mixture that  
appears to be white.

An ideal disinfectant is  
nonspecific in its ger-  
micidal action, nontoxic,  
harmless to human tissue,  
and remains effective in  
hard or saline water or in  
contact with organic  
matter.

Many disinfectants are in-  
soluble in water, but form  
emulsions in soap or  
detergent solutions.

The higher coal tar phenols  
are carcinogenic and are  
unsuitable for use as  
disinfectants.

## AREA 6 - ENVIRONMENTAL POLLUTION

### Topical Outline

### Understandings and Concepts

### Laboratory Experience

#### I. Introduction

A pollutant is a substance found in the environment which normally is lacking, or, if naturally occurring, is found in greater than normal concentrations.

Pollutants may be natural or man-made.

Contamination of our environment has increased to a point that it is a serious threat to the health and economic welfare of society.

In the past, man has depended on dilution and natural purification processes to control pollution.

Factors which contribute to the increasing contamination of the environment are the population explosion, the growth of industrial processes, the growth of large urban

## AREA 6 - ENVIRONMENTAL POLLUTION

### Standings Concepts

### Laboratory Experiences

### Supplementary Information

tant is a substance  
in the environment  
ormally is lacking,  
naturally occurring,  
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to control pollu-

which contribute  
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of the environment  
population explo-  
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processes, the  
f large urban

Natural pollutants include  
pollen, dust, silt, and  
microbes. Manmade pollu-  
tants include sewage, pesti-  
cides, industrial wastes,  
and automotive emissions.

The rate at which man adds  
pollutants to the environ-  
ment is so great that some  
authorities estimate that  
the total amount of pollu-  
tion in the world doubles  
every 10 years.

Man can no longer depend  
upon natural processes for  
pollution control.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

centers close to each other, and the desire for an ever higher standard of living.

The first important requirement of a pollution control program is an aroused community of informed citizens and officials.

Pollutants may be found in water, in air, and/or on land. A particular activity of man may cause pollution in all three areas.

II. Water

A. Water supply

Man obtains most of his water from surface water and ground water.

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Laboratory Experiences

Supplementary Information

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Discuss the role of the individual and of local, State, and Federal governments in controlling pollution.

Legislators, lawyers, public health officials, and sanitary engineers are good resource people for class visitations, either in person or via tape.

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People in their daily living activities add pollutants to the environment when they drive automobiles, heat their homes, discharge sewage, dispose of refuse, etc.

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Surface water includes lakes, rivers, streams, and reservoirs. Ground water is water naturally found beneath the surface of the earth.

## Topical Outline

## Understandings and Concepts

## Laboratory Experiences

The total amount of water on earth remains relatively constant. Water is continually circulating through a cycle of precipitation, runoff, infiltration, storage, evaporation, and reprecipitation called the water cycle.

A terrarium can be used to illustrate the natural water cycle. If a terrarium is unavailable, a sealed plastic bag containing a little water can be used to show the processes of evaporation and condensation.

The water from a major river can be used many times as it flows from the source of the river to its mouth. The only practical solution to a shortage of fresh water is more reuse of the same water.

When water from precipitation and "returned" ground water are not added to the water table at the same rate that they are removed, the depth of water in the table decreases and a water shortage may occur.

### B. Naturally occurring substances in the water supply

#### 1. Rainwater

Naturally occurring substances found in rainwater include fine particles of salt, dust, and smoke which served as condensation nuclei. The

### Laboratory Experiences

### Supplementary Information

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A terrarium can be used to illustrate the natural water cycle. If a terrarium is unavailable, a sealed plastic bag containing a little water can be used to show the processes of evaporation and condensation.

The demand for fresh water has been increasing. Some surveys indicate a shortage of fresh water in the future. The population of the United States increased two and one-half times from 1900 to 1960, but the use of water per day increased four times for the general population, seven times for agriculture, and eleven times for industry.

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The lowering of the water table in some parts of the country is a matter of great concern.

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may occur.

Traces of ozone, nitrogen oxides, argon, sulfur dioxide, ammonia, and other gases may be present in rainwater.

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Topical Outline

Understandings  
and Concepts

Laboratory Experience

2. Ground water

principal gases from the air dissolved in rainwater are oxygen, nitrogen, and carbon dioxide.

Most rainwater is weakly acidic because of the carbon dioxide dissolved in it.

When weakly acidic rainwater falls upon the earth, more carbon dioxide is taken up as the water infiltrates the soil, flows in streams, and/or is stored. Substances that dissolve in weak acids are leached by the ground water. This reduces the acidity and increases the concentration of minerals in the water.

Water containing ions of calcium, magnesium, and/or iron is called hard water.

Hard water renders soap ineffective as a cleaning agent.

Test the pH of rainwater.

Test the pH of ground water.

Compare the number of drops of "standard" soap solution needed to produce suds in samples of water from different sources.

Soap solutions can be "standardized" by comparing the number of drops needed to produce suds in distilled water.

Laboratory Experiences

Supplementary Information

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Test the pH of rainwater.

Test the pH of ground water.

Compare the number of drops of "standard" soap solution needed to produce suds in samples of water from different sources.

Soap solutions can be "standardized" by comparing the number of drops needed to produce suds in distilled water.

The pH value of rainwater ranges from 5.5 to 6.0.

Ground water containing weak alkaline materials may have a pH range of 8.0 to 8.5.

The number of drops of standard soap solution necessary to produce suds is a rough measure of the degree of hardness in water.

*Students may encounter the unit parts per million (p.p.m.). The unit is used to express small concentrations of substances in water without using fractions.*

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory E</u>
C. Water pollutants		Evaporate water from different sources, compare the amount of residue. Ignite residues. In residues will be organic residues.
1. Sewage	Sewage is water carrying human, animal, or organic wastes from homes, industrial establishments, or other places.	Demonstrate the ability to conduct electricity in measuring the conduction of dissolved substances.
	Sewage contains human and animal body discharges, household wastes, street washings, ground water, infiltration, and industrial wastes.	A 6.01 may be used to detect oil in washings.
	Bacterial action causes the decomposition of organic matter.	

### Laboratory Experiences

Evaporate water from different sources and compare the amount of residue. Ignite the residues. Inorganic residues will not char. Organic residues will char.

Demonstrate that the ability to conduct electricity is a way of measuring the concentration of dissolved minerals.

### Supplementary Information

$1.0 \text{ p.p.m.} = 1 \text{ mg./liter}$   
 $1 \text{ liter water} = 1,000,000 \text{ mg. water}$   
 $1 \text{ p.p.m.} = 1 \text{ mg./1,000,000 mg. water}$

Fresh sewage is a turbid liquid containing organic and inorganic "solids" which may be dissolved, suspended, or floating.

Organic solids include animal and plant waste products, dead animal matter, plant tissue, and synthetic organic materials such as soaps, detergents, frothing agents, and grease.

Inorganic matter in sewage includes sand, grit, gravel, silt, and mineral salts.

The bacteria may use organic matter for food and decompose it into simpler substances.

A 6.01 may be used to detect oil in street washings.

Topical Outline

Understandings  
and Concepts

Laboratory Exper

Aerobic bacteria require dissolved oxygen for their metabolism whereas anaerobic bacteria do not require oxygen.

As the concentration of aerobic bacteria increases, the amount of oxygen used by the bacteria increases, and the amount of available dissolved oxygen in the water decreases.

Decomposition products from aerobic bacteria do not give the water an offensive appearance or putrid odor.

As aerobic decomposition proceeds, the dissolved oxygen level may decrease to a point where anaerobic conditions develop.

The anaerobic decomposition forms a dark, putrid smelling sludge.

The determination of dissolved oxygen involves a simple titration as described

An aquarium in which a large amount of decomposing matter is present may be used to illustrate the formation of malodorous gases.

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Laboratory Experiences

Supplementary Information

The determination of dissolved oxygen (DO) involves a simple titration as described in A 6.02.

Low oxygen content can kill fish and other plant and animal life.

An aquarium in which a large amount of decaying matter is present may be used to illustrate that malodorous gases are formed.

H<sub>2</sub>S, a decomposition product, may be responsible for the putrid odor present during the anaerobic stage.

Topical Outline

Understandings  
and Concepts

Laboratory

Biochemical oxygen demand (BOD) refers to the quantity of dissolved oxygen utilized in the biochemical oxidation of organic matter in a specified time and at a specified temperature. It is a measure of the organic matter in waste waters which will undergo decomposition by microorganisms.

The 5-day BOD described in

Other organisms in addition to bacteria may remove dissolved oxygen from water. Also, certain chemical wastes discharged into water will undergo reactions removing oxygen from water. A high BOD test for a sample of water indicates that sewage may be present in the water, but it is not conclusive proof.

2. Infectious agents

Sewage contains many microorganisms which may include pathogenic bacteria and viruses from infected hosts. These may enter the sewage by way of intestinal body wastes.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information:

Chemical oxygen demand  
refers to the quantity  
of dissolved oxygen  
consumed in the biochemical  
oxidation of organic  
matter in a specified  
volume and at a specified  
temperature. It is a  
measure of the organic  
matter in waste waters  
which will undergo de-  
composition by micro-  
organisms.

The 5-day BOD test is  
described in A 6.03.

The BOD test is one of the  
principal tests applied to  
sewage. Generally, a  
sample of water is taken  
and its dissolved oxygen  
content immediately  
determined. Another sample  
of the water is taken at  
the same time, sealed, and  
held at 20° C. for 5 days.  
After the fifth day, its  
dissolved oxygen content  
is determined. The decrease  
in dissolved oxygen is  
called the biochemical  
oxygen demand for the 5  
days; the BOD is expressed  
in mg./l (p.p.m.) of sample.  
When a 5-day BOD test is  
made on polluted water, it  
is usually necessary to  
dilute the sample being  
tested to prevent all of  
the oxygen in the sealed  
sample from being used up  
before the end of the test.

Microorganisms in addition  
to bacteria may remove  
dissolved oxygen from  
water. Also, certain  
chemical wastes dis-  
solved into water will  
undergo reactions removing  
oxygen from water. A high  
BOD test for a sample of  
water indicates that  
oxygen may be present in  
the water, but it is not  
conclusive proof.

Parasitic bacteria which  
produce toxic or poisonous  
compounds that can cause  
diseases in the host are  
known as pathogenic  
bacteria.

Water which contains many micro-  
organisms which may in-  
clude pathogenic bacteria  
and viruses from infected  
individuals. These may enter  
sewage by way of in-  
dividual body wastes.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

An index for aquatic pollution is the concentration of E. coli, a nonpathogenic bacterium of the intestine.

Standards for public water supplies have been set by the U.S. Public Health Service. These standards provide definite minimums as to the number of samples examined and also the maximum number of coliform organisms allowable per 100 ml. of water.

Kits are commercially available that include materials and instructions for finding a coliform count by the membrane filter technique.

## Laboratory Experiences

Kits are commercially available that include materials and instructions for finding a coliform count by the membrane filter technique.

## Supplementary Information

Typhoid fever, endemic diarrhea, dysentery, and infectious hepatitis may be transmitted by a water supply polluted by improperly treated sewage.

Pathogenic bacteria are difficult to detect but are often intestinal associates of *E. coli*. The assumption is that as long as *E. coli* are present, there is a chance that some pathogenic bacteria are also present.

**Warning! Handle all bacterial cultures as if the organisms they contain are pathogenic. Incinerate them promptly after use.**

The threat posed by infectious agents to human health is reflected in numerous beach closings across the country. In 1967, out of 83 beaches along the southern shore of Lake Erie, 27 were unsafe for swimming for the whole season, and 28 only periodically safe.

Topical Outline

3. Heat

Understandings  
and Concepts

Heat is added to a waterway as water from industrial cooling processes is returned to the waterway at a higher temperature.

Increasing the temperature of a waterway is known as thermal pollution.

As the temperature of a waterway increases, the maximum content of dissolved oxygen decreases.

Heat affects the life processes of organisms living in water and interferes with the decomposition of wastes.

Laboratory Experi

Let a glass of cold set overnight. Observe the bubbles that come on the glass as some of the dissolved gases come out of solution because of the increased temperature of the water.

Have students find the level of samples of at different temperatures and compare their results with figures listed in solubility tables found in reference books.

standings  
concepts

Laboratory Experiences

Supplementary Information

added to a water-  
ter from indus-  
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temperature of a  
increases, the  
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Let a glass of cold water  
set overnight. Observe  
the bubbles that collect  
on the glass as some of  
the dissolved gases come  
out of solution because  
of the increased tempera-  
ture of the water.

Have students find the DO  
level of samples of water  
at different temperatures  
and compare their results  
with figures listed in  
solubility tables found in  
reference books.

ffects the life  
of organisms  
water and in-  
with the decom-  
of wastes.

Large quantities of fresh  
water are used for cooling  
by the Nation's industries.

Major contributors to  
thermal pollution are steel  
plants, fossil-fuel  
electrical plants, and  
nuclear reactors.

The growth of most algae  
is increased by an increase  
in the temperature of the  
water.

Some game fish can survive  
only in cool streams; if  
the stream temperature is  
raised, these die off and  
are replaced by less  
desirable species.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

4. Sediments

Silt, mud, and dust have always been water and air pollutants.

A 6.04 describes the settleable solids test.

By exposing the surface of the earth to erosion, man has become responsible for increasing the siltation of waterways.

The oldest and largest bulk pollutant is silt.

Silt can eventually destroy a water course. Silt can also affect the types of life in the water.

Evaporate and ignite the residue from silty water to show silt is mostly inorganic matter.

5. Radioactive substances

Most radioactive wastes produced are associated with the production of electricity by nuclear reactors.

The total quantity of radioactive wastes produced yearly is increasing.

High-level radioactive wastes which are considered too dangerous to be released to the environment are concentrated and stored for long periods of time before disposal.

Understandings  
and Concepts

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been water and air  
carriers.

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earth to erosion, man  
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transportant is silt.

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electricity by nuclear  
reactors.

Total quantity of  
radioactive wastes produced  
worldwide is increasing.

High level radioactive  
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turned to the environment  
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stored for long periods of  
time before disposal.

Laboratory Experiences

A 6.04 describes the  
settling solids test.

Evaporate and ignite the  
residue from silty water  
to show silt is mostly  
inorganic matter.

Supplementary Information

During the thirties,  
American farms annually  
lost half a million acres  
of topsoil from wind and  
water erosion in the Dust  
Bowl. Similar losses have  
occurred in the world as a  
result of exposing savannas  
and jungles to erosion.

An excess of silt causes  
fish to die.

The mining, milling, and  
preparation of fuel for  
reactors and weapons produce  
wastes containing natural  
radioisotopes.

Irradiation within the  
reactor produces wastes  
rich in fission products.

The necessity of storing  
radioactive liquid wastes  
in tanks for hundreds of  
years has led planners with-  
in industry to consider con-  
verting these wastes into  
solids for burial. Possible  
burial sites include salt  
mines and spaces cut deep  
into bedrock.

Topical Outline

Understandings  
and Concepts

Laboratory Ex

Radioactive wastes of low activity are released directly into the air or into waterways. These processes are carefully controlled.

Radioisotopes are released into the environment by fallout from nuclear tests conducted in the atmosphere. These fallout products can be concentrated by plants and animals in food chains.

Exposure to radiation from radioisotopes ingested into the body is much more dangerous than exposure to radiation outside the body.

Detergents, fertilizers, insecticides, pesticides, and other industrial chemical wastes are appearing in our water sources.

Samples of soil leached by water examined for radioactivity background level A 7.21.

Irradiated seeds purchased and examined for the irradiation of the seeds examined A 7.20.

Compare the rate of evaporation by evaporating samples taken from drinking sources that are naturally polluted or heavily polluted. Ignite the residue and test for the presence of organic and inorganic matter.

6. Minerals and chemical substances

Standings  
Concepts

Laboratory Experiences

Supplementary Information

toxic wastes of low activity are released into the air or waterways. These wastes are carefully handled.

Radioisotopes are released into the environment by fallout from nuclear tests conducted in the atmosphere. These fallout products can be concentrated by plants and animals in food chains.

Exposure to radiation from radioisotopes ingested into the body is much more serious than exposure to radiation outside the body.

Residues of pesticides, fertilizers, herbicides, and other industrial wastes are found in our water supply.

Samples of soil can be leached by water and the water examined for levels of radioactivity above background levels. See A 7.21.

Irradiated seeds can be purchased and the effects of the irradiation upon the seeds examined. See A 7.20.

Compare the residues left by evaporation of water samples taken from a drinking source, a moderately polluted stream, and a heavily polluted stream. Ignite the residues to test for the presence of organic and inorganic matter.

In a study of the lichen-caribou-Eskimo food chain, the concentration of radioactive cesium-137 was six times greater in the Eskimo than in the lichen.

Reindeer moss concentrates radioisotopes from fallout which, in turn, are transferred to reindeer as they graze. In 1965, it was reported that Laplanders, who eat reindeer, had reached the highest radiation exposures of any population.

Topical Outline

Understandings  
and Concepts

Laboratory Expe

Stable chemicals may build up to a concentration which is harmful to man when he drinks the water.

Plants and animals may concentrate chemicals in their tissues. When man uses the plants for food, he ingests the chemicals in harmful quantities.

Some chemicals change the pH of water and may affect the growth of organisms in the water or the corrosiveness of the water.

Compare the corrosion of iron nail by distilled water and by water sample of low or high pH value.

Chemicals which can be decomposed by bacteria are known as soft or biodegradable substances.

a. Plant nutrients

Agricultural chemicals are washed or leached off farm land into waterways.

Chemicals may accelerate the growth of some organisms and upset the balance of nature.

Eutrophication is the aging of a lake from an aquatic condition to a semiterrestrial or fully terrestrial state. This aging process

Laboratory Experiences

Supplementary Information

The dangers from many chemicals lie in their cumulative effect.

Dangerous concentrations of mercury and fluoride compounds from industrial wastes and pesticides have been found in aquatic organisms.

Compare the corrosion of a nail by distilled water, and by water samples having low or high pH values.

Phosphate fertilizer washed into a water course may accelerate the growth of algae. The growth of the algae upsets the balance of nature to the extent that a pond may be destroyed or a beach ruined.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

is largely a result of enrichment by nutrients.

In many bodies of water, the natural process of eutrophication has been accelerated to a considerable degree by pollution.

b. Pesticides

For many years, large quantities of pesticides have been used in agriculture. Some of these are extremely harmful to man, if ingested. Many are nonbiodegradable. These pesticides leach into the ground and wash into waterways. Like the radioactive pollutants, they can be concentrated in food chains.

Varying amounts of some pesticides have been found widespread in water supplies.

Some pesticides contain fluorine and yield fluoride ions after degradation.

Activities involving layer chromatography detection of some of insecticides and pesticides are described in the chromatography texts in Appendix B under A

A test for the fluorination is described in A

Laboratory Experiences

Supplementary Information

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Activities involving thin layer chromatography for detection of some of the insecticides and pesticides are described in the chromatography texts listed in Appendix B under Area 8.

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Adult trout in Lake George showed a high concentration of DDT. It did not kill the adult fish, but it did halt reproduction (many eggs did not hatch, and, if they did, the fish did not live beyond the fry stage).

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A test for the fluoride ion is described in A 6.05.

The long-range effects of pesticides upon the health of the general population is being investigated by public health authorities.

Topical Outline

Understandings  
and Concepts

Laboratory Exper

Pesticides vary in their degree of toxicity and in their biodegradability. In general, the chlorinated pesticides are most resistant to biodegradation and are highly toxic to aquatic life. The organic pesticides that contain phosphorus are less toxic to aquatic life and are more biodegradable. The carbamate group is noted for low toxicity to aquatic life and high biodegradability.

c. Industrial chemicals

Acids, bases, and sulfur compounds are among the industrial chemicals that contaminate waterways.

Determine the DO of a sample of water. add a small amount  $\text{Na}_2\text{SO}_3$  (a chemical might appear in industrial wastes). Stir, and determine the DO content of the water again. Note the lower DO value due to the oxidation of sulfite.

Organisms are sensitive to changes in pH.

Germinate seeds (See A 7.20) in solutions of varying pH. Soak the seeds first, and then keep them moistened with weak solutions of vinegar or household ammonia cleaner. Compare the rate of germination and the growth of the seedlings with a group of controls.

Standings  
Concepts

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biodegradability.  
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chemicals that  
ate waterways.

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es in pH.

Laboratory Experiences

Determine the DO content of a sample of water. Then add a small amount of  $\text{Na}_2\text{SO}_3$  (a chemical which might appear in industrial wastes). Stir, and determine the DO content of the water again. Note the lower DO value due to the oxidation of sulfite ions.

Germinate seeds (See A 7.20) in solutions of varying pH. Soak them first, and then keep them moistened with weak solutions of vinegar or household ammonia cleaner. Compare the rate of germination and the growth of seedlings with a group of controls.

Supplementary Information

Pesticides are grouped into three categories: inorganic, natural organic, and synthetic organic compounds. Major types of synthetic organics are those that contain:

- chlorine (DDT, endrin, lindane)
- phosphorus (parathion, malathion)
- carbamate (captan, sevin, ferbam).

Industrial chemicals may be added directly to the waterway or indirectly through the community sewage system.

Other chemical pollutants include preservatives, anti-oxidants, thickeners, thinners, moisteners, emulsifiers, and coloring agents.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

d. Salt water

Sea water seeps inland when the ground water removed from the soil exceeds the amount replaced by precipitation.

Small amounts of salts carried in water may accumulate on land due to continual evaporation and cause serious losses in agricultural productivity.

Try to germinate seeds using a saline solution that approximates the concentration of sea water.

e. Detergents

A major problem with detergents as pollutants is that their phosphate content is thought to hasten eutrophication of waterways.

A 6.06 may be used to illustrate the effect of detergents on algal growth.

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### Laboratory Experiences

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Try to germinate seeds using a saline solution that approximates the concentration of sea water.

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A 6.06 may be used to illustrate the effect of detergents on algal growth.

### Supplementary Information

During a recent drought period, the water supply in parts of Long Island was contaminated with salt water.

If sufficient precipitation occurs, enough fresh water will soak into the ground so that the net flow through the ground toward the sea prevents the entry of sea water into the ground reservoir.

Excessive irrigation practices may lead to high concentrations of salt if the irrigation water is lost primarily by evaporation rather than by percolation into the soil.

The first detergents were branched chain benzene sulfonates. The bacteria would "eat" the chain until the branch was met. Then the bacterial action would stop. Since the remaining chains were sufficiently long to keep the detergent properties, the "sudsing" effect was noticeable in the water supply.

All detergents manufactured today are biodegradable.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

f. Oil

A pollutant of our waterways and oceans is oil.

Accidents at sea may cause oil pollution.

Oil will not sink nor dissolve in water.

Crude oil slicks cannot be destroyed by fire.

Demonstrate the immiscibility of oil and water.

Pour a little heavy motor oil representing crude oil over some water in a beaker, and show that it will not continue to burn when set on fire.

D. Self-purification

Water can "purify itself" of natural pollutants.

Self-purification is dependent upon time, temperature, oxygen supply, and other environmental factors which regulate biological growth.

Laboratory Experiences

Supplementary Information

Certain concentrations of alkyl benzene sulfonate have been found to kill mayfly larvae and reduce shrimp and crayfish populations.

Outboard engines discharge oily exhausts into waterways; oil tankers often pump their sludge overboard.

The Liberian oil tanker, Torrey Canyon, in March of 1967, lost most of her 36 million gallons of oil into the sea. Fish and sea birds died by the thousands and resort beaches were contaminated.

Some waterways are so heavily polluted that natural purification processes are unable to produce clear water.

Demonstrate the immiscibility of oil and water.

Pour a little heavy motor oil representing crude oil over some water in a beaker, and show that it will not continue to burn when set on fire.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

Self-purification of a stream is generally considered to take place in four stages with the stream divided into four zones which merge into each other.

1. Degradation

The zone of degradation occurs immediately below the point of pollution. The dissolved oxygen in the water decreases. Aerobic decomposition of sewage is prevalent.

2. Decomposition

The zone of decomposition is characterized by anaerobic decomposition. Dissolved oxygen is very low and may reach zero.

3. Recovery

In the zone of recovery, the dissolved oxygen increases, and the number of microorganisms in the stream decreases.

4. Clean water

In the clean water zone, the decomposition of organic solids is mostly complete. Oxygen is at or near the saturation point.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

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When a heavy load of sewage is received, the stages of purification may require many miles of streambed before the process is complete.

In the zone of degradation, the stream becomes turbid with visible floating and suspended solids. The fish life decreases.

In the zone of decomposition, foul odors are produced as products of the anaerobic decomposition. Fish life is absent. If the pollution load of the stream is light enough, this stage of self-purification may not appear.

In the zone of recovery, the number of bacteria decreases as conditions for rapid growth become less favorable.

Topical Outline

E. Water treatment

Understandings  
and Concepts

The methods used in the treatment of water depend, to a large extent, upon the purpose for which the water is to be used.

Most of the water treatment processes may be applied to sewage treatment.

All water treatment plants, whether designed to remove sewage or produce potable water, have devices to remove or cut up the larger suspended or floating materials.

Primary treatment for sewage involves the removal of suspended solids by the physical process of sedimentation in settling tanks. Chemicals may be added which improve the sedimentation process.

In secondary treatment plants, the water containing sewage remaining after primary treatment is pumped to "trickling filters" where biochemical decomposition occurs.

Laboratory Expe

Field trips to the water and/or sewage treatment plants can provide useful learning experiences for pupils.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

used in the  
of water depend,  
extent, upon  
for which the  
be used.

Field trips to the local  
water and/or sewage treat-  
ment plants can provide a  
useful learning experience  
for pupils.

A representative of the  
Public Health Service,  
water works, or sewage  
plant is usually available  
to talk with the pupils at  
school.

water treat-  
ment may be  
sewage treat-

treatment plants,  
designed to re-  
duce or produce  
effluent, have de-  
veloped or cut up  
suspended or  
colloidal materials.

In preliminary treatment,  
some devices in common use  
are screens, grinders, and  
grit chambers.

treatment for  
removes the re-  
suspended solids  
chemical process  
sedimentation in set-  
tling tanks  
Chemicals  
which improve  
sedimentation process.

Physical separation by sedi-  
mentation removes 40-60  
percent of the suspended  
solids. If chemicals are  
added, 80-90 percent of the  
suspended solids are re-  
moved. Primary treatment  
may reduce the BOD by 25 to  
30 percent.

primary treatment  
water con-  
tent remaining  
secondary treatment  
"trickling  
filter" where biochemical  
oxidation occurs.

Secondary treatment is com-  
parable to the zone of re-  
covery in the self-purifica-  
tion of a stream. Bacterial  
films form on the surfaces  
of the rocks or tiles used  
in the "trickling filter,"  
and it is there that the de-  
composition takes place.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

1. Aeration

Tertiary treatment plants improve still more the effluent before discharge.

Aeration is the spraying of water into the air.

Aeration introduces oxygen into the water, permits the escape of dissolved gases such as  $\text{CO}_2$  and  $\text{H}_2\text{S}$ , and removes volatile substances which may cause undesirable taste and odor.

Use A 6.07 to show that aeration increases the amount of dissolved air in water.

Add a few drops of universal indicator to some carbonated soda water. Bubble air through the water or pour it from one container to another so  $\text{CO}_2$  can escape. Note the effect on the pH as  $\text{CO}_2$  escapes.

2. Adsorption of gases

Activated charcoal has the ability to adsorb great quantities of gases and volatile liquids to its surface.

Use A 6.08 to illustrate removing odors by adsorption.

3. Coagulation and sedimentation

Suspended particles that are more dense than water and large enough to be affected by the pull of gravity will settle upon standing.

Use the Tyndall effect to show the presence of colloidal materials in tap water.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Secondary treatment plants  
are still more the  
rule than the exception before discharge.

One method is the spraying  
of water into the air.

Aeration introduces oxygen  
into the water, permits  
escape of dissolved  
gases such as  $\text{CO}_2$  and  $\text{H}_2\text{S}$ ,  
removes volatile  
compounds which may cause  
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amount of dissolved air in  
water.

Add a few drops of uni-  
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carbonated soda water.  
Bubble air through the  
water or pour it from one  
container to another so  
 $\text{CO}_2$  can escape. Note the  
effect on the pH as  $\text{CO}_2$   
escapes.

Use A 6.08 to illustrate  
removing odors by adsorp-  
tion.

Use the Tyndall effect to  
show the presence of  
colloidal materials in tap  
water.

Some tertiary plants re-  
move nutrients when algal  
growth in the discharge  
water is a particular prob-  
lem.

Aeration may be a process  
used in any sewage treat-  
ment plant.

Reducing the  $\text{CO}_2$  content  
reduces the corrosive  
tendency of water.

Control of taste and color  
by aeration is limited.

Charcoal is used in fish  
tanks as well as municipal  
water supplies to remove  
dissolved gases. In both  
cases, aeration must follow  
to replace the oxygen re-  
moved along with the other  
gases.

Colloidal particles will  
not settle readily on  
standing.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

4. Chlorination

Chlorine may be added to water for the purpose of disinfection.

As water is reused on an increasing scale, the variety and concentration of contaminants in the water supply which are not affected by chlorination increases.

Chlorine may be added to water in the form of a gas or in compounds such as calcium hypochlorite or sodium hypochlorite.

Water with high pH value is difficult to disinfect.

Prepare colloidal suspensions containing varying amounts of clay. Show that the amount of coagulant necessary to remove the suspended material depends upon the turbidity.

Use suspensions of equal turbidity, but varying pH, to show that the amount of coagulant required depends upon the pH of the suspension.

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Laboratory Experiences

Prepare colloidal sus-  
pensions containing varying  
amounts of clay. Show  
that the amount of coagu-  
lant necessary to remove  
the suspended material  
depends upon the turbidity.

Use suspensions of equal  
turbidity, but varying pH,  
to show that the amount  
of coagulant required de-  
pends upon the pH of the  
suspension.

Supplementary Information

Electrolytes and coagulants,  
such as aluminum sulfate,  
may be used to coagulate  
particles so they settle  
or can be filtered out of  
the suspension.

Disinfection is the killing  
of the larger portion of the  
harmful and objectional  
microorganisms in, or on,  
a medium.

Some public health authori-  
ties suspect that contami-  
nants in drinking water which  
are not affected by chlorina-  
tion may have long-range  
effects upon the population.

Chlorine combines with water  
to form hypochlorous and  
hydrochloric acids. When  
dissolved in water, hypo-  
chlorites yield hypochlorite  
ions.

Hypochlorous acid disso-  
ciates at pH levels below  
6.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

Chlorine reacts with many compounds in sewage. Little disinfection results from this action. The amount of chlorine used by both organic and inorganic substances is defined as the chlorine demand.

Disinfection is caused mostly by the amount of chlorine remaining (residual chlorine) after the chlorine demand has been satisfied.

Determination of residual chlorine by titration described in A 6.09 colorimetric method described in the Standard Methods text listed in the bibliography.

5. Water softening

Minerals causing hardness in water are removed by using precipitation or ion-exchange methods to remove  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$ .

Precipitation is achieved by the use of lime ( $\text{CaO}$ ) or ( $\text{Na}_2\text{CO}_3$ ).

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Laboratory Experiences

Supplementary Information

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chlorine

Nitrates, manganese, iron,  
and  $H_2S$  react with and re-  
move chlorine. Ammonia  
reacts with chlorine to  
form chloramines, which  
have less disinfecting  
qualities than free chlorine.

is caused  
amount of  
ining (resid-  
) after the  
nd has been

Determination of residual  
chlorine by titration is  
described in A 6.09. A  
colorimetric method is de-  
scribed in the Standard  
Methods text listed in  
the bibliography.

Chlorine may destroy bac-  
terial cells directly or  
kill bacteria indirectly by  
inactivating their enzymes.

The temperature of the  
water and the length of time  
 $Cl_2$  remains in the water  
affect the disinfecting  
reaction rate.

ing hardness  
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tation or  
methods to  
nd  $Mg^{++}$ .

The ion-exchange method has  
become the primary treat-  
ment.

is achieved  
lime ( $CaO$ )

Lime reacts with  $Ca(HCO_3)_2$   
and  $Mg(HCO_3)_2$  to produce  
insoluble carbonates.

Soda ash is anhydrous  
sodium carbonate. It reacts  
with  $Ca^{++}$  and  $Mg^{++}$  to form  
insoluble carbonates.

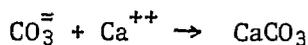
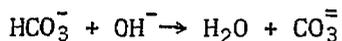
Topical Outline

Understandings  
and Concepts

Laboratory Experiences

The buildup of scale from hard water in hot water pipes and boilers is a problem of both homeowners and industrial firms.

A base or basic salt, such as borax or trisodium phosphate, can be used for the precipitation of the metallic bicarbonates from hard water:



Ion-exchange materials replace the calcium and magnesium ions by other cations that do not affect the cleansing action of soap.

In the laboratory, mixtures of acid-exchange resins and base-exchange resins may be used to remove metallic and non-metallic ions from water to produce demineralized water.

### Laboratory Experiences

### Supplementary Information

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water  
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Homeowners who use hard water spend more money for soap per year than if their water were soft.

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CO<sub>3</sub>

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action

In the laboratory, mixtures of acid-exchange resins and base-exchange resins may be used to remove metallic and non-metallic ions from water to produce demineralized water.

Home water softeners generally use zeolite or Permutit to replace the calcium and magnesium ions by sodium ions. The zeolite or Permutit softeners can be recharged by flushing with a solution of sodium chloride.

An ion-exchange substance may be either a complex sodium-silico-aluminate or an organic polymer resin which replaces calcium and magnesium ions with sodium or hydrogen ions that do not affect the cleansing action of soap.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

III. Air

A. Composition  
of the air

Under "normal conditions" the atmosphere is composed of approximately 79 percent nitrogen, 20 percent oxygen, and 1 percent of a variety of gases including water vapor, carbon dioxide, and inert gases.

B. Causes of air  
pollution

Most air pollution results from combustion, vaporization, or division of matter into small particles which are emitted as dusts and mists.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

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roximately  
itrogen, 20  
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riety of gases  
ter vapor,  
de, and inert

lution results  
ion, vaporiza-  
ision of  
small parti-  
re emitted as  
sts.

The high sodium content of some water softened by deionization may be a health problem for some people.

Since air is a mixture, its percentage composition is not fixed.

A major source of pollution is the burning of fuels to produce electricity, steam, energy for propelling vehicles, and heat to warm buildings and carry on industrial processes.

Many industries produce vapors from the evaporation of solvents and fumes from manufacturing and refining processes.

Industries which crush, grind, mix, cut, and spray materials almost always emit clouds of dust or mist into the air.

Topical Outline

Understandings  
and Concepts

Laboratory

C. Some major  
air polluters

1. Industry

Our industrial complex is  
an important source of  
air pollution.

2. Internal  
combustion  
engines

Air pollution from auto-  
mobiles, trucks, and buses  
creates the most serious  
air pollution problems for  
many cities.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

ur industrial complex is  
an important source of  
air pollution.

air pollution from auto-  
mobiles, trucks, and buses  
creates the most serious  
air pollution problems for  
many cities.

Steam generating plants;  
quarries and cement plants;  
metal-fabricating, chemical,  
and petrochemical plants;  
and refineries are among  
the industrial facilities  
which produce air pollu-  
tion.

The number of motor vehicles  
in this country is in-  
creasing at a faster rate  
than the population. In  
addition to water and  
carbon dioxide, when 1,000  
gallons of gasoline are  
burned in the average auto-  
mobile, about 3,200 pounds of  
carbon monoxide, 200 to  
400 pounds of hydrocarbons,  
25 to 75 pounds of oxides  
of nitrogen, 18 pounds of  
aldehydes, and 17 pounds  
of oxides of sulfur are  
produced. Ozone and lead  
compounds are also produced.  
Altogether, some 150  
chemicals have been found  
in automobile exhaust,  
including benzopyrene, a  
potent cancer-producing  
agent.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Expe</u>
3. Furnaces and incinerators	Householders add to air pollution when they heat their homes and burn rubbish and leaves in backyard incinerators.	
D. Air pollutants	A number of air sampling stations have been established throughout the country to sample and measure air pollutants.	For the effect of pollution on nylon A 6.10.
1. Solids	Solids such as dust, metal particles, and ashes are air pollutants.	Use the fume hood to treat the character of a smoke tested A 6.11.
	The smoke coming from an industrial or home chimney or burning cigarette, cigar, or pipe is a colloidal dispersion of a solid in a gas. There may be other products in addition to the solids in the smoke from these sources.	Observe dust particles in air by using A 6.12. Investigating the density of air is described in A 6.13. Collection of wind-blown particles is described in A 6.14. The amount of dust at a location may be measured. See A 6.15.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

holders add to air pollution when they heat homes and burn rubbish and leaves in back-incinerators.

Number of air sampling stations have been established throughout the country to sample and measure air pollutants.

Substances such as dust, metal particles, and ashes are air pollutants.

Smoke coming from an industrial or home chimney, burning cigarette, pipe, or pipe is a collection of dispersion of a substance in a gas. There are other products in addition to the solids in smoke from these sources.

For the effect of air pollution on nylon, see A 6.10.

Use the fume hood to illustrate the characteristics of a smoke tested in A 6.11.

Observe dust particles in air by using A 6.12.

Investigating the cleanliness of air is described in A 6.13.

Collection of windblown particles is described in A 6.14.

The amount of dustfall in a location may be measured. See A 6.15.

Smoking, as a personal source of air pollution, adds CO, hydrocarbons, oxides of nitrogen, and other compounds to the air.

Measured volumes of air are drawn through large filters which catch and hold solid particles and liquid droplets. Air is also drawn through solutions which absorb specific gases.

The burning of garbage, trash, and rubbish, and the burning of leaves in incinerators are prime sources of the fine suspended particles of dust, soot, and other solids in air.

Suspended solids soil houses and clothing, and can irritate eyes.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

2. Liquids

Liquids such as hydrocarbons, oils, tars, and organic solvents pollute the air.

Use A 6.16 to illustrate pollution of the air.

Liquids may exist in air as aerosols.

A 6.17 can be used to illustrate the effect of pollution on plants.

An aerosol is a colloidal dispersion of a liquid in a gas.

3. Gases

Common gas pollutants of air are sulfur dioxide, carbon monoxide, hydrogen sulfide, oxides of nitrogen, hydrocarbons, carbon dioxide, and ozone.

a. Carbon monoxide

Carbon monoxide is produced by the incomplete combustion of a carbon fuel.

The laboratory burner can be used to illustrate complete and incomplete combustion.

Carbon monoxide reduces the oxygen-carrying capacity of the blood.

b. Oxides of nitrogen

Nitrogen oxides are produced by burning coal, oil, gasoline, and some rocket fuels.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Liquids such as hydrocarbons, oils, tars, and organic solvents pollute the air.

Use A 6.16 to illustrate pollution of the air.

Aerosol sprays, hydrocarbons in automobile exhaust and from dry cleaning plants, and evaporation of paint solvents are some of the sources of liquid pollutants. The exhaust of jet engines forms an oil aerosol.

Liquids may exist in air as aerosols.

A 6.17 can be used to point out the effect of oil pollution on plants.

While a colloidal suspension of a solid in a gas may be considered to be an aerosol, generally it is called a smoke.

An aerosol is a colloidal dispersion of a liquid in gas.

Common gas pollutants of air are sulfur dioxide, carbon monoxide, hydrogen sulfide, oxides of nitrogen, hydrocarbons, carbon dioxide, and ozone.

The laboratory burner can be used to illustrate complete and incomplete combustion.

Carbon monoxide is produced by the incomplete combustion of a carbon fuel.

Carbon monoxide reduces the oxygen-carrying capacity of the blood.

Nitrogen oxides are produced by burning coal, oil, gasoline, and some rocket fuels.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Nitrogen oxides contribute to smog formation.

Smogs are formed when there is a high production of pollutants and a stagnant air mass over the area for an extended period of time.

Smog formation is often associated with the occurrence of air inversions.

Smog products are irritating to the eyes and induce respiratory diseases.

c. Gaseous sulfur compounds

Gaseous sulfur compounds are produced by burning coal, oil, and leaves.

Details for constructing a temperature inversion apparatus can be found in the references listed in the bibliography.

See A 6.18 for a method measuring the content of SO<sub>2</sub> in the air.

A measure of the relative acidity of an air sample is described in A 6.19.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

ogen oxides contrib-  
to smog formation.

Photochemical pollution is  
a name given to smog for-  
mation. The sunlight causes  
a reaction between the  
oxides of nitrogen and  
hydrocarbons. The resulting  
products may be more harm-  
ful than the original pollu-  
tants.

are formed when there  
high production of  
tants and a stagnant  
mass over the area for  
extended period of time.

Details for constructing  
a temperature inversion  
apparatus can be found in  
references listed in the  
bibliography.

formation is often  
associated with the occur-  
rence of air inversions.

An air inversion occurs when  
colder air underlies warmer  
air and prevents normal  
convection currents from  
operating.

products are irri-  
tating to the eyes and in-  
respiratory diseases.

ous sulfur compounds  
produced by burning  
oil, and leaves.

See A 6.18 for a method of  
measuring the content of  
SO<sub>2</sub> in the air.

H<sub>2</sub>S and SO<sub>2</sub> can affect the  
paint on our homes. H<sub>2</sub>S  
is also 2 1/2 times as  
poisonous as CO and similar  
to HCN in the degree of  
toxicity.

A measure of the relative  
acidity of an air sample  
is described in A 6.19.

Topical Outline

Understandings  
and Concepts

Laboratory Expe

d. Hydrocarbons

Unburned hydrocarbons are found in the exhaust of vehicles.

E. Prevention of air pollution

The best method of preventing air pollution is to remove pollutants at their source and prevent their introduction into the air.

Solid particles can be made to settle from air by electrostatic methods.

For construction of electrostatic precipitator see A 6.20.

Low-boiling-point substances can be condensed by lowering their temperatures.

Pass steam through a condenser to illustrate condensation of a gas.

Pollutants with acid properties can be neutralized with bases.

Pollutants with basic properties can be neutralized with acids.

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Laboratory Experiences

Supplementary Information

rocarbons are  
exhaust of

Volatile hydrocarbons are components of fuels such as gasoline and diesel fuel. When spilled, these fuels evaporate quickly.

hod of pre-  
pollution is  
llutants at  
and prevent  
uction into

les can be  
le from air  
atic methods.

For construction of an electrostatic precipitator, see A 6.20.

The particles are given an electric charge and then are attracted to an oppositely charged plate.

point sub-  
be condensed  
their tempera-

Pass steam through a water condenser to illustrate condensation of a gas.

Sometimes a pressure change is used in addition to reduced temperature.

Mercury vapors which are dangerous to health are condensed by means of high condensing towers.

with acid prop-  
be neutralized

with basic prop-  
be neutralized

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Excess water vapor can be removed by deliquescent substances.

Use calcium chloride example of a deliquescent substance.

Soot can be burned completely to form  $\text{CO}_2$ .

Use A 6.21 to illustrate "after burning."

Soluble substances in the air can be removed by water and other solvents.

Gases can be adsorbed on activated charcoal.

Some automobiles are equipped to have greater air intake and/or exhaust recycling systems to help attain better combustion of the exhaust gases.

Fuels that have a lower sulfur content can be burned in specially designed burners.

Covering surfaces of volatile materials will cut down evaporation.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

er vapor can be  
deliquescent

Use calcium chloride as an  
example of a deliquescent  
substance.

e burned com-  
form CO<sub>2</sub>.

Use A 6.21 to illustrate  
"after burning."

It is an economic advantage  
to burn carbon fuels com-  
pletely.

stances in the  
removed by  
other solvents.

be adsorbed on  
charcoal.

biles are  
have greater  
and/or exhaust  
systems to help  
er combustion  
ust gases.

Pupils will probably be  
familiar with the federal  
requirements set for exhaust  
control on automobiles.  
Continual research is being  
done to improve or find  
a substitute for the in-  
ternal combustion engine.

have a lower  
ent can be  
pecially de-  
ers.

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ials will cut  
ation.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

IV. Land

Ashes, garbage, abandoned cars, septic tank residues, chemicals, and trash of all kinds are among the solid wastes which need continuous disposal.

See A 6.22 for an activity involving the biodegradability of solids.

The disposal of millions of tons of refuse each year is a problem which has increased with population growth.

The tendency for various industries to use single-use packaging techniques for their products has aggravated the refuse disposal problem.

A. Refuse disposal

1. Open dumps

Open dumping is the waste disposal method most commonly used today.

2. Sanitary landfills

Sanitary landfills are dumps where the refuse is added, compacted, and buried beneath a layer of earth.

dings  
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Laboratory Experiences

Supplementary Information

ge, abandoned  
tank resi-  
als, and trash  
are among the  
which need  
isposal.

See A 6.22 for an activity  
involving the biodegrad-  
ability of solids.

of millions  
refuse each year  
which has in-  
population

Most major cities of the  
world had no systematic  
refuse collection and dis-  
posal programs until well  
into the 19th century.

for various  
to use single-  
g techniques  
products has  
the refuse  
blem.

g is the waste  
thod most  
ed today.

Open dumps are unsightly,  
malodorous, and a breeding  
place for rodents and disease  
organisms. Because of these  
disadvantages, it is becoming  
increasingly difficult for  
municipalities to find new  
sites for dumps.

ndfills are  
the refuse is  
acted, and  
ath a layer of

Relatively few land dis-  
posal sites are sanitary  
landfills. An advantage of  
the sanitary landfill is  
that the land is reusable  
again for other purposes.

Topical Outline

3. Incineration

Understandings  
and Concepts

Incinerators are used by some of the larger cities to burn their refuse.

Laboratory Experiences

For an activity dealing with the problems of incineration, see A 6.23.

See A 6.24 for finding the scrap value of an aluminum can.

B. Prevention of  
land pollution

More extensive use of biodegradable, corrodible, and combustible substances for packaging would alleviate the land pollution problem.

Many materials now being abandoned can be recycled for further use. The extra cost to manufacture articles from reclaimed materials instead of from new ones is often small.

Findings  
Abstracts

are used by  
larger cities  
of refuse.

Laboratory Experiences

For an activity dealing  
with the problems of in-  
cineration, see A 6.23.

See A 6.24 for finding the  
scrap value of an aluminum  
can.

ive use of bio-  
corrodible, and  
substances  
g would alle-  
nd pollution

is now being  
n be recycled  
use. The  
o manufacture  
n reclaimed  
stead of from  
often small.

Supplementary Information

Incinerators require less  
room than open dumps but  
their emissions add to the  
problems of air pollution,  
and not all of the materials  
put into an incinerator can  
be burned.

Other methods of refuse dis-  
posal include feeding gar-  
bage to animals and using  
refuse for fill. Ecological-  
ly valuable wetlands near  
large cities are being  
destroyed by dumping. Much  
of San Francisco Bay has  
been filled in this way.  
Other large coastal cities  
load their refuse on barges  
for disposal at sea.

Desirable packaging alterna-  
tives may include the use  
of cellulose in place of  
nonbiodegradable wraps,  
rustable steel in place of  
aluminum for cans, and paper  
in place of foils.

Proposals have been made  
that a "user tax" be put  
upon manufactured products  
which could be used to sub-  
sidize recycling of their  
reusable materials. If this  
was adopted for automobiles  
alone, it would be more  
advantageous for the last

Topical Outline

Understandings  
and Concepts

Laboratory Experi

The practice of abandoning land after removal of a desirable resource should be avoided.

Since many pollutants affect the total environment, prevention of water and air pollution also helps prevent land pollution.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

practice of abandoning  
after removal of a  
valuable resource should  
be avoided.

owner of an auto to turn it  
in for scrap instead of  
abandoning it.

Years ago the lumber indus-  
try abandoned the "cut-and-  
slash" philosophy. Con-  
servatismists have urged  
that companies operating  
open pit and strip mines be  
required to restore the  
land they use to its orig-  
inal condition. Communi-  
ties should be urged to  
operate landfills instead  
of dumps for refuse dis-  
posal.

many pollutants  
in the total environ-  
ment. Prevention of water  
pollution also  
helps prevent land pollu-

## AREA 7 - SOME MODERN MATERIALS

The nature of many of the chemicals used in the preparation of polymers makes them unsafe for pupil use. Unless otherwise specified, all polymer preparations should be limited to teacher demonstrations carried out under a hood.

### Topical Outline

#### I. Polymers

### Understandings and Concepts

A polymer is a substance composed of many repeating units called monomers.

The process by which monomers are joined is called polymerization.

### Laboratory Experiences

Display some polymers and have pupils "classify" them. See A 7.01.

Use A 7.02 to obtain natural polymer casein from milk.

To demonstrate monomer forming polymers, join paper clips or safety pins to make a long chain.

Add other clips or pins to make side chains and cross-works.

## 7 - SOME MODERN MATERIALS

of many of the chemicals used in the preparation of polymers makes them suitable for pupil use. Unless otherwise stated, all polymer preparations should be carried out under a teacher demonstration cabinet or under a hood.

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s

### Laboratory Experiences

### Supplementary Information

Substance  
repeating  
units.

Display some polymers and have pupils "classify" them. See A 7.01.

There are many natural polymers produced by plants and animals.

Use A 7.02 to obtain the natural polymer casein from milk.

Starch, cellulose, and proteins are natural polymers.

There are many synthetic polymers.

Nylon, polyethylene, and Bakelite are examples of synthetic polymers.

Which mono-  
mers called

To demonstrate monomers forming polymers, join paper clips or safety pins to make a long chain.

Add other clips or pins to make side chains and networks.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

A plastics material can be described as an artificial material, usually an organic polymer, which at some time in the shaping process is a fluid.

A. Formation of polymers

Polymers may be formed by condensation or by addition reactions.

Understanding of the merization processes be developed by the stick models.

1. Condensation

A condensation reaction often results from the "splitting out" of a water molecule from monomer units so that the remaining structures bond together.

A 7.03 may be used to illustrate the condensation polymerization reaction.

Condensation polymers may undergo more condensations to produce longer chain molecules.

## Laboratory Experiences

## Supplementary Information

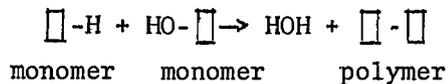
The term plastics has no strictly scientific definition. In most classifications rubber, metal, ceramic, wood, and leather are not considered to be plastics.

Understanding of the polymerization processes can be developed by the use of stick models.

A 7.03 may be used to illustrate the condensation polymerization reaction.

If water is "split out," a condensation reaction may also be known as a dehydration synthesis.

A condensation process may be visualized as:



Condensation polymers do not have the same percentage composition as their monomers.

The monomer of cellulose is glucose,  $C_6H_{12}O_6$ .

The polymer is  $C_6H_{11}O_5(C_6H_{10}O_5)_n C_6H_{11}O_6$

Each molecule may have from 2,000-9,000 glucose units.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

2. Addition

A catalyst may be used to speed up polymerization reactions. Other chemicals may be added to control the length of the chains.

An addition polymerization results from the joining of molecules of unsaturated compounds by "opening" double or triple bonds in the carbon chain.

A 7.04 can be used to illustrate the addition polymerization process.

B. Some representative polymers

1. Polyamides

A polyamide is a polymer obtained from substances containing amine and carboxyl groups.

A 4.09 deals with amide linkages.

Condensation occurs between the amine and carboxyl groups. The condensation polymer contains an amide linkage.

Understandings  
Concepts

Laboratory Experiences

Supplementary Information

It may be used to polymerization. Other chemicals added to control the length of the chains.

It is used in polymerization from the joining of molecules of unsaturated hydrocarbons by "opening" of double or triple bonds in the polymer chain.

It is a polymer formed from substances containing amine and carboxylic acid groups.

Condensation occurs between amine and carboxylic acid. The condensation product contains an amide linkage.

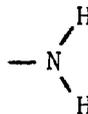
A 7.04 can be used to illustrate the addition polymerization process.

A 4.09 deals with amide linkages.

*Pupils will be expected to recognize a condensation reaction when illustrated by equations using structural formulas.*

The monomer of polyethylene is  $C_2H_4$ . The polymer is  $(C_2H_4)_n$ .

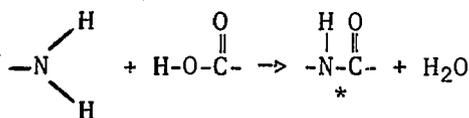
Amine group structure is represented by



The carboxylic group has the structure



Condensation resulting in an amide linkage is represented as



\*An amide linkage is a carbonyl-to-nitrogen bond.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
a. Proteins	<p>Proteins are polyamides formed by successive condensation of amino acids.</p> <p>An amino acid is an organic compound containing both an amine group (-NH<sub>2</sub>) and an organic acid (carboxyl) group (-COOH).</p> <p>Units of amino acids can function as an amine, as an acid, or as both.</p> <p>By forming amide linkages, amino acids polymerize to form proteins.</p> <p>Proteins are very large molecules.</p>	<p>Teachers can demonstrate the formation of nylon by the use of CH 7.18-b,</p>
b. Nylons	<p>Nylons are polyamide polymers formed by condensation reactions between diamines and dicarboxylic acids.</p>	<p>Teachers can demonstrate the formation of nylon by the use of CH 7.18-b,</p>
2. Phenolic plastics	<p>Phenolic plastics are made by condensation reactions between a phenol and an aldehyde.</p>	<p>A 7.03 involves the condensation between aldehyde and phenol models.</p>

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Laboratory Experiences

Supplementary Information

amides  
sive con-  
no acids.

an organic  
ing both  
-NH<sub>2</sub>) and  
(carboxyl)

acids can  
mine, as  
both.

linkages,  
merize to

y large

amide poly-  
condensation  
n diamines  
acids.

Teachers can demonstrate  
the formation of nylon by  
the use of CH 7.18-b.

Nylon is a general name  
for all synthetic fiber-  
forming polyamides.

*Nylon 66 is produced by  
the reaction between  
adipic acid and hexameth-  
ylenediamine.*

s are made  
reactions  
and an

A 7.03 involves the conden-  
sation between aldehyde  
and phenol models.

A phenol is a compound  
containing one or more  
benzene ring structures in  
which hydroxyl groups are  
united to one or more of  
the ring carbon atoms.

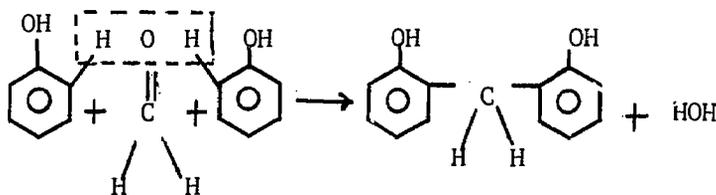
Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Bakelite is a phenol-formaldehyde poly-condensation product.

- Condensation occurs between phenol and formaldehyde monomers:



A teacher demonstrates how to show the preparation of a Bakelite type of polymer. The procedure is listed in A 7.05 and 7.18-a.

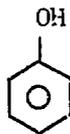
Ball-and-stick models can be used to illustrate the formation of Bakelite.

Laboratory Experiences

Supplementary Information

The name phenol may be used as a general name for a class of compounds or as a name for the specific compound  $C_6H_5OH$ .

The structural formula for the compound phenol is



The structural representation of the aldehyde group is



Bakelite was the first commercial synthetic polymer.

phenol-for-  
condensation

occurs  
l and for-  
omers:

A teacher demonstration to show the preparation of a Bakelite type of polymer is listed in A 7.05 or CH 7.18-a.

H  
+ HOH

Ball-and-stick models can be used to illustrate the formation of Bakelite.



Findings  
Concepts

Laboratory Experiences

Supplementary Information

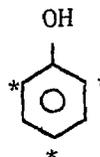
condensations  
the chain.

ion chains can  
on any of the  
linkage sites  
network.

er "sets" into  
form when this  
is built, and  
ite plastic is

are made by con-  
reactions between  
which are poly-  
ohols and acids  
than one carboxyl

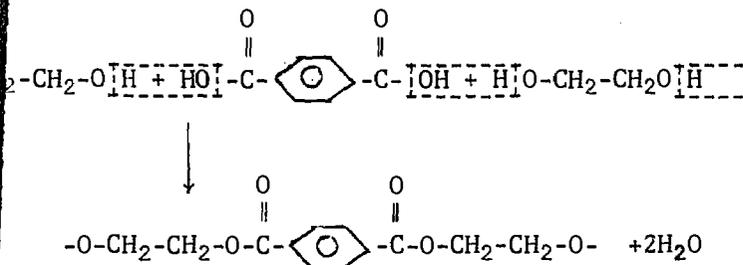
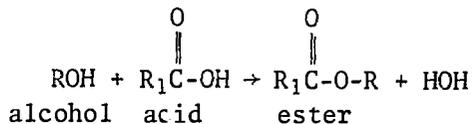
made by conden-  
sations between  
glycol and  
ic acid.



Asterisk (\*)  
indicates most  
common linkage  
sites.

Materials with a network  
structure like Bakelite  
resist deformation when  
heated or subjected to  
pressure.

Esters are made by reacting  
an alcohol and an organic  
acid.



Dacron

Topical Outline

4. Vinyl plastics

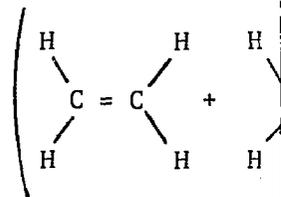
Understandings and Concepts

Vinyl plastics are formed by addition reaction between monomers containing the C=C structure.

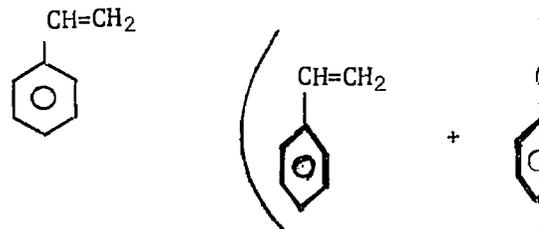
The monomer of polyethylene is ethylene, C<sub>2</sub>H<sub>4</sub>

Laboratory Ex

Pupils can use stick models to form the formation of the

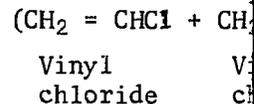


The monomer of polystyrene is styrene



Vinyl chloride is a monomer included in many vinyl plastics.

See A 7.06 for formation of a vinyl



Understandings  
and Concepts

Vinyl plastics are formed by addition reaction between monomers containing the C=C structure.

The monomer of polyethylene is ethylene, C<sub>2</sub>H<sub>4</sub>

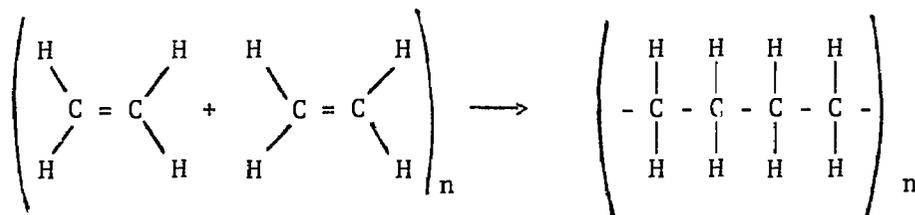
Laboratory Experiences

Pupils can use ball-and-stick models to show the formation of the polymers.

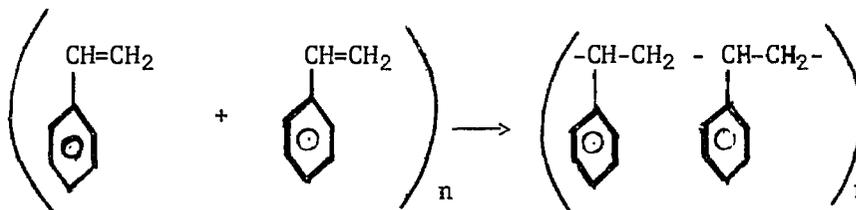
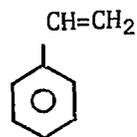
Supplementary Information

The monomers may or may not be identical. However, all must have the C=C structure.

Addition polymerization of ethylene can be represented



The monomer of polystyrene is styrene

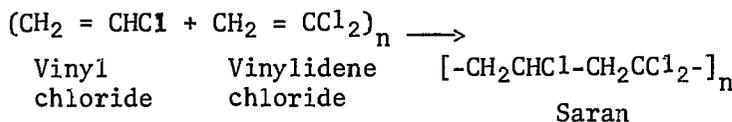


The addition polymerization of styrene can be represented

Vinyl chloride is a monomer included in many vinyl plastics.

See A 7.06 for identification of a vinyl chloride.

The monomers for Saran are vinyl chloride and vinylidene chloride.



Topical Outline

Understandings  
and Concepts

Laboratory Experiences

5. Silicones

Silicones are polymers having a chain structure of -Si-O-Si-O-.

Models can be used to show the structure of the silicone chain.

"Bouncing" or "silly" putty shows interesting behavior.

a. Synthesis

Silicones are formed by hydrolysis of organosilicon chlorides, followed by a condensation reaction between the silicon monomers.

P  
Cl-S  
P

2 HO-

Understandings  
Concepts

are polymers  
chain structure  
Si-O-

are formed by  
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chlorides, followed  
condensation reaction  
the silicon mono-

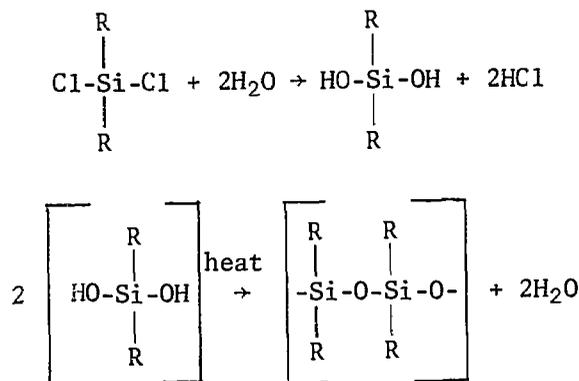
Laboratory Experiences

Models can be used to show  
the silicone chain.

"Bouncing" or "silly" putty  
shows interesting behavior.

Supplementary Information

Silicon can form four covalent bonds. Although the silicon atoms can covalently bond to other silicon atoms, long silicon chains are not possible. However, long chains containing -Si-O-Si-O- linkages are stable.



Successive condensations  
lengthen the chain.

Networks can be obtained  
if the synthesis starts  
with an organosilicon  
trichloride.

Topical Outline

Understandings  
and Concepts

Laboratory Ex

b. Properties

The properties of the silicones depend upon the structure of the chain and the nature of the groups of atoms attached to the chain.

Silicones tend to be relatively inert and noncombustible.

Silicones are excellent electrical insulators.

Silicones are water repellent.

Silicones have properties which are stable over a wide range of temperatures.

Compare the effing water on pa and on a silicon wax.

C. Some types of polymers

A particular polymer may have one or more of the characteristics described below.

1. Elastomers

Elastomers are polymers showing some degree of elasticity.

Show the elasticity (within limits) of synthetic rubber. Measure the length during, and after it.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

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the chain and  
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ached to the

Short chain silicones are  
oils and greases rather  
than plastics.

nd to be rela-  
and noncom-

Silicone resins in paints  
form lasting finishes.

e excellent  
nsulators.

Silicone rubbers are not  
affected by heat.

e water repel-

The viscosity of silicone  
oils does not significantly  
change at low or high tem-  
peratures.

ve properties  
able over a  
f temperatures.

Compare the effect of boil-  
ing water on paraffin wax  
and on a silicone stopcock  
wax.

Silicones retain their  
plasticity regardless of  
pressure or heat.

polymer may  
more of the  
ics described

re polymers  
degree of

Show the elastic property  
(within limits) of a piece  
of synthetic rubber.  
Measure the length before,  
during, and after stretch-  
ing it.

Polyisoprene, neoprene,  
and butadiene-styrene are  
examples of elastomers.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Elastomers have long "folded" molecules that act like a "molecular spring." Upon being stretched, the molecules stretch out. When the stretching force is released, the molecules resume their folded position.

Stretching a rubber band requires energy. When the band returns to its original shape, energy is released. This energy change can be detected as heat by holding a band across the lips. When the band is stretched and returned to its original shape.

Elastomers may be addition or condensation polymers which may contain one or two kinds of monomers.

Teachers can demonstrate the formation of a synthetic rubber by the reaction of CH<sub>2</sub>=CHCl + H<sub>2</sub>O.

Polymers formed from two or more kinds of monomers are called copolymers.

Some elastomers such as neoprene are resistant to organic solvents, chemicals, and air oxidation.

Compare the effect of nail polish remover, HCl on natural rubber and neoprene.

2. Fibers

Fibers are polymers composed of long molecules which can align themselves close together to form strands.

Natural and synthetic fibers can be identified by microscopic inspection. Natural fibers tend to be smooth and cylindrical.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

mers have long  
" molecules that  
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their folded posi-

Stretching a rubber band requires energy. When the band returns to the original shape, energy is released. This energy change can be detected as heat by holding a rubber band across the lips as the band is stretched and returned to its original shape.

Elasticity is the ability of a substance to return to its original shape after being deformed.

mers may be addition  
ensation polymers  
ay contain one or  
ds of monomers.

Teachers can demonstrate the formation of a synthetic rubber by the use of CH 7.18-c.

*Neoprene is synthesized by changing acetylene to vinylacetylene to a chloroprene monomer. The chloroprene monomers polymerize and are vulcanized into neoprene.*

s formed from two  
kinds of monomers  
led copolymers.

GRS rubber is a copolymer of butadiene and styrene.

astomers such as  
e are resistant to  
solvents, chem-  
and air oxidation.

Compare the effect of NaOH, nail polish remover, and HCl on natural rubber and neoprene.

are polymers com-  
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ogether to form  
.

Natural and synthetic fibers can be identified by microscopic inspection. The threads of a synthetic fiber tend to be smooth and cylindrical.

Linen, cotton, silk, and wool are natural fibers.

Dacron and Orlon are synthetic fibers.

Topical Outline

Understandings  
and Concepts

Laboratory Exp

When some synthetic fiber chains are rearranged by stretching them so they are parallel and closely packed, the fiber becomes stronger.

Synthetic fibers have some properties like those of natural fibers. They may also have dissimilar properties.

3. Thermoplastic polymers

Thermoplastics soften on heating and harden on cooling. Thermoplastics may be repeatedly softened and hardened.

The long chain molecules are held in place by "mutual entanglement" or by crystallinity when the plastic is cold.

When a thermoplastic is heated, the long chain molecules can slide over one another to form a different shaped solid.

Use A 7.07 for a of the properties fibers.

Properties such strength and res abrasion can be also.

Changing the sha thermoplastic ma illustrated in A

The disappearance tallinity occurs temperature when lucent plastic b transparent. A demonstration is some paraffin wa a candle.

Understandings  
and Concepts

Some synthetic fibers are rearranged by pulling them so they are parallel and closely packed. The fiber becomes stronger.

Some fibers have some properties like those of natural fibers. They may have dissimilar properties.

Elastics soften on heating and harden on cooling. Thermoplastics soften repeatedly when softened.

Long chain molecules are held in place by "entanglement" or crystallinity when the material is cold.

A thermoplastic is a material in which the long chain molecules can slide over each other to form a more compact solid.

Laboratory Experiences

Use A 7.07 for a comparison of the properties of synthetic fibers.

Properties such as wet strength and resistance to abrasion can be tested also.

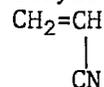
Changing the shape of a thermoplastic material is illustrated in A 7.08.

The disappearance of crystallinity occurs at a certain temperature when a translucent plastic becomes transparent. A simple demonstration is to melt some paraffin wax or burn a candle.

Supplementary Information

Polymers forming high tensile strength fibers can be used for fabrics: Orlon, Dacron, nylon, Vinyon, and viscose rayon yarns.

Orlon is made by an addition reaction between acrylonitrile units,



Lucite, polystyrene, and saran are examples of thermoplastic substances.

*Lucite is the acrylic resin, methyl methacrylate.*

Topical Outline

Understandings  
and Concepts

Laboratory Expe

4. Thermosetting  
and cold-  
setting  
plastics

Thermosetting plastics soften upon being heated, but undergo changes in structure which set the material in a permanent form.

When plastic "sets," the chains cross-link to form a network. The chains no longer can be moved across each other.

By undergoing a chemical change with a catalyst, some plastics can set at room temperature. They are called cold-setting plastics.

Like thermosetting plastics, cold-setting plastics cannot be resoftened once they have been shaped and hardened.

Thermosetting and cold-setting plastics are resistant to high temperatures.

A 7.09 deals with a setting plastic.

For an activity that used to test for the plastic and thermose properties, see A 7.

Pupils can classify of plastics by A 7.11

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Thermosetting plastics soften upon being heated, but undergo changes in structure which set the material in a permanent form.

The temperatures and pressures needed for molding articles from thermosetting plastics cannot be safely obtained in the high school laboratory.

When plastic "sets," the chains cross-link to form a network. The chains no longer can be moved across each other.

An example of a thermosetting plastic is Bakelite.

By undergoing a chemical change with a catalyst, some plastics can set at room temperature. They are called cold-setting plastics.

A 7.09 deals with a cold-setting plastic.

Like thermosetting plastics, cold-setting plastics cannot be resoftened once they have been shaped and hardened.

Thermosetting and cold-setting plastics are resistant to high temperatures.

For an activity that can be used to test for thermoplastic and thermosetting properties, see A 7.10.

Pupils can classify kinds of plastics by A 7.11.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
II. Industrial Metals	An industrial metal generally contains other elements which may be metallic or nonmetallic.	
	The additional elements in an industrial metal may be either the "natural" impurities left after metallurgical treatment of their ores, or "artificial" impurities deliberately injected by the metallurgist.	
	Adding other elements to a metal is called alloying.	
	An industrial metal containing significant amounts of other elements is called an alloy.	
A. "Natural" impurities	Most metals are found in the combined form as oxides, sulfides, or carbonates, along with other rock-like materials.	
1. Concentration of ore	Concentration of the ore involves removal of unwanted nonmetallic minerals in order to make the metallurgy of a mineral more economical.	CH 8.26 a, b, c(1), d deal with concentration processes.

Findings  
Concepts

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Laboratory Experiences

CH 8.26 a, b, c(1), c(2),  
d deal with concentration  
processes.

Supplementary Information

Pure substances are seldom  
encountered in modern  
metallic materials.

The carbon, sulfur, phos-  
phorus, and oxygen left  
in cast iron are examples  
of "natural" impurities.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory</u>
	Substances may be separated if they differ in their density, or in their ability to be attracted by a magnet, to be wet by water, or to "attract" air bubbles.	
	Substances may be separated by changing their ability to attract water by means of xanthates.	Concentrating tation can be by CH 8.27.
	Some metallic compounds become magnetic by partial reduction of the compound.	See CH 8.28:
2. Reduction	Most metallic oxides are reduced by carbon and carbon monoxide.	CH 8.19, CH 8. hood), and CH fume hood) can illustrate the metallurgical
	Sulfides and carbonates must be converted to oxides before reduction.	
	Some nonmetallic impurities that may be left after reduction are sulfur, phosphorus, carbon, oxygen, and silicon.	
	Metallic impurities left in the metal generally include metals having similar properties.	

Standings  
Concepts

Laboratory Experiences

Supplementary Information

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Concentrating ores by flo-  
tation can be illustrated  
by CH 8.27.

See CH 8.28.

CH 8.19, CH 8.21-a (use fume  
hood), and CH 8.22 (use  
fume hood) can be used to  
illustrate the general  
metallurgical processes.

Hematite heated with char-  
coal can produce a mag-  
netic oxide which can be  
separated easily from non-  
magnetic materials.

*Pupils will be expected to  
know the following general  
reactions and how to use  
them to obtain Fe, Zn, Pb,  
and Sn.*

*Metallic oxide + C → CO +  
metal*

*Metallic oxide + CO → CO<sub>2</sub>  
+ metal*

*Metallic sulfide + O → SO<sub>2</sub>  
+ metallic oxide*

*Metallic carbonate → CO<sub>2</sub>  
+ metallic oxide.*

*Pupils are not responsible  
for knowing the construc-  
tion of furnaces and con-  
verters.*

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
B. "Artificial" impurities - alloying	Artificial impurities are generally added by melting all of the metals together and cooling the melt to produce the alloy.	Make Wood's metal or by using CH 8.42c (1) (2).
C. Properties and uses of alloys	Alloying an element with a metal produces a substance with properties unlike those of the components.	CH 8.42-b can be used to illustrate how atoms of different sizes may affect the hardness of the
	An alloy tends to be harder than any of its components. <ul style="list-style-type: none"> <li>. Pure silver is made harder by alloying with copper. The silver-copper alloy is used to make sterling silver for tableware and jewelry.</li> </ul>	
	An alloy tends to have a melting point that is lower than those of the components. <ul style="list-style-type: none"> <li>. Wood's metal, composed of tin, cadmium, and lead, melts in hot water, but none of the components do.</li> </ul>	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Special impurities are usually added by melting the metals together and cooling the melt to form the alloy.

Adding an element with a different atomic weight produces a substance with properties unlike those of the components.

Aluminum tends to be harder than any of its components. Sterling silver is made by alloying with copper. The silver-copper alloy is used to make sterling silver for tableware and jewelry.

Aluminum tends to have a melting point that is lower than the average of the components.

Aluminum is a soft metal, composed of aluminum, cadmium, and lead, which reacts in hot water, but not with any of the components.

Make Wood's metal or solder by using CH 8.42c (1) or (2).

CH 8.42-b can be used to illustrate how atoms of different sizes may affect the hardness of the alloy.

The nonmetallic impurities left in cast iron cause brittleness.

Some molten metals are immiscible. Alloys of these metals are made from mixtures of very fine powders of the metals. The mixtures are heated under pressure.

Carbon increases brittleness.

Aluminum, manganese, magnesium, and chromium increase resistance to corrosion.

Copper increases hardness.

Bismuth decreases the melting point.

*Pupils will be held responsible for knowing that varying the percentage composition of an alloy may change its properties. However, they are not expected to memorize the percentage composition of alloys.*

## Topical Outline

## Understandings and Concepts

## Laboratory Experiences

An alloy tends to be a poorer conductor of electricity (has higher electrical resistance) than any of its components.

- . A nickel-chromium alloy called nichrome has so much resistance to electrical current that it is used for the heating elements in electrical toasters.

An alloy tends to be less active than any of its components.

- . Stainless steel is relatively slow to react with most chemicals. Chromium is one of the constituents of stainless steel.

### III. Radioisotopes

#### A. Nature of radioactivity

When working with radioisotopes, particularly those in unsealed containers, it is essential that the rules for handling these materials be followed at all times. A list of these precautions is given in CH 6.02.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

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steel is rela-  
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stainless steel.

When working with radio-  
isotopes, particularly  
those in unsealed con-  
tainers, it is essential  
that the rules for handling  
these materials be followed  
at all times. A list of  
these precautions is given  
in CH 6.02.

*Pupils will have encountered  
some of the concepts listed  
at the left in Science 7, 8,  
9, Block L (pp. 2-61).*

*The Atomic Energy Commis-  
sion's series of booklets  
entitled "Understanding the  
Atom" is a very complete set  
covering all topics on  
radioisotopes included in  
this unit. Complete sets  
of the series are available  
free to school librarians*

## Topical Outline

## Understandings and Concepts

## Laboratory Experi

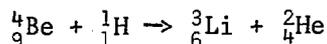
A radioisotope is any isotope which undergoes radioactive decay, with the emission of a characteristic radiation.

Hide a source of radioactivity. Have a few pupils locate it by a detecting instrument.

### 1. Stability of nuclei

Nuclei of radioisotopes achieve stability through radioactive decay. Some radioisotopes decay at a faster rate than others.

Elements can be made radioactive by bombarding them with high energy particles, such as protons ( ${}^1_1\text{H}$ ), neutrons ( ${}^1_0\text{n}$ ), and alpha particles ( ${}^4_2\text{He}$ ). These elements can then emit charged particles from their nuclei and become atoms of a different element if the number of protons in the nucleus changes.



### 2. Nuclear energy

When a nuclear particle is emitted, a small amount of mass is converted into kinetic energy of the particle.

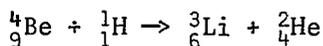
For a discussion of equivalence of mass and energy, see CH 6.14.

### Understandings and Concepts

A radioisotope is any isotope which undergoes radioactive decay, with the emission of a characteristic radiation.

Nuclei of radioisotopes achieve stability through radioactive decay. Some radioisotopes decay at a faster rate than others.

Elements can be made radioactive by bombarding them with high energy particles, such as protons ( ${}^1_1\text{H}$ ), neutrons ( ${}^1_0\text{n}$ ), and alpha particles ( ${}^4_2\text{He}$ ). These elements can then emit charged particles from their nuclei and become atoms of a different element if the number of protons in the nucleus changes.



When a nuclear particle is emitted, a small amount of mass is converted into kinetic energy of the particle.

### Laboratory Experiences

Hide a source of radioactivity. Have a team of pupils locate it by use of a detecting instrument.

For a discussion on the equivalence of matter and energy, see CH 6.14.

### Supplementary Information

*and to teachers, who can make them available for reference or for use by groups. Requests made on school or library letterheads, indicating the proposed use, should be sent to USAEC, P.O. Box 62, Oak Ridge, Tennessee 37830.*

One cannot predict that a particular nucleus of a radioisotope will decay at a given time.

*Pupils will be expected to recognize transmutations when illustrated by equations.*

The mass-loss is converted into energy according to Einstein's statement of equivalence of mass and energy,  $E=mc^2$ .

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

The kinetic energy possessed by radioactive decay particles is transformed into thermal or radiant energy, which may be used to produce electrical energy through a number of energy conversion techniques.

The production of energy by nuclear means may be accomplished by fission and fusion reactors.

a. Fission  
reactors

In a nuclear reactor, a controlled fission process occurs when neutrons moving at the proper speed penetrate the nucleus of a fissionable atom, causing it to cleave apart and release other neutrons to carry on the fission process with another fissionable atom. The radioisotopes  $U^{235}$  and  $Pu^{239}$  are fissionable and emit enough neutrons to sustain or increase the rate at which fission takes place. Large amounts of heat are released by the fission process; this heat can be used to make steam for the production of electric power.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

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Large amounts  
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*Pupils will not be held responsible for calculating the energy released during a nuclear transformation.*

All processes for making potable water from saline water consume energy. It has been found that nuclear energy is economical for large-size desalting plants.

*Pupils are not responsible for knowing the construction of nuclear reactors.*

The nuclear reactors used by electric companies require large amounts of water to cool the reactor. This heated water when released into a stream or lake may cause a thermal pollution problem.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
b. Fusion reactors	<p>The fission products from nuclear reactors are highly radioactive and cannot be discarded as ordinary wastes. They must be stored for a long time or disposed of in special ways.</p> <p>In a fusion reaction, nuclei of lighter elements combine to form a nucleus of a heavier element. The mass of the heavier nucleus is less than the sum of the masses of the lighter nuclei; the difference in mass is converted into energy.</p> <p>The radioactive waste from a fusion process is considerably less than that from the fission process.</p>	<p>For use of a Geiger counter see A 7.12 and A 7.13.</p>
3. Major types of nuclear radiation	<p>Nuclear particles or electromagnetic radiations of major importance emitted by radioisotopes are alpha particles, beta particles, gamma rays, and neutrons.</p>	
a. Alpha particles	<p>Alpha radiation consists of helium nuclei having a mass of approximately 4 a.m.u. and a charge of plus 2.</p>	
b. Beta particles	<p>Beta radiation consists of electrons emitted from the nucleus. Their mass is 1/1836 of a proton, and they carry a single negative charge.</p>	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

ission products from  
r reactors are highly  
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radiation consists of  
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of a proton, and they  
a single negative

This problem is increasing  
as more nuclear reactors  
are put into use by the  
electrical industry.

Fusion reactions are  
responsible for the emission  
of energy from the stars.

Work is being done to  
develop fusion reactors  
which can maintain the  
fusion reaction long enough  
for the heat from the  
reaction to be used.

For use of a Geiger counter,  
see A 7.12 and A 7.13.

Alpha particles have ranges  
in air of only a few centi-  
meters and can be stopped  
by a single sheet of paper.

Beta particles are more pene-  
trating than alphas, but can  
be stopped by thin sheets  
of aluminum.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

c. Gamma rays

Gamma radiations are very high frequency electromagnetic waves. These waves have shorter wave lengths than X rays. Gamma radiations have no charge or mass.

d. Neutrons

Neutron radiation is the emission of neutrons from the nucleus of a radioisotope. This happens in fission and some fusion reactions. The neutron has a mass of approximately 1 a.m.u. and no charge.

B. Some properties and uses of radioisotopes

Some properties of radioisotopes have made them useful in many areas, such as medical diagnosis, biochemistry, geology, and therapy.

1. Uses based on chemical reactivity

Radioisotopes are chemically similar to the non-radioactive isotopes of the same element.

Preparing radioacti for absorption by p is described in A 7

Many radioisotopes are used as tracers. They are added to a system to enable the experimenter to follow the course of a reaction without seriously altering the conditions.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Gamma radiations are very high frequency electromagnetic waves. These waves have shorter wavelengths than X rays. Gamma radiations have no charge and no mass.

Neutron radiation is the emission of neutrons from the nucleus of a radioactive isotope. This happens in fission and some fusion reactions. The neutron has a mass of approximately 1.00866 a.m.u. and no charge.

Some properties of radioisotopes have made them useful in many areas, such as medical diagnosis, biochemistry, geology, and therapy.

Radioisotopes are chemically similar to the non-radioactive isotopes of the same element.

Many radioisotopes are used as tracers. They are added to a system to enable the experimenter to follow the course of a reaction without seriously altering the

Gamma radiations are highly penetrating and present one of the greatest potential hazards to humans.

Both gamma radiation and neutrons are very penetrating. Strictly speaking, it is not possible to absorb gamma radiation completely. However, a sheet of lead 5 centimeters thick will stop more than 99 percent of a beam of gamma radiation. Neutrons can be stopped, but they have been known to penetrate 20 centimeters of lead.

Preparing radioactive CO<sub>2</sub> for absorption by plants is described in A 7.14.

The use of C<sup>14</sup> as a tracer has given us a better understanding of the mechanisms of many organic reactions.

Some of the complex biochemical pathways in photosynthesis have been traced by using C<sup>14</sup>.

Topical Outline

2. Uses based on radioactivity

Understandings and Concepts

Radioisotopic tracers are detected by the radiation they emit.

Radioisotopes are used in medical diagnosis.

Laboratory Experience

For determining the minimum activity of a radioisotope required for detection, see A 7.15.

For activities related to medical and industrial uses of tracers, see A 7.16 and A 7.17.

standings

Concepts

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Laboratory Experiences

For determining the  
minimum activity of a  
radioisotope required for  
detection, see A 7.15.

For activities related to  
medical and industrial  
uses of tracers, see A 7.16  
and A 7.17.

Supplementary Information

To minimize radiation  
damage when tracing, a  
physician or radiologist  
will select an isotope with  
a short half-life and which  
will be quickly eliminated  
from the body. As a  
further precaution, the  
smallest possible amount of  
the isotope that can be  
accurately detected will  
be used.

Diagnostic injections of  
radioisotopes destroy less  
than .01 percent of the  
viable cells.

Tc<sup>99</sup> is being used  
successfully by neuro-  
surgeons to pinpoint brain  
tumors. Tumors in the  
brain are known to concen-  
trate technetium much more  
than do healthy brain cells.  
Formerly, P<sup>32</sup> was used for  
this purpose.

I<sup>131</sup> is taken up by the  
thyroid gland. The rate  
of uptake can be used to  
diagnose hyper- and hypo-  
thyroidism.

Topical Outline

Understandings  
and Concepts

Laborator

Radioisotopes are used in therapy.

Ionizing radiations damage or destroy cells in general, but the cells most vulnerable are those most frequently undergoing division.

Foods exposed to low levels of radiation can be kept much longer before spoiling. The radiations kill bacteria, yeasts, molds, and insect eggs.

Some radiation is absorbed as it passes through matter. By placing a source of radiation on one side of a moving object and a detector on the other side, physical dimensions or other properties of the object can be monitored.

For an act  
gauging, se

## Understandings and Concepts

Radioisotopes are used in therapy.

Ionizing radiations damage and destroy cells in general, but the cells most vulnerable are those that frequently undergo division.

Foodstuffs exposed to low levels of radiation can be kept much longer before spoiling. The radiations kill bacteria, yeasts, molds, and insect eggs.

The radiation is absorbed as it passes through a detector. By placing a source of radiation on one side of a moving object and a detector on the other side, physical dimensions and other properties of the object can be monitored.

## Laboratory Experiences

For an activity involving gauging, see A 7.18.

## Supplementary Information

A cancer, by definition, consists of rapidly dividing cells.

Therapeutic injections of radioisotopes contain about 1,000 times more activity than diagnostic injections.

Radium, cobalt-60, and iodine-131 are used in cancer therapy.

Some meats have been stored after irradiation for considerable lengths of time without refrigeration. The use of irradiation has been approved for sprout inhibition of white potatoes and disinfestation of wheat and flour from insects.

Radioisotope thickness gauges are being used to measure the thickness during manufacture of such products as paper, metal sheets, textiles, tire fabrics, and floor coverings. A gauge is also in use in the beverage industry which causes unfilled and partially filled cans and bottles to be rejected from the assembly line.

Topical Outline

Understandings  
and Concepts

Laboratory Experience

3. Uses based on rate of decay and half-life

The rate of radioactive decay (the rate of emission of nuclear radiation) is usually expressed by means of the half-life of the particular isotope involved. The time required for one-half of a given number of radioactive atoms to undergo decay is the half-life for that radioisotope. After 1, 2, 3, or 4 half-lives, the activity of the radioisotope will fall, respectively, to  $1/2$ ,  $1/4$ ,  $1/8$  or  $1/16$  of its initial value.

For half-life measurements see A 7.19 and CH 6.13a

The half-life of a radioactive element is considered a constant. The rate of decay of radioisotopes is not changed by heat, pressure, state of chemical combination of the element, or time.

See CH 6.10 for the lack of effect of chemical changes on radioactivity.

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Laboratory Experiences

Supplementary Information

Radioisotopes are also used in polymerization, polymer modification, catalysis, fiber modification, growth acceleration and inhibition, insect control, sterilization of pharmaceuticals and medical equipment, friction and wear determinations, and nondestructive testing.

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For half-life measurements,  
see A 7.19 and CH 6.13a.

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, or time.

See CH 6.10 for the lack of  
effect of chemical change  
on radioactivity.

*Pupils are not expected to  
memorize the half-life  
value of any radioisotope.*

Topical Outline

Understandings  
and Concepts

Laboratory Ex

Radioisotopes give a fairly consistent method of dating some geologic events.

$U^{238}$  has a half-life of 4.5 billion years. The stable product is  $Pb^{206}$ .

Radiocarbon,  $C^{14}$ , found in  $CO_2$  in the atmosphere, disintegrates spontaneously to  $N^{14}$ . Its half-life is about 5,580 years.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Isotopes give a  
very consistent method  
of dating some geologic  
rocks.

Uranium has a half-life of  
4.5 billion years. The  
stable product is  $Pb^{206}$ .

Carbon-14,  $C^{14}$ , found in  
the atmosphere, dis-  
integrates spontaneously to  
nitrogen. Its half-life is about  
5730 years.

Many minerals contain  
measurable amounts of  
uranium. By finding the  
ratio of  $Pb^{206}$  to the  $U^{238}$   
still remaining, the age  
of the mineral can be  
computed.

In addition to the decay  
of  $U^{238}$  to  $Pb^{206}$ ,  
similar radioactive pairs  
such as  $K^{40}/Ar^{40}$  and  
 $Sr^{87}/Rb^{87}$  have been used  
for dating.

The fact that the ratio of  
isotopes in the carbon from  
living matter is the same as  
that of the carbon in the  
air means that a measurement  
of the  $C^{14}$  content of an  
old piece of wood or shell  
may give a measure of the  
time elapsed since the or-  
ganism died and ceased to  
acquire new carbon from the  
air or water.

Because the half-life of  
 $C^{14}$  is very much shorter  
than that of uranium, it is  
valuable in dating material  
of relatively recent origin  
(not more than about 40,000  
years old).

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Experiences</u>
C. Detection of nuclear radiation	Most methods for detecting radiation depend upon the detection of ionization caused by radiation.	
1. Film	Photographic film is sensitive to radiation from radioisotopes.	For making radioautographs using coleus leaves and X-ray film, see CH 6.11.
2. Electroscope	A charged electroscope is discharged faster when the air around it is ionized by radiation.	Place a source of radiation near the knob of a charged electroscope and note the rate at which the electroscope discharges. Use another charged electroscope as a control.
3. Geiger counter	Geiger counters are best for counting beta particles. Alpha particles are stopped by the window unless it is very thin. Only a small percent of the gamma radiation entering the tube activates the counter.	For information pertaining to the Geiger counter, see CH 6.05.
4. Scintillation counter	Scintillation counters are more efficient for counting gamma radiation and can also measure much higher levels of radiation than the Geiger counter.	

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Methods for detecting radiation depend upon the type of ionization produced by the radiation.

*Pupils are not responsible for knowing the construction of radiation-counting instruments.*

Photographic film is sensitive to radiation from many radioisotopes.

For making radioautographs using coleus leaves and X-ray film, see CH 6.11.

X-ray film is more suitable than ordinary photographic film for making radioautographs.

A Geiger-Müller tube discharges faster when the rate of ionization is high and it is ionized.

Place a source of radiation near the knob of a charged electroscopescope and note the rate at which the electroscopescope discharges. Use another charged electroscopescope as a control.

Scintillation counters are best for detecting beta particles. Alpha particles are stopped by the window of the counter. The window is very thin. Only a small percent of the radiation entering the counter activates the counter.

For information pertaining to the Geiger counter, see CH 6.05.

Radiation entering through the window of a Geiger counting tube causes ionization of gas molecules in the tube. This results in a pulse of current which registers on a meter or is indicated in various other ways.

Scintillation counters are efficient for detecting gamma radiation. They also measure much higher levels of radiation than a Geiger counter.

Radiation striking the crystal detector of a scintillation counter causes a small flash of light which is amplified by a photomultiplier tube, producing a current which registers on a meter.

Topical Outline

Understandings  
and Concepts

Laboratory Ex

D. Radiation and human safety

Radiations emitted by radioisotopes can cause damage to living cells by the ionization they produce.

A list of rules laboratory procedures be followed when with radioisotopes given in CH 6.02

The amount of ionization produced depends upon the radiation rate, exposure time, and the radiation source.

A 7.20 deals with effects of radiation seeds.

Atoms of nonradioactive isotopes cannot be made radioactive by exposure to the radiation emitted by the natural decay of radioisotopes.

See A 7.21 for an regarding radioactivity out in rain and s

Findings  
Concepts

Laboratory Experiences

Supplementary Information

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ing cells by  
n they pro-

A list of rules for laboratory procedures to be followed when working with radioisotopes is given in CH 6.02.

It is extremely important that rules of laboratory procedure be established and enforced when working with unsealed radioisotopes. No activity should ever be considered in which the radioisotopes are ingested by humans.

ionization  
ends upon the  
te, exposure  
radiation

A 7.20 deals with the effects of radiation on seeds.

Units of radiation measurement have been established which are used in maintaining health and safety standards.

The roentgen applies only to X rays and gamma rays. One roentgen of radiation produces about  $1.8 \times 10^{12}$  ion pairs per gram of tissue.

The Roentgen Equivalent Man, known as the REM, is that quantity of any kind of radiation which produces the same biological damage as 1 roentgen of X rays. A whole body exposure of 500 REM is usually lethal.

radioactive  
not be made  
by exposure  
tion emitted  
al decay of  
s.

See A 7.21 for an activity regarding radioactive fall-out in rain and snow.

Different kinds of radiation differ in their Relative Biological Effectiveness (RBE). An alpha particle causes 20 times as much damage to tissue as

Topical Outline

Understandings  
and Concepts

Laboratory Experience

Atoms are made radioactive only when they have been exposed to high energy particles, such as those produced by accelerators, nuclear reactors, and thermonuclear explosions.

Using a radioisotope to determine the efficiency of a cleanser is described in A 7.22.

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radioactive  
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elerators,  
s, and  
xplosions.

Laboratory Experiences

Using a radioisotope to  
determine the efficiency of  
a cleanser is described  
in A 7.22.

Supplementary Information

a gamma radiation. Its  
RBE is 20. Protons cause  
10 times as much damage to  
tissue as gamma radiation.  
Their RBE is 10. Beta  
particles have an RBE of  
1.

## AREA 8 - CHEMICAL ANALYSIS

Since this area lends itself so well to laboratory work, there may be more activities listed than can be completed in allotted time. Teachers should choose the activities which best meet the situation.

<u>Topical Outline</u>	<u>Understandings and Concepts</u>	<u>Laboratory Ex</u>
I. Qualitative Analysis	Qualitative analysis is the identification of the substances present in a sample of matter.  Qualitative analysis depends upon similarities and dissimilarities in the properties of ions, atoms, or molecules.	A major part of laboratory work should be the identification of ions or substances contained in unknown solutions.
A. Precipitation	An insoluble substance formed in reacting solutions is called a precipitate.  Some ions are identified by the precipitates they can form.	Identification of known precipitates involved in A 8.02 deals with separation of two precipitated ions.  Identification of ions by precipitation given in A 8.03.

## AREA 8 - CHEMICAL ANALYSIS

Since this area lends itself so well to laboratory work, there may be more activities listed than can be completed in the allotted time. Teachers should choose the activities which best meet the local situation.

### Understandings and Concepts

### Laboratory Experiences

### Supplementary Information

Qualitative analysis is the identification of the ions present in a sample of matter.

A major part of the laboratory work should consist of the identification of ions or substances contained in unknown samples.

Qualitative analysis may also identify structural details of a sample of matter.

Qualitative analysis is based upon similarities in the properties of ions, or molecules.

*Pupils will be held responsible for identification of ions on the basis of properties such as solubility and color which can be determined from reference charts.*

A slightly soluble substance in reacting solutions is called a precipitate.

Identification of an unknown precipitate is involved in A 8.01.

A slightly soluble substance can be made to precipitate by concentrating and cooling its solution.

Unknown ions are identified by precipitates they form.

A 8.02 deals with the separation of two precipitated ions.

Identification of halide ions by precipitation is given in A 8.03.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

B. Spectroscopy

Mixtures of some ions can be separated by successive precipitation.

Use the separation of Group I ( $\text{Ag}^+$ ,  $\text{Hg}^{++}$ , and  $\text{Pb}^{++}$ ) to show successive precipitations. Directions can be found in most analytic chemistry manuals.

When a beam of sunlight is passed through a prism or a diffraction grating, the complete rainbow is formed with one color blending into the next.

Pass a narrow beam of sunlight through a prism to obtain a continuous spectrum.

A line spectrum contains narrow bands of light energy which represent some parts of a continuous spectrum.

When elements or their compounds are sufficiently excited in their vapor phase, they yield radiant energy which forms the characteristic spectral lines used to identify each element.

Look through a spectroscope to see the line spectrum produced by excited gases in a discharge tube. Directions for making a spectroscope are given in A 8.04 and for setting up a discharge tube in CH 2.17-c.

In a darkened room pupils can see the line spectrum of a gas in a discharge tube by looking through

Understandings  
and Concepts

of some ions can  
be detected by succes-  
sive precipitation.

A beam of sunlight  
is dispersed through a prism  
and a fraction grating,  
and a complete rainbow is  
seen. Each color is  
seen with one color  
into the next.

A spectrum contains  
bands of light en-  
ergy which represent some  
of a continuous

elements or their  
compounds are sufficient-  
ly abundant in their vapor  
to yield radiant  
energy which forms the  
distinctive spectral  
lines used to identify  
elements.

Laboratory Experiences

Use the separation of  
Group I ( $\text{Ag}^+$ ,  $\text{Hg}^{++}$ , and  
 $\text{Pb}^{++}$ ) to show successive  
precipitations. Direc-  
tions can be found in most  
analytic chemistry man-  
uals.

Pass a narrow beam of sun-  
light through a prism to  
obtain a continuous spec-  
trum.

Look through a spectro-  
scope to see the line  
spectrum produced by ex-  
cited gases in a dis-  
charge tube. Directions  
for making a spectroscope  
are given in A 8.04 and  
for setting up a discharge  
tube in CH 2.17-c.

In a darkened room pupils  
can see the line spectrum  
of a gas in a discharge  
tube by looking through

Supplementary Information

The use of hydrogen sul-  
fide to precipitate sul-  
fides is not recommended.  
 $\text{H}_2\text{S}$  is more poisonous  
than CO.

Because of its speed and  
accuracy, spectroscopy  
has become one of the most  
important analytical meth-  
ods.

Each color line in the  
line spectrum represents  
a discrete amount of en-  
ergy.

*The excited atom is dis-  
cussed in Unit I, Section  
IV A 3.*

Electrons may be excited  
by heating the elements or  
their compounds in a flame,  
by exposing them to light,  
or by enclosing their gas-  
eous phase between the  
high voltage terminals of  
a discharge tube. Usually  
discharge tubes can be  
found in physics laborato-  
ries.

Topical Outline

Understandings  
and Concepts

Laboratory E

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gratings moun

Some vaporized materials give off a limited set of wave frequencies (colors) to which the eye is sensitive. A crude spectroscopic analysis can be made by identifying the color of the flame in which the material is being vaporized.

Pupils can id  
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8.05 lists so  
mixtures.

C. Chromatography

Chromatography is a process by which the components of a mixture are separated from a fixed or stationary phase by a moving phase.

Emphasis shoul  
on the use of  
raphy techniqu

1. Phases

The fixed phase may consist of a column of finely divided solid or a liquid held on a firm support.

Inspect the sur  
some marble chi  
have been immer  
per sulfate. A  
to explain why  
color doesn't "

The moving phase may consist of a liquid or gaseous solvent.

Place the end o  
of filter paper  
and watch the li

Standings  
Concepts

Laboratory Experiences

Supplementary Information

replicas of diffraction gratings mounted in glass.

Pupils can identify unknown ions by the colors they impart to flames. A 8.05 lists some unknown mixtures.

Color interference produced by the presence of some ions can be reduced by the use of appropriate filters.

*Pupils are not expected to memorize the colors imparted to flames but are expected to interpret the results of laboratory tests on the basis of reference charts.*

Emphasis should be placed on the use of chromatography techniques.

Chromatographic separations of mixtures are of primary importance in industry today. Chromatography has made many analytical procedures obsolete since chromatographic separations generally can be obtained more rapidly.

Inspect the surface of some marble chips which have been immersed in copper sulfate. Ask pupils to explain why the blue color doesn't "wash off."

Often the fixed phase is called the adsorbent.

Place the end of a strip of filter paper in water, and watch the liquid move

Other names for the moving phase are "eluent," "sol-

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

2. Rate of flow

There is no way to predict the best choice of phases for a particular separation. They must be worked out by trial and error.

The components of the mixture move along the fixed phase at different velocities.

The velocities of the components vary directly with their solubilities in the liquid phase and inversely with their sorption in the fixed phase.

Substances can be identified by their rate of flow factor,  $R_f$ .

up the paper. Compare speed of the moving water with that of other solvents moving up other strips of filter paper

A 8.06 and A 8.07 can be used to show solvent-sorbent component relationships

Findings  
Concepts

Laboratory Experiences

Supplementary Information

up the paper. Compare the speed of the moving water with that of other solvents moving up other strips of filter paper

vent," "solvent system," and "developing solvent."

The moving phase may contain more than one substance.

A description of gas chromatography is given in CH 3.44.

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by trial

A 8.06 and A 8.07 can be used to show solvent - adsorbent component relationships

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R<sub>f</sub>.

Topical Outline

Understandings  
and Concepts

Laboratory Ex

The  $R_f$  factor is derived from the distance the eluent and substance travel along the fixed phase.

See A 8.08 for an  $R_f$  reference

Have pupils identify "spots" on paper grams by determining

$$R_f = \frac{\text{Distance a component moves}}{\text{Distance eluent moves}}$$

$R_f$  values and the table made

3. Identification

Often substances are identified by the  $R_f$  factor for the absorbent-solvent system.

Develop chromatograms of the same substances in various solvents and determine the  $R_f$  values of

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

factor is derived  
the distance the  
and substance  
along the fixed

See A 8.08 for developing  
an  $R_f$  reference table.

When an  $R_f$  factor indicates  
the possible presence of  
a specific substance, make  
a confirmation test: place  
a drop of the unknown on  
the starting line near the  
spot of the specific sub-  
stance, and run a chromato-  
gram. If the known and  
unknown are identical, the  
two spots will be alike  
and equally distant from  
the starting line. Addi-  
tional proof can be ob-  
tained by varying the sol-  
vents and adsorbents in  
making the chromatograms.

once a component moves  
once eluent moves

Have pupils identify  
"spots" on paper chromato-  
grams by determining the  
 $R_f$  values and then using  
the table made in A 8.08.

$R_f$  values can be affected  
by the concentration of  
the components and impur-  
ities in the solvent. Use  
the techniques listed above  
to verify results.

*Pupils will be expected to  
use and interpret  $R_f$  ref-  
erence tables found in  
texts.*

substances are iden-  
tified by the  $R_f$  factor  
in a solvent-adsorbent

Develop chromatograms of  
the same substance in var-  
ious solvents and compare  
the  $R_f$  values obtained.

$R_f$  tables for solvent-  
adsorbent systems are  
found in chromatography  
texts. See the Biblio-

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

Some substances are identified as colored bands or spots on the fixed phase.

Colorless components may be identified by spraying the chromatogram with chemicals producing a color change or fluorescence.

Some substances may be identified within the moving phase as it leaves the fixed phase.

Find the fingerprints "left" on filter paper. Spray the paper with ninhydrin and gently warm the paper. Various shades of purple will appear where amino acids were left by the fingers.

4. Adsorption

Components of some mixture can be adsorbed or fastened to the fixed phase.

Separate the chlorophylls from plants by using an adsorption column. See Activity CH 3.43 c.

standings  
Concepts

Laboratory Experiences

Supplementary Information

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Find the fingerprints  
"left" on filter paper.  
Spray the paper with nin-  
hydrin and gently warm the  
paper. Various shades of  
purple will appear where  
amino acids were left by  
the fingers.

Separate the chlorophylls  
from plants by using an  
adsorption column. See  
Activity CH 3.43 c.

*graphy in Appendix B.*

If two substances form a  
single spot in the solvent,  
separation generally can  
be achieved by the use of  
a second solvent.

Two-dimensional chromatog-  
raphy first separates  
"groups" and then by chang-  
ing the solvent and the  
direction of its flow sep-  
arates out the components  
of the groups. Amino acids  
are generally separated by  
two-dimensional chromatog-  
raphy on paper or a thin  
film.

If samples of solvent are  
collected as it flows from  
a column or drips from the  
end of a filter paper, the  
faster moving components  
can be found in the sol-  
vent while other compo-  
nents are still bound to  
the adsorbent.

Adsorbents are generally  
oxides, hydrated oxides,  
and salts.

Topical Outline

Understandings  
and Concepts

Laboratory

The liquid phase also can be adsorbed on the fixed phase.

The moving phase and the components of the mixture compete for adsorption sites on the fixed phase.

The competition results in the components moving along the fixed phase at different velocities. Thus, the components are separated.

5. Thin layer

Thin films of a gel or "activated" adsorbent fixed to a support such as glass or plastic are faster and easier to use than columns or paper separations.

Directions for T found in A 8.09.  
Amino acid separation on silica gel layers described in A 8.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

phase also can  
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adsorption  
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spots moving along  
phase at differ-  
ent rates. Thus, the  
spots are separated.

of a gel or  
adsorbent  
support such as  
cellulose are faster  
to use than  
paper separa-

Directions for TLC can be  
found in A 8.09.

Amino acid separations on  
silica gel layers are  
described in A 8.10.

There are several factors  
that affect the degree of  
adsorption. Some factors  
are the natures of the  
adsorbent, the solvent,  
and the components of the  
mixture, and the surface  
area of the adsorbent.

The components which are  
bound more strongly to the  
adsorbent move less rapidly  
along the fixed phase than  
the components which are  
held loosely to the adsor-  
bent.

Generally, the more power-  
ful or active an adsorbent  
is, the more powerful or  
active an eluent must be  
in order to move compo-  
nents through the fixed  
phase.

The term, TLC, refers to  
thin layer chromatography.

Both adsorption and par-  
tition chromatography can  
be carried out on thin  
films.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

D. Gas evolution

Thin films are made by spreading a thin layer of a slurry of adsorbent in a suitable solvent over a plate of glass or a sheet of plastic. The film is dried, usually in an oven. Before use, the film must be exposed to air so that water vapor may become bonded onto the adsorbent. The hydration activates the adsorbent.

Some substances can be identified by reactions producing a characteristic gas.

An acid and a carbonate or a bicarbonate will form  $\text{CO}_2$  gas.

- .  $\text{CO}_2$  turns limewater milky.

An acid and a sulfite will form  $\text{SO}_2$  gas.

- .  $\text{SO}_2$  turns purple  $\text{KMnO}_4$  solution to colorless.

Pupils can identify bicarbonate, carbonate, ammonium, sulfide and/or sulfite compounds in a group of unknown samples. Most laboratory manuals show laboratory apparatus set-ups for these tests.

Findings  
Concepts

Laboratory Experiences

Supplementary Information

made by  
thin layer of  
adsorbent in  
solvent over a  
glass or a sheet  
The film is  
dried in an oven.  
The film must  
be dried in  
air so that  
it may become  
the adsorbent.  
It activates

Silica gel is one of the  
substances most commonly  
used to make thin films.

"G" grade indicates that  
an adsorbent contains  
plaster of paris to help  
hold it to the support.

Tests can be  
run for  
reactions  
characteristic

Pupils can identify bicar-  
bonate, carbonate, ammo-  
nium, sulfide and/or sul-  
fite compounds in a group  
of unknown samples. Most  
laboratory manuals show  
laboratory apparatus set-  
ups for these tests.

A fume hood should be used  
in carrying out tests  
forming gases. The gener-  
ator should be taped or  
wrapped with a towel and  
a thistle tube used for  
the addition of the acid  
if the gas is to be bub-  
bled into the test solu-  
tion.

carbonate or  
will form

limewater

sulfite will

purple  $\text{KMnO}_4$   
to colorless.

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

An acid and a sulfide will form  $H_2S$  gas.

- .  $H_2S$  turns moist lead acetate paper black.

Restrict testing of moist lead acetate paper and use only small quantities of unknown sample.

If the reaction is carried out in a test tube, a drop of testing solution on the end of a stirring rod can be used to identify the gas. The lead method uses only a small amount of sample and produces a small quantity of gas.

NaOH solution or solid  $Ca(OH)_2$  and an ammonium compound will produce  $NH_3$  gas.

- .  $NH_3$  turns moist red litmus blue.

II. Quantitative Analysis

Quantitative analysis measures only the amount of a specific component.

The techniques of quantitative analysis must keep loss of the desired component to a minimum.

Understandings  
and Concepts

and a sulfide will  
S gas.  
S turns moist lead  
acetate paper black.

solution or solid  
and an ammonium  
and will produce  $\text{NH}_3$

turns moist red  
litmus blue.

Quantitative analysis  
uses only the amount  
of a specific component.

Techniques of quanti-  
tative analysis must keep  
in mind the desired compo-  
sition to a minimum.

Laboratory Experiences

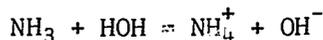
Restrict testing of  $\text{H}_2\text{S}$  to  
moist lead acetate paper  
and use only small quan-  
tities of unknown samples.

If the reaction is carried  
out in a test tube, a large  
drop of testing solution  
on the end of a stirring  
rod can be used to iden-  
tify the gas. The latter  
method uses only a small  
amount of sample and pro-  
duces a small quantity of  
gas.

Supplementary Information

Hydrogen sulfide gas is  
extremely poisonous.

Ammonia gas reacts to some  
degree with water to form  
 $\text{NH}_4^+$  and  $\text{OH}^-$ .



When NaOH solution is used  
as a reactant, gentle heat  
may be needed to liberate  
the gas.

Quantitative analysis uses  
reactions resulting in the  
formation of a product that  
can be isolated.

Much of industry's quanti-  
tative analysis is done by  
instrument analysis.

Topical Outline

Understandings  
and Concepts

Laboratory Experi-

The precision of quantitative analysis results is determined by the limitations of the equipment used.

Have pupils use with different sensitivities to determine mass of a few strands of thread or grains. Compare the results and account for the differences.

A. Gravimetric methods

A direct gravimetric method measures the mass of the component of interest.

Directions for finding percentage composition of various substances found in most high school laboratory manuals.

An indirect method measures the loss of mass due to a volatile species escaping.

B. Volumetric methods

1. Gas measurement

Gas analysis measures the volume of a gas produced or consumed.

Measure the amount of gas produced by baking soda or effervescing tablets and powders used to neutralize stomach acid. See A 8.11.

2. Titrating normal solutions

Titrations are used to find the volume of a standard solution that is chemically equivalent to that

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

The precision of quantitative analysis results is determined by the limitations of the equipment used.

Have pupils use balances with different sensitivities to determine the mass of a few strands of thread or grains of sand. Compare the results and account for the differences.

The direct gravimetric method measures the mass of the component of interest.

Directions for finding the percentage composition of various substances can be found in most high school laboratory manuals.

The indirect method measures the loss of mass due to a volatile species escaping.

Finding the percent of water in a hydrated crystal requires the use of the indirect method of measurement.

Gas analysis measures the volume of a gas produced or consumed.

Measure the amount of  $\text{CO}_2$  produced by baking powders or effervescing tablets and powders used to neutralize stomach acid. See A 8.11.

Point out that pressure and temperature have an effect on the accuracy of measuring volumes of gases. *Pupils are not required to know how to convert gas measurements to STP.*

Standard solutions are used to find the volume of a standard solution that is chemically equivalent to that

---

Topical Outline

Understandings  
and Concepts

Laboratory Experience

of an unknown solution.

The normality (N) of a solution is the number of gram equivalents of solute in a liter of solution.

Pupils should be able to prepare a specified volume of a solution with a definite normality.

. One gram equivalent of an acid is the mass in grams that furnishes 1 mole (1 g.) of hydrogen ions.

. One mole of an acid or base contains 1 or more moles of hydrogen or hydroxide ions.

. One gram equivalent of a base is the mass in grams that furnishes 1 mole (17 g.) of hydroxide ions.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

of an unknown solution.

The normality (N) of a solution is the number of gram equivalents of solute in a liter of solution.

Pupils should be able to prepare a specified volume of a solution with a definite normality.

*For a specific reaction, gram equivalents can be based upon any ion. However, pupils will be responsible only for gram equivalents of acids, based on the hydrogen ion equivalent, and of bases, based on the hydroxide ion equivalent.*

. One gram equivalent of an acid is the mass in grams that furnishes 1 mole (1 g.) of hydrogen ions.

. One mole of an acid or base contains 1 or more moles of hydrogen or hydroxide ions.

One mole of HCl contains only 1 mole of hydrogen ions; one mole of H<sub>2</sub>SO<sub>4</sub> has 2 moles of hydrogen ions; and one mole of H<sub>3</sub>PO<sub>4</sub> yields 3 moles of hydrogen ions.

An acid which contains 2 moles of hydrogen ions per mole of acid is called a diprotic acid.

. One gram equivalent of a base is the mass in grams that furnishes 1 mole (17 g.) of hydroxide ions.

A base which contains 2 moles of hydroxide ions per mole of base is called a dihydroxy base.

Topical Outline

Understandings  
and Concepts

Laboratory

The normality of an acid or base can be determined by slowly combining it with a base or acid of known normality (standard solution) until neutralization occurs. This process is called titration.

Titration given in manuals.

The end point of the titration may be determined by the use of appropriate indicators.

The normality of the unknown solution can be calculated from the following equation:

Determine the acetic acid kinds of amount of antacid pre neutralize.

Volume of unknown solution x its normality =  
volume of known solution  
x its normality.

C. Instrument analysis

1. pH meters

Many titrations involve bringing a solution to a specific pH.

Understandings  
and Concepts

Laboratory Experiences

Supplementary Information

Normality of an acid  
base can be determined  
by slowly combining it  
with a base or acid of  
known normality (standard  
solution) until neutral-  
ization occurs. This pro-  
cedure is called titration.

Titration exercises are  
given in most laboratory  
manuals.

End point of the titra-  
tion may be determined by  
the use of appropriate  
indicators.

The end point of the titra-  
tion can be determined by  
temperature changes or  
electrode potential  
changes. End points deter-  
mined by the above methods  
are achieved by instrument  
analysis.

Normality of the  
unknown solution can be  
calculated from the follow-  
ing equation:

Determine the amount of  
acetic acid in different  
kinds of vinegar or the  
amount of acid a stomach  
antacid preparation can  
neutralize.

Volume of unknown solu-  
tion  $\times$  its normality =  
Volume of known solution  
 $\times$  its normality.

Some titrations involve  
adding a solution to a  
solution of specific pH.

Topical Outline

Understandings  
and Concepts

Laboratory Experi

The pH scale can be used to express the strength of an acid or base.

- . A pH 7 indicates a neutral solution containing equal concentrations of hydrogen ions and hydroxide ions.
- . A pH under 7 indicates that there are more hydrogen ions than hydroxide ions in the solution.
- . As the concentration of hydrogen ions increases, the pH decreases.
- . A pH greater than 7 indicates that there are more hydroxide ions than hydrogen ions in the solution.
- . As the concentration of the hydroxide ions increases, the pH increases.

Compare the colors of universal indicator in various acid, base, and neutral solutions with the scale for the indi

A pH meter measures the pH of a solution more accurately than indicators

If a pH meter is available, have the pupils do acid-base titratio

Standings

Concepts

le can be used  
the strength of  
base.

indicates a neu-  
tation containing  
concentrations of  
ions and hydrox-  
s.

er 7 indicates  
re are more  
ions than  
e ions in the

concentration of  
ions increases,  
decreases.

reater than 7 indi-  
that there are  
hydroxide ions than  
ions in the

concentration of  
hydroxide ions  
es, the pH  
es.

r measures the  
olution more  
y than indicators

Laboratory Experiences

Compare the colors of uni-  
versal indicator in var-  
ious acid, base, and salt  
solutions with the pH color  
scale for the indicator.

If a pH meter is available,  
have the pupils do an  
acid-base titration.

Supplementary Information

*Pupils are not expected to  
become involved with the  
calculation of pH from the  
negative log of the hydro-  
gen ion concentration.*

Point out that an indi-  
cator changes color at a  
pH specific for the indi-  
cator. Not all indicators  
change at a pH of 7.

The pH meter depends upon  
electrode potential  
changes. The instrument

Topical Outline

Understandings  
and Concepts

Laboratory Experiences

2. Colorimeters  
and spectro-  
photometers

do.

Upon dissolving, some sub-  
stances form colored solu-  
tions.

The depth of color of a  
solution increases as the  
concentration of the sol-  
ute increases.

As light is passed through  
a solution, some light is  
absorbed and the rest is  
transmitted.

The amount of light trans-  
mitted through a solution  
can be measured by a  
photoelectric cell in  
instruments known as color-  
imeters or spectrophotome-  
ters.

Compare the results with  
those obtained by using  
phenolphthalein and methyl  
orange indicators.

Compare the colors of a  
series of known dilutions  
of copper sulfate or  
potassium permanganate.  
Directions for making the  
dilutions are found in  
A 8.12.

Determine the concentration  
of a solution by matching  
it against equal volumes  
of the series prepared  
above.

standings  
Concepts

Laboratory Experiences

Supplementary Information

Compare the results with those obtained by using phenolphthalein and methyl orange indicators.

can be used successively by pupils.

lving, some sub-  
rm colored solu-

of color of a  
ncreases as the  
ion of the sol-  
ses.

Compare the colors of a series of known dilutions of copper sulfate or potassium permanganate. Directions for making the dilutions are found in A 8.12.

is passed through  
n, some light is  
and the rest is  
ed.

Determine the concentration of a solution by matching it against equal volumes of the series prepared above.

The most simple form of colorimeter is based on matching an unknown with a known standard.

t of light trans-  
rough a solution  
asured by a  
tric cell in  
ts known as color-  
r spectrophotome-

A photoelectric cell changes light energy into electrical energy.

As the amount of light falling on a photoelectric cell increases, the electrical current in the circuit increases.

Specific frequencies of light absorbed or transmitted can be measured by

Topical Outlines

Understandings  
and Concepts

Laboratory Experience

By comparing the amount of transmission or absorption with that of standard solutions of the solute, the unknown concentration of solute in a given solution can be determined.

## Laboratory Experiences

## Supplementary Information

placing colored filters, a prism, or a diffraction grating in the optical system.

Generally, the transmission of a series of known dilutions of a specific solute is plotted to make a standardized transmission-concentration graph. After determining the amount of transmission, the technician can read the concentration of a solution from the standardized graph.

*If a spectrophotometer or colorimeter is available, the teacher may wish to develop this section in depth.*

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ption  
sol-  
the  
of  
ution

## APPENDIX A - LABORATORY ACTIVITIES

### A 1.01 Change of Phase

Insert a thermometer into the two-hole stopper of a distilling flask. Position the thermometer bulb will be opposite the delivery tube arm of the flask which is supported on an iron ring stand. Put the stopper with the water. Pupils should observe that the "steam" coming from the arm. The true steam is the invisible gas between the boiling water and the

### A 1.02 Long Form of the Periodic Table

Pupils may be interested in deriving a long form Periodic Table. Divide an adding machine into 104 1-inch wide boxes. Starting at the left end from 1 to 104.

Pass out an alphabetical list of all the elements (except the transition metals) in alphabetical arrangement and atomic number for each. Instruct the pupils to refer to the list in any box on their paper strip that has a number equal to the atomic number. Mark 1 electron in its highest principal energy level. Use another mark to indicate elements with only 8 electrons in their highest principal energy level.

Use masking tape to fasten the left edge of the strip to the upper left corner of paper, manila folder, or desk top. Cutting the strip where necessary so that the same kind of marked boxes are under each other. Remind pupils as one reads from left to right or top to bottom. The strips will not be of their unequal lengths.

In order to "flatten" the chart, cut between the two boxes of the first row enough so that box 10 of the second row can be located directly under box 1. Pupils will see the necessity for further cutting and shifting the strip. If a shift appears necessary, point out that the table will become too large. A section could be cut out and fastened "down below." When the arrangement is complete, label the periods (horizontal rows) and groups (vertical columns). Insert symbols in the "cutout sections."

If the table is fastened inside a manila folder, students can conveniently use the Periodic Tables and add additional information about the elements as it goes by each year.

## APPENDIX A - LABORATORY ACTIVITIES

o-hole stopper of a distilling flask so that when the stopper is in place, it will be opposite the delivery tube arm of the flask. Pour some water into a flask and place it on an iron ring stand. Put the stopper with the thermometer in place, and boil the water. Explain to the pupils that the "steam" coming from the arm is really a fog of condensed steam. This is the gas between the boiling water and the condensed fog.

Using a long form Periodic Table. Divide a 9-foot strip of paper from a roll of paper into 12 wide boxes. Starting at the left end of the strip, number the sections 1 through 12.

Write the names of all the elements (except the transition elements), giving the electronic configuration for each. Instruct the pupils to refer to the list and to place a "1" in the box that has a number equal to the atomic number of an element that has only one principal energy level. Use another mark to identify boxes representing elements that have their highest principal energy level.

Attach the left edge of the strip to the upper left-hand corner of a large sheet of paper. Starting from the top. Cutting the strip where necessary, pupils should arrange the strip so that the boxes are under each other. Remind pupils that the numbers must increase from left to right and from top to bottom. The strips will not be flat but will form loops due to the way they are attached.

Make a cut between the two boxes of the first strip, and shift box 2 over far enough so that box 2 of the second row can be located directly under it when the second row is flattened. This is the way to proceed for further cutting and shifting to straighten row 4. When another row is added, explain to the pupils that the table will become too large for convenient use and that a different arrangement is needed. Flatten "down below." When the arrangement has been completed, number the groups (vertical columns). Insert symbols, and label the series represented.

When the arrangement is completed, insert it into a manila folder, students can conveniently keep their own "homemade" periodic table. This is a valuable piece of information about the elements as it is taught throughout the school year.

#### A 2.01 Reactions Between Aqueous Solutions

An interesting laboratory problem can arise from mixing equal volumes of from a number of prepared solutions, and identifying any products resulting from two solutions.

Direct pupils to find as many reacting combinations as they can within a few ground rules concerning the amounts of solutions to be used and timing before starting another.

Some diluted aqueous solutions that provide a wide range of reactions are  $\text{BaCl}_2$ ,  $\text{CuSO}_4$ ,  $\text{AgNO}_3$ ,  $\text{K}_2\text{CO}_3$ ,  $\text{NaOH}$ , and  $\text{FeCl}_3$ .

#### A 2.02 Quicklime from Limestone

Place a few small pieces of marble or limestone on a wire screen support burner under the screen, and adjust the support so that the screen crosses the cone. Heat the limestone intensely with the burner for 15 to 20 minutes. Compare their appearance with pieces of the original unheated limestone. Add water with a dropper or pipette to both heated and unheated samples. Note any evidence of a chemical change.

If pupils need further evidence that a chemical change has occurred during the test, test both heated and unheated pieces with wet red or neutral litmus. Neutral litmus turns the litmus blue.

#### A 2.03 Reading Labels on Reagent Bottles

Display a number of bottles of reagents, each labeled with the appropriate name as  $\text{CuS}$ ,  $\text{CuSO}_3$ ,  $\text{CuSO}_4$ ,  $\text{NaHCO}_3$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{MgO}$ ,  $\text{HgO}$ ,  $\text{FeCl}_2$ , and  $\text{FeCl}_3$ .

Ask the pupils to select the bottles containing any reagent, the name of which is given as part of the laboratory work.

Pupils can develop skills in recognition of formulas as well as in understanding the meaning of labels during the selections of chemicals.

#### A 2.04 Adapting Feltboard Techniques

The feltboard techniques described in CH 1.17 and CH 1.18 can be used by substituting small circles of colored construction paper for felt circles.

arise from mixing equal volumes of aqueous solutions, two at a time, and identifying any products resulting from the interaction of the

g combinations as they can within a given period of time. Establish amounts of solutions to be used and the need for completing one combina-

provide a wide range of reactions are:  $\text{Pb}(\text{NO}_3)_2$ ,  $\text{KI}$ ,  $\text{HCl}$ ,  $\text{MgSO}_4$ ,  $\text{FeCl}_3$ .

limestone on a wire screen supported by a ringstand. Set a Bunsen burner support so that the screen crosses the point of the blue inner cone of the burner for 15 to 20 minutes. Cool the pieces and compare with original unheated limestone. Add water drop by drop with a medicine dropper to unheated samples. Note any evidence of chemical reaction.

a chemical change has occurred during the heating of the limestone, test with wet red or neutral litmus. Notice that the heated limestone

tests, each labeled with the appropriate formula. Include such items as  $\text{MgO}$ ,  $\text{HgO}$ ,  $\text{FeCl}_2$ , and  $\text{FeCl}_3$ .

containing any reagent, the name of which appears on a list given

tion of formulas as well as in understanding the need for careful use of chemicals.

CH 1.17 and CH 1.18 can be used by pupils doing individual work. Construction paper for felt circles and a piece of cardboard for

the feltboard. The colored papers can be fastened to the cardboard tape.

A manila folder can be used not only for the cardboard but also for The substitute materials can be used in the same manner as feltboard

#### A 2.05 Combining Mole Ratio

Make up 100 ml. of a 1 molar solution of NaOH and 100 ml. of a 1 molar acid. Label each solution 0.001 moles/ml.

Pour 10 ml. of the base into each of three test tubes. To the first 10 ml.; and to the third, add 20 ml. of the acid.

Stir the solution in each test tube, and test its pH using a few ml. of litmus. Point out that an acid neutralizes a base. Ask the pupils which test

Calculate the number of moles of acid put as a solute into each test

$$\text{vol. (ml.)} \frac{x \text{ moles}}{\text{ml.}} = \text{moles acid used}$$

Find the apparent mole-combining ratio involved in this reaction.

---

#### A 3.01 Regular Tetrahedron

From strips of cardboard, cut four equilateral triangles 4 inches on one side. Use tape to make a tetrahedron.

---

#### A 4.01 Changing Alkanes to Alcohol

- a. Build a model of a methane molecule and an -OH functional group. A hydroxyl group can be put on the methane molecule to form methyl alcohol. One of the functional groups must be substituted for a hydrogen atom, go on

---

papers can be fastened to the cardboard by pins, thumbtacks, or bits of masking

not only for the cardboard but also for storing the materials.

be used in the same manner as feltboard materials.

solution of NaOH and 100 ml. of a 1 molar solution of hydrochloric acid.  
les/ml.

each of three test tubes. To the first test tube, add 5 ml.; to the second  
20 ml. of the acid.

st tube, and test its pH using a few ml. of universal indicator solution.  
alizes a base. Ask the pupils which test tube contains the neutral solution.

s of acid put as a solute into each test tube containing the base:

$$\text{vol. (ml.)} \frac{x \text{ moles}}{\text{ml.}} = \text{moles acid used}$$

ning ratio involved in this reaction.

---

t four equilateral triangles 4 inches on each side. Assemble with cellulose

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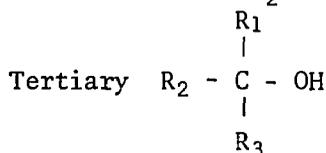
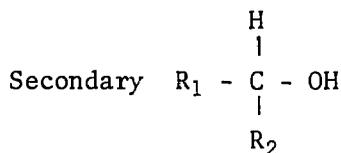
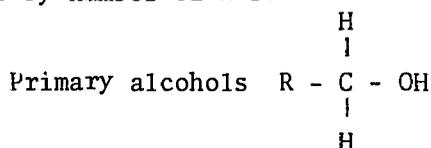
ne molecule and an -OH functional group. Ask the pupils how the functional  
methane molecule to form methyl alcohol. Once the pupils understand that  
t be substituted for a hydrogen atom, go on to part b.

- b. Set up a problem: Using no more than one -OH group on a carbon atom from the first five members of the alkanes. Record the structural formulas for alcohols containing the same number of carbons as those with other carbon counts in corresponding columns.

Pupils should discover straight chain (normal) alcohols, isomers which is not an "end" carbon, and those containing more than one

In discussing the results, organize their findings, as:

Types by number of R's:



#### A 4.02 Solubilities of Alcohols

The use of semimicro techniques can reduce the concentration of reagents to the safety aspect of the laboratory experience.

Into each of four test tubes, put 10 drops of water. To each tube add one drop of alcohol. Stir the mixture. Record the results. Use ethanol, n-propanol, 2-propanol, n-butanol for use.

Compare the depth of any immiscible layers. The least soluble alcohol is the "alcohol layer."

more than one -OH group on a carbon atom, make as many alcohols as possible of the alkanes. Record the structural formula representing each model. For alcohols containing the same number of carbon atoms in one column, list them in corresponding columns.

For (normal) alcohols, isomers in which the -OH is on a carbon atom other than those containing more than one functional group.

Record their findings, as:

Types by number of -OH groups:

Monohydroxy 1 -OH

Dihydroxy 2 -OH groups

Trihydroxy 3 -OH groups

To reduce the concentration of volatile vapors from alcohols and conduct laboratory experience.

10 drops of water. To each tube, add 10 drops of an alcohol, a different alcohol. Propanol, 2-propanol, n-butanol, glycerol, and n-pentanol are suitable

layers. The least soluble alcohol will have the greatest depth of

A 4.03 Oxidation of a Primary Alcohol - Formation of Aldehyde Group

Have the pupils make a methanol model, and take out some oxygen "atoms" to change the model so it has one C, two H, and one O atom. Observe the model. The final model may not have the same composition as  $C_3H_6O$ . Pupils will note that two hydrogen atoms are removed. The extra O atoms taken from the box should give a high yield of formaldehyde.

Show a homologous series 
$$\begin{array}{c} \text{H} \\ | \\ \text{H} - \text{C} = \text{O} \end{array}$$

Remove the hydrogen indicated in the diagram and substitute alkane groups. Propanal, and butanal will be formed. This should develop a general formula.

A 4.04 Oxidation of a Secondary Alcohol - Formation of Ketone Group

Start with a model of 2-propanol and some oxygen "atoms." Have the pupils change the model to represent a composition of  $C_3H_6O$ . The final model may not have the same composition as  $C_3H_6O$ . Ask the pupils to indicate what is added. By changing the length of the carbon chains, the homologous series can be developed.

A 4.05 Oxidation of an Aldehyde

Prepare an oxidizing agent of 1 g.  $KMnO_4/100 \text{ ml. H}_2O$ . To 15-20 ml of acetaldehyde. The odor of vinegar should be observed. Warm the mixture if necessary.

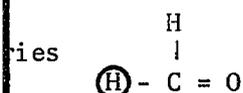
A 4.06 Oxidation To Form a Carboxylic Group, Using Models

Ask pupils to change a model of  $CH_4$  to  $CH_2O_2$ . The only restriction is that two oxygen atoms cannot bond together. Show that  $HCOOH$  is formed by adding carbon chains in place of the hydrogen on the carbon atom.

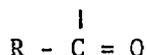
The preparation of an acid by oxidation of a primary alcohol can be shown by changing  $CH_3OH$  and changing it to  $HCOOH$ . Hydrogen must be removed, and oxygen added.

### Primary Alcohol - Formation of Aldehyde Group

Use a methanol model, and take out some oxygen "atom" balls from the kit. Ask the pupils to make a model that has one C, two H, and one O atom. Observe bonding requirements: 1 for H, 4 for C, 2 for O. Pupils will note that two hydrogen atoms are removed. Ask for a possible way these could be removed. Two O atoms taken from the box should give a hint. The substance formed, HCHO, is



As indicated in the diagram and substitute alkane chains of 1, 2, and 3 carbons. Ethanal,  $\text{CH}_3\text{CHO}$ , will be formed. This should develop a general aldehyde formula



### Secondary Alcohol - Formation of Ketone Group

Use 2-propanol and some oxygen "atoms." Have the pupils figure out how to change the composition of  $\text{C}_3\text{H}_8\text{O}$ . The final model may not have an H atom on the oxygen or the oxygen not attached. Ask the pupils to indicate what had to be removed and what needed to be added. As the length of the carbon chains, the homologous series can be shown.

### Aldehyde

Use a solution of 1 g.  $\text{KMnO}_4/100 \text{ ml. H}_2\text{O}$ . To 15-20 ml. of the oxidizing solution, add 10 drops of the aldehyde. The odor of vinegar should be observed. Warm the solution in a hot water bath if necessary.

### Carboxylic Group, Using Models

Use a model of  $\text{CH}_4$  to  $\text{CH}_2\text{O}_2$ . The only restriction other than usual bond requirements is that two oxygen atoms cannot bond together. Show that  $\text{HCOOH}$  is the start of a homologous series by substituting an alkyl group in place of the hydrogen on the carbon atom.

The formation of a carboxylic acid by oxidation of a primary alcohol can be shown by starting with a model of the alcohol and showing its conversion to  $\text{HCOOH}$ . Hydrogen must be removed, and oxygen added. This is an oxidation reaction.

Normal alcohol partial oxidation, aldehyde oxidation, acid.

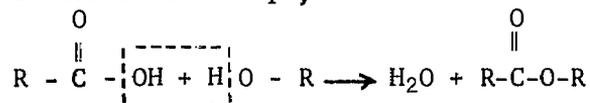
#### A 4.07 Esterification

Have models of methanol and methanoic (formic) acid available.

Ask pupils to combine the two molecules by removing only two hydrogen atoms a molecule of water.

Some pupils will use the OH of the alcohol; others, the OH of the acid. The pupils of the function of tagged atoms.

By use of a radioactive isotope, it was found that the reaction proceeded:



Pupils should note that  $\begin{array}{c} \text{O} \\ \parallel \\ - \text{C} - \text{O} - \end{array}$  is the functional group of esters. (A

#### A 4.08 Amine Group

a. Make a model of an  $\text{NH}_3$  molecule. Remove one hydrogen atom. The result is an amine group  $\begin{array}{c} \text{H} \\ \diagup \text{N} \\ \diagdown \text{H} \end{array}$ . Attach alkane carbon chains to show the formation of

b. Make a model of  $\text{H} - \text{O} - \text{C} \begin{array}{c} \text{O} \\ \parallel \\ \text{---} \end{array} \begin{array}{c} \text{H} \\ | \\ \text{C} \\ | \\ \text{H} \end{array} - \begin{array}{c} \text{H} \\ \diagup \text{N} \\ \diagdown \text{H} \end{array}$ . Point out that structures show

functional groups, a carboxylic group and an amine group. The combination

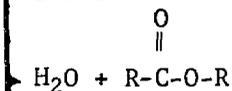
oxidation, acid.

ic (formic) acid available.

ules by removing only two hydrogen atoms and one oxygen atom to form

alcohol; others, the OH of the acid. This is an opportunity to inform  
oms.

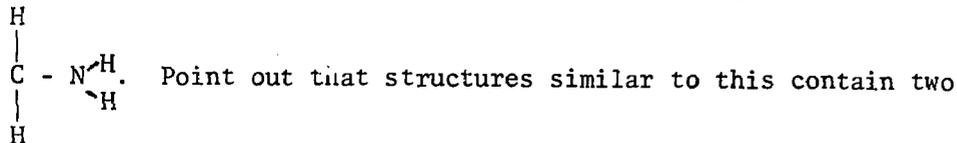
was found that the reaction proceeded:



is the functional group of esters. (A memory device - "Esters coo")

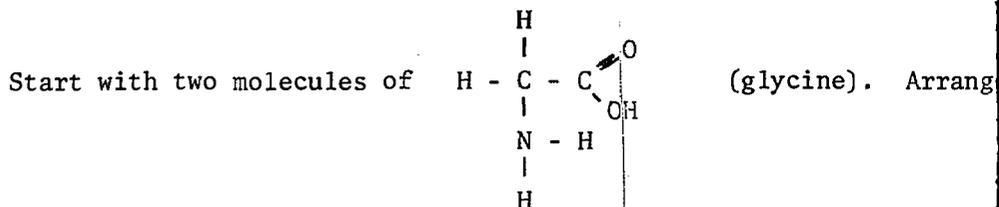
Remove one hydrogen atom. The resulting functional group is an

carbon chains to show the formation of amine compounds.

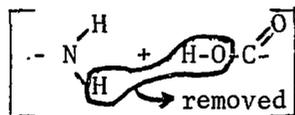


group and an amine group. The combination makes an amino acid molecule.

A 4.09 Amide Linkage



one faces the amide ending of the other. Connect the two models b



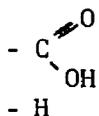
A dipeptide with an amide linkage has been formed. By using a thi  
 tide can be formed.

If each pupil makes a model of a different amino acid, a "protein"  
 together by removal of H<sub>2</sub>O and establishment of an amide linkage.

A 4.10 Glyceride Structures

By an esterification process (A 4.07), join an ethanoic acid molec  
 erol model and methanoic acid molecules to each of the two remaini  
 sulting model represents an ester of glycerol called a glyceride.

Extend the carbon chain of the acetate (an ethanoic acid group) to  
 If chains of from 12-18 carbons are also put on the other "acid" c  
 result.



(glycine). Arrange the models so the carboxylic group of

other. Connect the two models by removing a water molecule.

has been formed. By using a third molecule of glycine, a longer pep-

ifferent amino acid, a "protein" can be formed by joining the models  
 ablishment of an amide linkage.

07), join an ethanoic acid molecule model to one -OH group of a glyc-  
 cules to each of the two remaining -OH groups of glycerol. The re-  
 of glycerol called a glyceride.

tate (an ethanoic acid group) to 12 carbons (if balls are available).  
 e also put on the other "acid" chains, a fatty glyceride molecule would

A 5.01 Effect of Heat on the Enzyme, Rennin

Crush a Junket tablet (rennin source), and dissolve it in 10 ml. of distilled water solution in a water bath for 5-10 minutes, then cool the solution to room temperature.

Crush and dissolve a Junket tablet in 10 ml. of distilled water (room temperature).

Into each of two test tubes, place 20 ml. of warm milk (25-30°C.). To the first tube add 1 ml. of the heated enzyme solution, and to the other tube 1 ml. of the unheated enzyme solution. Allow the milk to "set into a pudding." Because of heat destruction of the enzyme, coagulation will not occur in the milk that contains the heated junket tablet.

The "coagulating effect" of the enzyme, rennin, is really coagulation of casein.

A 5.02 Stages of Boiling Syrup

Boiling a sugar solution causes a solution of simple sugars to be formed. As the water-to-sugar ratio increases, the syrup assumes various "stages."

Add 100 g. of sugar to 60 ml. of hot water in a 250-ml. beaker. Stir the sugar until it is completely dissolved. Suspend a thermometer from a clamp and adjust the position of the thermometer so that the bulb is centered in the solution. Heat the solution over a low flame, and record the temperature when the solution begins to boil. When the solution reaches 105°C., test it by placing a few drops of the solution in an evaporating dish. Describe the appearance and consistency of the syrup. Continue to boil the solution, and test the solution at intervals of 5°C. by placing a few drops in cold water. Above 140°C., the syrup is apt to caramelize, so heating should be stopped. Heating over a low flame is recommended.

*Remind pupils that boiling syrup is much hotter than boiling water and can be easily spilled on the skin.*

The success of this exercise depends upon the absence of seed crystals of sugar. If seed crystals of sugar initially appearing on the beaker wall are "washed down," a stirring rod can be used to remove crystals.

An alternate method of testing the solution is by the use of a hydrometer. If a hydrometer is used, a hydrometer syrup will be necessary. Hydrometers may be found in general science and chemistry.

## Enzyme, Rennin

(rennin source), and dissolve it in 10 ml. of distilled water. Heat the enzyme solution for 5-10 minutes, then cool the solution to room temperature.

Crush a junket tablet in 10 ml. of distilled water (room temperature).

Place 20 ml. of warm milk (25-30°C.). To the first tube, add 1 ml. of the heated enzyme solution, and to the other tube 1 ml. of the unheated enzyme solution. Compare the time required to form a pudding. Because of heat destruction of the enzyme, coagulation should not occur with the tube that contains the heated junket tablet.

The action of the enzyme, rennin, is really coagulation of casein, a milk protein.

Heat causes a solution of simple sugars to be formed. As the simple sugar to water solution becomes a syrup it assumes various "stages."

Place 60 ml. of hot water in a 250-ml. beaker. Stir the mixture until the sugar has dissolved. Remove the thermometer from a clamp and adjust the position of the thermometer so the bulb is in the solution. Heat the solution over a low flame, and record the temperature at which the solution begins to boil. When the solution reaches 105°C., test it by putting a few drops into a cold porcelain dish. Describe the appearance and consistency of the "sugar solution." Continue heating, and test the solution at intervals of 5°C. by putting some of the solution into a cold porcelain dish. At 140°C., the syrup is apt to caramelize, so heating beyond that temperature is not recommended.

*Boiling syrup is much hotter than boiling water and can cause very serious burns when*

Exercise depends upon the absence of seed crystals of sugar. Be sure that any crystals appearing on the beaker wall are "washed down." A wet cloth around the end of the beaker is used to remove crystals.

Testing the solution is by the use of a hydrometer. Larger quantities of boiling water may be used. Hydrometers may be found in general science and physics laboratories.

A 5.03 Hydrolysis of Proteins

- a. Place two or three small pieces of hard-cooked egg white in dilute HCl to the first and 15 ml. of water to the second water and boil for 1/2 - 1 hour. Note the effect on the acid to marinating meats in vinegar solution to tenderize.
- b. Meat tenderizers contain enzymes which promote the hydrolysis of a tenderizer on hard-cooked egg white.
- c. Remove as much flesh as possible from a joint, and boil for 1/2 hour or for 1/2 hour in a pressure cooker. Strain the liquid. When the liquid is cooled, the gelatin formed during hydrolysis will solidify.

A 5.04 Coagulation of Proteins

- a. By heat:  
Remove an egg from its shell, and drop the egg into boiling water. Boil some milk for 2-3 minutes. Let it cool.
- b. By acid:  
Add dilute HCl drop by drop to skim milk. As the addition of acid the proteins coagulate. Relate this activity to the souring of milk. Responsible for the curdling.

A 5.05 Coagulation of Gluten in Flour and Factors Affecting it

- a. Mix enough water with flour to form a dough. Knead the dough in a bag and tie the bag with a string. Immerse the bag in a large amount of water through the dough to remove the starch. Hold the bag under water until the bag is clear. Open the bag and note the elastic strands.
- b. Pupils can compare the amount of gluten in various flours by kneading in cold water and kneading all doughs for the same amount of time. Measure the gluten's volume, weight, and resistance to being stretched.

To conserve time, it is suggested this part be assigned to one of the flours.

Use samples of cake, regular pastry, graham, whole wheat,

all pieces of hard-cooked egg white in each of two test tubes. Add 15 ml. of  
t and 15 ml. of water to the second. Set the test tubes in a beaker of boiling  
2 - 1 hour. Note the effect on the egg in each case. Relate the results of the  
ats in vinegar solution to tenderize them.

ain enzymes which promote the hydrolysis of the protein. Test the effect of the  
oked egg white.

as possible from a joint, and boil the remaining bones and gristle for 1-2 hours  
pressure cooker. Strain the liquid in which the joint was cooked. When the  
gelatin formed during hydrolysis will form a gel.

s shell, and drop the egg into boiling water.  
3 minutes. Let it cool.

y drop to skim milk. As the addition of acid continues, "cottage cheese"  
Relate this activity to the souring of milk. Lactic acid in sour milk is re-  
dling.

#### Flour and Factors Affecting it

flour to form a dough. Knead the dough for 2 or 3 minutes. Put it in a cloth  
with a string. Immerse the bag in a vessel of cold water and work the water  
remove the starch. Hold the bag under running water until the water coming from  
en the bag and note the elastic strands of gluten.

the amount of gluten in various flours by using 50 g. of a flour and 25 ml. of  
ing all doughs for the same amount of time. After the starch has been washed out,  
weight, and resistance to being stretched can be compared.

is suggested this part be assigned to a "team," each member being responsible for

regular pastry, graham, whole wheat, and rye flours for comparison.

- c. Effect of kneading:  
Prepare doughs from 50 g. of all purpose flour and 25 ml. of water. Knead one dough for 5 minutes. Remove the starch from each and compare the results.
- Compare the mixing method for muffins and bread listed in cookbooks.
- d. Effect of sugar:  
Mix a dough, and knead for 2 or 3 minutes for each of the following:  
1. 50 g. flour, 65 g. sucrose, and 25 ml. H<sub>2</sub>O  
2. 50 g. flour, 15 g. sucrose, and 25 ml. H<sub>2</sub>O  
3. 50 g. flour and 25 ml. H<sub>2</sub>O  
Wash out the starch and compare gluten formation. Relate the results to the effect of sugar in bread and cake doughs and to the textures of each.
- e. Effect of liquid:  
Mix two doughs, one having 50 g. flour to 25 ml. H<sub>2</sub>O, and the other 50 g. flour to 50 ml. H<sub>2</sub>O. Knead each for 2-3 minutes, wash out starch, and compare gluten formation. Discuss the effect of liquid in making cakes or rolls.
- f. Effect of egg:  
Make dough for each of the following, knead for 3-5 minutes, and wash out starch.  
1. 50 g. flour and 25 ml. H<sub>2</sub>O  
2. 50 g. flour, 25 ml. H<sub>2</sub>O, and 15 ml. beaten egg  
3. 50 g. flour and 50 ml. beaten egg

Compare gluten formation. Discuss the effect of too much egg in batters and cakes. Divide the class into several parts can be quickly covered by teams, each team being responsible for one part of the experiment for one mixture. Class discussion should center around a comparison of results.

#### A 5.06 Colloidal Properties of Starch

- a. Starch and water mixture.  
Add 2 grams of starch to 100 ml. of water and stir. Compare the appearance of the mixture with that of a sugar solution. Filter a few milliliters of the solution and compare it with the original mixture.
- b. Boiling starch and water mixture.  
Carefully heat the remaining starch and water mixture and boil it for a few minutes. Note the change in appearance. A test for a colloidal solution is the Tyndall test.

purpose flour and 25 ml. of water. Knead one dough for 1 minute and remove the starch from each and compare the amount of gluten.

ffins and bread listed in cookbooks.

3 minutes for each of the following:

and 25 ml. H<sub>2</sub>O

and 25 ml. H<sub>2</sub>O

gluten formation. Relate the results to the relative amounts of starch and to the textures of each.

flour to 25 ml. H<sub>2</sub>O, and the other 50 g. flour to 40 ml. H<sub>2</sub>O. Knead the starch, and compare gluten formation. Discuss the effect of too much

ing, knead for 3-5 minutes, and wash out the starch:

and 15 ml. beaten egg

in egg

the effect of too much egg in batters and doughs. The last three trials, each team being responsible for one part and each pupil on a team should center around a comparison of results.

of water and stir. Compare the appearance of the resulting mixture. Filter a few milliliters of the solution, and compare the filtrate

starch and water mixture and boil it for a minute or two. Note any change. A colloidal solution is the Tyndall test. Darken the room, and

direct a narrow beam of light through the beaker containing the  
of the transmitted light with that obtained when the beam is pas  
de-ionized water will show the Tyndall effect!)

- c. Cool the colloidal starch solution, and note any change in consi  
cules tend to form a network that "traps" the water and the gel  
Relate this action to the thickening of gravy and the use of lau

#### A 5.07 Insolubility of Lipids

- a. Put 10 ml. of water into each of four test tubes. To the first  
oil; to the second, a few milliliters of cooking or olive oil;  
or lard; to the fourth, some oleomargarine. (A piece about the  
amount of solid lipid.)

Compare their solubilities.

- b. The above procedure may be repeated with vinegar. Water and vin  
in cooking.

#### A 5.08 Emulsifying Action of Eggs and Starch

- a. Place equal amounts of the following substances in four numbered  
lution, starch solution, egg white diluted with an equal amount

To each test tube, add 3 drops of cottonseed oil. Shake each tub  
substances remain mixed with the oil.

- b. Pour 30 ml. of cooking oil and 15 ml. of vinegar into a small gi  
ously. Divide the mixture into two portions. Allow one portion  
that form. Add a few milliliters of egg yolk to the second port  
again. Watch to see if the mixture still separates into layers.

Relate the results in these activities to the use of egg in mayo  
of flour and eggs on the fat in cake.

#### A 5.09 Chemicals Suitable for a Baking Powder

Test the effect of water on starch, sodium bicarbonate, calcium mono  
tartaric acid, calcium dihydrogen phosphate, and potassium aluminum s

of light through the beaker containing the starch solution. Compare the path of light with that obtained when the beam is passed through distilled H<sub>2</sub>O. (Tap or show the Tyndall effect!)

starch solution, and note any change in consistency of solution. The starch molecule network that "traps" the water and the gel results. Note the thickening of gravy and the use of laundry starch to give "body" to fabrics.

Put into each of four test tubes. To the first, add a few milliliters of cottonseed oil; to the second, a few milliliters of cooking or olive oil; to the third, a small amount of butter; to the fourth, some oleomargarine. (A piece about the size of a pea should give an adequate amount.)

activities.

This experiment may be repeated with vinegar. Water and vinegar are the solvents most often used.

### Emulsions and Starch

Put into the following substances in four numbered test tubes: water, dilute soap solution, egg white diluted with an equal amount of water.

Add 3 drops of cottonseed oil. Shake each tube vigorously, and note which of the substances emulsifies with the oil.

Add 5 ml. of oil and 15 ml. of vinegar into a small glass jar, and shake the mixture vigorously. Divide the mixture into two portions. Allow one portion to stand, and note the two layers. Add 5 milliliters of egg yolk to the second portion, and shake the jar vigorously. Note if the mixture still separates into layers.

Apply these activities to the use of egg in mayonnaise, flour in gravy, and the effect of fat in cake.

### Baking Powder

Identify the components of baking powder: starch, sodium bicarbonate, calcium monohydrogen phosphate, cream of tartar, potassium dihydrogen phosphate, and potassium aluminum sulfate.

Which combinations of the above materials will produce  $\text{CO}_2$ ? Any combination make up an active ingredient of a baking powder.

#### A 5.10 The Role of Proteins in Leavening

Mix thoroughly 2 teaspoonfuls of cream of tartar, 1 teaspoonful of baking cornstarch. Divide the mixture into two equal portions in 100-ml. beakers. Add 10 g. of powdered egg white, and mix well. Now add 10 ml. of water to each. Observe the nature and durability of the foam that forms in each case. Try to stabilize cake batter and keep a cake from falling.

#### A 5.11 Controlling Crystal Growth in Candy Making

##### a. Size of crystals

Boil a sugar and water solution until  $114^\circ\text{C}$ . is reached, and then pour into four evaporating dishes. Beat the first portion at once and the others at  $70^\circ\text{C}$ .,  $60^\circ\text{C}$ ., and  $40^\circ\text{C}$ .

Using a low-power magnification of 200x, examine the crystals from each dish. The size of the crystals varies with the temperature at which they form.

##### b. Substances controlling crystal size

Prepare the following mixtures in separate beakers:

1. 50 g. cane sugar and 25 ml.  $\text{H}_2\text{O}$  (control)
2. 50 g. cane sugar and 0.1 g. of cream of tartar in 25 ml.  $\text{H}_2\text{O}$
3. 50 g. cane sugar and 4 ml. of vinegar in 25 ml.  $\text{H}_2\text{O}$
4. 50 g. cane sugar and 10 ml. of light corn syrup in 25 ml.  $\text{H}_2\text{O}$
5. 50 g. cane sugar and 25 ml.  $\text{H}_2\text{O}$  and 3 ml. glycerine

Boil each mixture until  $115^\circ\text{C}$ . is reached; then pour it into an evaporating dish. Examine each sample for 2 minutes.

Compare the textures of the mixtures, and discuss measures that can be taken to control crystal size. Cookbooks will verify your answers.

To save time, groups of students can be assigned the experiment. Each pupil responsible for one of the mixtures. Group results can be compared.

*Caution pupils about hot boiling syrup and about avoiding seed crystals in*

materials will produce CO<sub>2</sub>? Any combination that does produce CO<sub>2</sub> may be a baking powder.

1 g. cream of tartar, 1 teaspoonful of baking soda, and 1 teaspoonful of sugar are divided into two equal portions in 100-ml. beakers. To the first beaker, add 10 ml. of water and stir well. Now add 10 ml. of water to each beaker, and stir in thoroughly. Compare the amount of foam that forms in each case. The proteins from egg and flour prevent the cake from falling.

#### Candy Making

Heat the mixture until 114°C. is reached, and then pour equal portions into each of four beakers. Pour the first portion at once and the other three after they have cooled.

Under a magnifying glass or microscope of 200x, examine the crystals from each portion and note how the size varies with the temperature at which they form.

1. size  
1. in separate beakers:

1. H<sub>2</sub>O (control)
- 1 g. of cream of tartar in 25 ml. H<sub>2</sub>O
- 1 g. of vinegar in 25 ml. H<sub>2</sub>O
- 1 g. of light corn syrup in 25 ml. H<sub>2</sub>O
1. H<sub>2</sub>O and 3 ml. glycerine

Heat the mixture until 114°C. is reached; then pour it into an evaporating dish. Immediately beat

the mixture, and discuss measures that can be taken to insure a soft creamy candy. Compare the results.

This experiment can be assigned the experiment. Each pupil within a group will be responsible for one of the beakers. Group results can be compared.

*Discuss the results of the experiment and about avoiding seed crystals in the beaker.*

A 5.12 Effect of Bleaches on Fibers

Put a different type of fiber (wool, linen, cotton, silk, nylon, or another eral test tubes. Cover each fiber with water, and add 5 ml. of chlorine bleach. Wash away the bleach and observe the fibers.

Repeat the procedure by substituting hydrogen peroxide or dilute oxalic acid for the bleach.

Compare the effects of the bleaches on each fiber.

A 5.13 Effect of Disinfectants on Bacterial Growth

Prepare six sterile, nutrient agar plates.

Keep the first one unexposed for a control.

Expose each of the remaining plates to air for 2 minutes. Then add two drops of a disinfectant solution to each dish. Cover the dishes and let them set for 2-3 days. Disinfectants are a deodorant soap solution, Lysol, zepherin chloride, chlorine bleach, and so on. (The use of tap water will prove it is not a disinfectant.)

Observe bacterial growth in each dish daily. Be sure to keep the dishes covered to prevent the cultures or endangering pupils with any pathogenic bacteria.

At the conclusion of the experiment, the cultures should be sterilized before the dishes are disposed of. Disposable plastic dishes are used. The plastic dishes and cultures can be

(wool, linen, cotton, silk, nylon, or another synthetic fiber) into seven fiber with water, and add 5 ml. of chlorine bleach. After 5 minutes, rinse the fibers.

tuting hydrogen peroxide or dilute oxalic acid solution for the chlorine

aches on each fiber.

#### Bacterial Growth

agar plates.

For a control.

plates to air for 2 minutes. Then add two drops of a different disinfectant to the dishes and let them set for 2-3 days. Disinfectants that might be used (Lysol, zepherin chloride, chlorine bleach, and/or any household cleaner. Be sure it is not a disinfectant.)

each dish daily. Be sure to keep the dishes covered to avoid contaminating the plates with any pathogenic bacteria.

Experiment, the cultures should be sterilized before discarding the agar unless otherwise used. The plastic dishes and cultures can be burned in the incinerator.

#### A 6.01 Water Pollution from Oil

Put a drop of thin motor oil on water in a large shallow container such as a c wood or metal across the water. Note the rainbow effect as the thickness of t be necessary to illuminate the surface.)

Repeat the process using water collected from a puddle on a wet street.

#### A 6.02 Determining the Dissolved Oxygen Content of Water

The determination of dissolved oxygen is one of the most important tests used The following references describe this test in detail: Standard Methods for t Wastewater, Laboratory Procedures for Waste Water Treatment for Plant Operator and Clearing the Air (a study unit distributed to schools by the American Petr

The following solutions are required to run the test: 0.1N manganous sulfate per liter); alkali-iodide-azide solution (500 g. of NaOH and 135 g. of NaI. D and dilute to a liter. Then dissolve 1 gram of sodium azide,  $\text{NaN}_3$ , per 100 ml solution. This gives an alkali-iodide-azide solution which is stable for 2 we solution (dissolve 6.21 g. of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  in water and dilute to one liter); (5 grams of starch added to 1 liter of boiling water).

1. Take about 300 ml. of the water to be tested and add 2 ml. of the  $\text{MnSO}_4$  so alkali-iodide-azide solution. Mix by inverting the bottle for 20 seconds.
2. Allow the  $\text{Mn}(\text{OH})_2$  precipitate formed to settle, then add 2 ml. of conc.  $\text{H}_2$  will be formed in the solution in proportion to the dissolved oxygen origi
3. Measure 200 ml. of the solution from step 2 into an Erlenmeyer flask.
4. Titrate the solution in the Erlenmeyer flask with  $\text{N}/_{40}$  thiosulfate solutio resulting solution is pale yellow.
5. Add 1 ml. of starch solution to the flask and titrate slowly until the blu disregarding any return of color.

in a large shallow container such as a cookie sheet. Pull a strip of the rainbow effect as the thickness of the oil film changes. (It may

be observed from a puddle on a wet street.

#### Test of Water

This is one of the most important tests used in water pollution control. For test in detail: Standard Methods for the Examination of Water and Wastewater, Wastewater Treatment for Plant Operators, and Conserving our Waters (distributed to schools by the American Petroleum Institute).

To run the test: 0.1N manganous sulfate solution (480g. of  $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$  in 500 g. of NaOH and 135 g. of NaI. Dissolve separately, combine, and add 1 gram of sodium azide,  $\text{NaN}_3$ , per 100 ml. of the alkali-iodide solution which is stable for 2 weeks); N/40 sodium thiosulfate (10g.  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  in water and dilute to one liter); conc.  $\text{H}_2\text{SO}_4$ ; starch indicator (1g. in boiling water).

To be tested and add 2 ml. of the  $\text{MnSO}_4$  solution and 2 ml. of the starch solution by inverting the bottle for 20 seconds.

Allow to settle, then add 2 ml. of conc.  $\text{H}_2\text{SO}_4$  and shake. Free iodine is in proportion to the dissolved oxygen originally in the water.

Transfer step 2 into an Erlenmeyer flask.

Transfer to a 250 ml. Erlenmeyer flask with N/40 thiosulfate solution until the color of the

blue color disappears, then titrate slowly until the blue color disappears,

If exactly  $N/40$  thiosulfate solution is used to titrate 200 ml. of sample, the number of ml. of thiosulfate used is equivalent to the number of parts per million of dissolved oxygen in the water. Water at 20°C. holds about 9 p.p.m. of oxygen when saturated.

#### A 6.03 The 5-day BOD Test on Water

The 5-day BOD (Biochemical Oxygen Demand) test involves making two separate determinations of dissolved oxygen (see A 6.02) on samples taken from the same body of water at the same time. One sample is tested immediately, if possible. If this is not feasible, and the initial test must be made more than 4 hours after sampling, the initial sample of water should be refrigerated until tested.

The second sample should be kept in the dark at 20°C. for 5 days before testing it. The dissolved oxygen content of the second sample should be lower than that of the first sample. The difference between the two determinations is the Biochemical Oxygen Demand. If there are not enough organisms, the oxygen content of the water may drop to 2 mg./l. or even zero. If necessary, it is necessary to add water to some of the original sample and determine the dissolved oxygen content of this mixture as well as that of the pure water used for dilution. The difference between the two determinations, divided by the volume of sample alone in the original body of water,

#### A 6.04 Settleable Solids Test

Gently pour a measured quantity (usually 1 liter) of a well-mixed sample of silty water into a graduated cylinder and allow to stand for a total period of 1 hour. After the sample has stood for 1 hour, gently rotate the graduate between the hands to loosen the solids that may have settled. Allow to settle 15 minutes longer. Read from the graduations the volume of solid material that has settled in the graduate. Results are expressed as ml. of solids per liter which settled in 1 hour.

$$\text{ml. of solids} \times \frac{1000 \text{ ml.}}{\text{ml. of sample}} = \text{ml. of settleable solids per liter.}$$

More accurate results may be obtained if glass cones or stoppered funnels are calibrated in place of the graduates. The larger the sample of water, the more accurate the results.

#### A 6.05 Testing for the Fluoride Ion

Fluoride ion analyses are modifications of a single colorimetric method which involves the formation of a preformed color by the fluoride ion. The preformed color comes from the reaction between the fluoride ion and either alizarin or SPADNS dyes. The color is formed more slowly with the alizarin dye. The color produced is called a "lake" and the intensity of color fades from red to yellow if the solution is allowed to stand.

ion is used to titrate 200 ml. of sample, the number of milliliters of the number of parts per million of dissolved oxygen in the sample. m. of oxygen when saturated.

Demand) test involves making two separate determinations for dissolved oxygen taken from the same body of water at the same time. The first sample is taken. If this is not feasible, and the initial test must be delayed for more than 24 hours, the sample of water should be refrigerated until tested.

in the dark at 20°C. for 5 days before testing it for dissolved oxygen. The second sample should be lower than that of the first one. The determination is the Biochemical Oxygen Demand. If the body of water contains a high amount of the water may drop to 2 mg./l. or even zero. When this happens, take a portion of the original sample and determine the dissolved oxygen of the portion. The same water used for dilution. The difference between these values, times the volume of the original sample, divided by the volume of sample alone, equals the BOD of the

usually 1 liter) of a well-mixed sample of silty water into a large graduated cylinder and stand for a total period of 1 hour. After the sample has stood for 45 minutes, shake the cylinder between the hands to loosen the solids that may adhere to the sides. Read from the graduations the volume of solid material deposited in the cylinder. This is expressed as ml. of solids per liter which settled in 1 hour.

= ml. of settleable solids per liter.

When used if glass cones or stoppered funnels are calibrated in ml. and the volume of water is known. The larger the sample of water, the more accurate the results.

Applications of a single colorimetric method which involves the bleaching of a color. The preformed color comes from the reaction between zirconium ions and a color-forming reagent. The color is formed more slowly with the alizarin dye. The color intensity of color fades from red to yellow if the concentration of

zirconium ions decreases. Fluoride ions combine with zirconium ions to form zirconium fluoride. The more fluoride ions present, the greater the change from red to yellow.

The SPADNS test may be made quantitatively by making a set of reference solution concentrations and reading the absorbences at 570 millimicrons with a spectrophotometer described in Standard Methods for the Examination of Water and Waste Water.

The qualitative test requires making the following solutions:

SPADNS solution - Dissolve 0.96g. (sodium 2-parasulfophenylazo 1,8 dihydroxy naphthalene also called Eastman 7309, in de-ionized water and dilute to 100 ml.)

Zirconyl-acid reagent - Dissolve 0.133 g. zirconyl chloride octahydrate ( $ZrCl_4 \cdot 8H_2O$ ) in de-ionized water. Add 350 ml. of conc. HCl and dilute to 1000 ml.

The procedure involves mixing equal quantities of SPADNS and zirconyl acid reagent. Ten ml. of this reagent is then added to 50 ml. of water. A change from a red to a yellow color indicates the presence of the fluoride.

#### A 6.06 Detergents and Algal Growth

Inoculate two sterile water samples with a blue-green algae such as Nostoc commune. Add 1 to 2 ml. of a liquid detergent commonly used for washing dishes. After 24 hours of growth of the algae. A microscopic examination may be necessary if small amounts of water have been used.

#### A 6.07 Effect of Aerating Water

Divide a sample of cold water into two portions. Vigorously beat one sample in a blender. Put both samples of water in stoppered containers, and let stand for 24 hours. Note the amount of air bubbles that collect on the container as the water warms. The amount of air leaving the water as it warms is a rough comparison of the amount of air in the two water samples.

#### A 6.08 Adsorption With Charcoal

Activate some wood charcoal by gently heating it in an oven or over a low flame.

From an odiferous fish tank, obtain a 100-200-ml. water sample. Add the activated charcoal, and let the mixture stand for several minutes. Note the amount of charcoal adsorbs the gases.

de ions combine with zirconium ions to form a stable complex ion  $ZrF_6^{--}$ . The greater the change from red to yellow.

titatively by making a set of reference solutions of known fluoride ion absorbences at 570 millimicrons with a spectrophotometer. The method is in the Examination of Water and Waste Water.

Make the following solutions:

(sodium 2-parasulfophenylazo 1,8 dihydroxy-3,6 naphthalene disulfonate) (Cyanine 7309, in de-ionized water and dilute to 500 ml.

0.133 g. zirconyl chloride octahydrate ( $ZrOCl_2 \cdot 8H_2O$ ) in about 25 ml. of de-ionized water. Add 350 ml. of conc. HCl and dilute to 500 ml.

Equal quantities of SPADNS and zirconyl acid reagents to produce a stable reagent. Ten ml. of this reagent is then added to 50 ml. of the water to be tested. A color change indicates the presence of the fluoride ion.

Use with a blue-green algae such as Nostoc or Gleocapsa. In one culture, a reagent commonly used for washing dishes. After several days, compare the results. Microscopic examination may be necessary if small amounts of culture and large

Divide into two portions. Vigorously beat one sample of water with an egg beater in several portions of water in stoppered containers, and let them stand overnight. Compare the results. Collect on the container as the water warms to room temperature. The results as it warms is a rough comparison of the amount of dissolved air in the

Gradually heating it in an oven or over a low flame.

Use in a 100-200-ml. water sample. To the water, add a spoonful of the reagent mixture and stand for several minutes. Note the reduction in odor as the

#### A 6.09 Determining Residual Chlorine by the Iodometric Method

The iodometric method for determining residual chlorine is described in Examination of Water and Waste Water. The method described the thiosulfate solution followed by a blank determination to correct for reagents used. Omitting the blank simplifies the procedure for residual chlorine.

The iodometric method depends upon the fact that chlorine in water reacts with iodide to free iodine if the pH is less than 8.0. The released iodine and this solution is titrated quantitatively with thiosulfate solution to determine the end point. The temperature of the water sample used should be between 6.0 and 8.0. If the water being tested has a pH of 6.0 to 8.0, the minimum amount of thiosulfate will range from 1.0 to 1.8 mg./l. The concentration of free chlorine determined from the following equation:  $\text{mg./liter Cl} = \frac{(A) \times N}{1000}$

where A is the volume of thiosulfate used in the titration, and N is the normality of the thiosulfate solution.

The procedure is as follows: Dissolve 25g. of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  in 100 ml. of water to make a 0.1N thiosulfate solution. Add 5 ml. of acetic acid and about 1 g. of potassium iodide to the sample being tested. Stir until the KI is dissolved, and then titrate the sample with the thiosulfate solution until the yellow color of the liberated iodine becomes pale. Then add a few drops of orthotoluidine and continue to titrate slowly until the blue color disappears.

When orthotoluidine is added to water, a characteristic yellow color is produced. This color, when used with standard solutions, gives a quantitative measure of free chlorine. Some ions interfere with this simple test which takes little time. This test is used by companies which sell equipment for swimming pools.

#### A 6.10 Effect of Air Pollution on Nylon

Cut a 4-inch x 4-inch opening in two pieces of cardboard. Strengthen the opening in one cardboard and glue the other cardboard on top of it. Support the mount so that the nylon is held in a horizontal position. Place the nylon in an unobstructed and safe place such as on the school roof or in another room for 90 days. A sample stored inside for the same period should be used as a control.

At the end of its exposure period, examine each sample for broken fibers (with a microscope, or magnifying glass). Record the number of breaks per square inch.

## Iodometric Method

residual chlorine is described in Standard Methods for the

The method described there calls for a titration with a standard blank determination to correct for interfering substances in the water. This simplifies the procedure and gives an approximate value for residual

the fact that chlorine in water will oxidize iodide ions from potassium less than 8.0. The released iodine imparts a yellow color to the water, titrated with thiosulfate solution. A starch indicator is used to determine the water sample used should be as close to 20°C. as possible. Between 6.0 to 8.0, the minimum quantity of total available residual chlorine and the concentration of free chlorine in the water being tested can be

Equation:  $\text{mg./liter Cl} = \frac{(A) \times N \times 35,450}{\text{ml. sample}}$ , where A is the number of ml. of sample and N is the normality of the thiosulfate solution.

Prepare 25g. of  $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$  in de-ionized water to make a liter of 0.1N solution. Add 5% acetic acid and about 1 g. of KI to a 500-ml. sample of the water to be tested, and then titrate the sample with the standard thiosulfate solution until the released iodine becomes pale. Then add 1 ml. of starch solution and titrate to a colorless end point.

This test, a characteristic yellow color is produced by chlorine in the water. The test solutions, gives a quantitative measure of the chlorine concentration. This test which takes little time. Kits are available for this test from swimming pools.

Prepare a slide mount of the nylon. Stretch a square piece of nylon hose over the other cardboard on top of it so as to form a slide mount of the nylon. This is held in a horizontal position between two wooden blocks. Expose the slide to the sun or sky such as on the school roof. Expose one sample for 30 days, and a control slide inside for the same period may be used as a control for comparison.

Examine each sample for broken threads (use a slide projector, low-power) and record the number of breaks per day of exposure for each sample.

The known probable destructive agents of nylon hose are hot particles, sulfuric acid, acid aerosols, nitrogen oxides, phenolic particulates, engines, and solvent vapors and droplets.

#### A 6.11 Characteristics of a Smoke

Place a few drops of concentrated hydrochloric acid in a small dish and a few drops of concentrated ammonia. DO NOT MIX THESE CHEMICALS! They will react to form a cloud of white, solid ammonium chloride.

#### A 6.12 Dust Pollution

Very small particles can often be seen by a very bright reflected light that is invisible in ordinary light. Have pupils observe the motes (small particles) as it passes into a darkened corner of the room. Ordinarily, one can see these small particles.

#### A 6.13 Investigating the Cleanliness of Air

Polluted air may contain many more suspended solids than clean air. This can be seen when filtered from the air. Air samplers run by State and local health departments of air through fiber glass filters, and the particles trapped in them determine their identity.

A simple air sampler can be made that will show the relative cleanliness of localities. If there is an old vacuum cleaner available, fasten a piece of filter paper by the edges over the screen so that it will catch the dust. Place the vacuum cleaner in a suitable location, and let it run for a few minutes. Remove the filter paper.

Light transmittance or reflectance may be used to measure the darkness of the air. A turbidimeter can be made by using a light meter or solar cell hooked up to a meter. The light reflected from the surface of the paper. Obtain a reading with a piece of clean filter paper used as a control to provide a basis for comparison.

If a sensitive balance is available, the mass of the trapped particles can be determined. The paper before and after exposure. The paper may also be rinsed in a solvent and the resulting solution determined.

ents of nylon hose are hot particles contained in smoke, soot with sulfur oxides, phenolic particulates, aldehydes from internal combustion droplets.

hydrochloric acid in a small dish. Close by, place a dish containing a . DO NOT MIX THESE CHEMICALS! The gaseous vapors of these two substances are, solid ammonium chloride.

seen by a very bright reflected light even though they are practically invisible. Pupils observe the motes (small dust particles) in a beam of sunlight entering the room. Ordinarily, one would not be aware of the existence of

### Air

more suspended solids than clean air. Much of this material is dark and can be seen. Air samplers run by State and Federal agencies draw measured amounts of air, and the particles trapped in the filters are collected and analyzed to

measure air quality. That will show the relative cleanliness of air samples from different locations. To make an air cleaner available, fasten a wire screen to the end of the hose and place it over the edges of the screen so that air can be drawn through the filter paper. Place the apparatus in a suitable location, and let it run for several hours drawing air through the

apparatus. The apparatus may be used to measure the darkening of the surface. A simple reflectometer or solar cell hooked up in series to a microammeter to measure the current passing through the face of the paper. Obtain a reading from the exposed paper and also from a standard as a control to provide a basis for comparison.

Finally, the mass of the trapped particles may be found by weighing the filter. The paper may also be rinsed in a measured quantity of water, and the pH of

#### A 6.14 Collection of Wind-Blown Particles

Wind-blown particles may be collected on the surface of a sticky paper wrapper hung in a vertical plane in a suitable location. The paper may be prepared by a supplier (Fasson Products Division of Avery Paper Company, 250 Chester Street). A 3-inch diameter piece of wood dowel is fastened to a suitable base, and the jar is fastened to the top of the dowel so that the jar is in an upside-down position. If the jar used is  $2 \frac{3}{4}$  inches in diameter, the size of the collecting

The sticky paper is wrapped around the jar, the jar mounted on the dowel, and where the wind will have a clean sweep. Mark the paper where it faces north. After exposure, spray the paper with a clear lacquer and compare the results with a photographic standard for particles per square inch (obtainable from Technica P. O. Box 116, Park Ridge, New Jersey 07656).

#### A 6.15 Measuring the Amount of Dustfall

Add 1 quart of distilled water into a clean wide-mouth glass jar (1-gallon size) with the top to keep insects out. Place the jar outdoors in an exposed place, 5 feet above the ground. Add distilled water from time to time to keep the water level up to 1 quart. Rain or snow less the jar overflows; if it does, start again. Freezing should be avoided to prevent cracking.

At the end of a 30-day exposure, transfer all the liquid in the jar, a little into a weighing dish of known mass, and heat carefully to avoid spattering. Scrape the residue and flush with a stream of water. This wash water should also be added to the evaporator.

Evaporate all the water and weigh the dish and its contents. Calculate by surface area the dust in terms of milligrams per square centimeter of exposed area for 30 days. If other than 30 days is used, make the necessary adjustment. Measurements of dust in tons per square mile for 30 days. Use the factor-label (multiplying by unit factors) to convert results to these units.

#### A 6.16 Liquid Pollutants

Use a perfume atomizer or an aerosol can of air freshener to spray a mist into a window. Observe the tiny droplets of moisture. Caution! Do not use anything that no open flames are in the room during the spraying or for several minutes.

ted on the surface of a sticky paper wrapped around a small jar which is  
table location. The paper may be prepared locally or purchased from a  
of Avery Paper Company, 250 Chester Street, Painesville, Ohio). A  
l is fastened to a suitable base, and the jar top of the jar to be used  
el so that the jar in an upside-down position can be screwed to the jar  
thes in diameter, the size of the collecting strip can be 2 x 10 inches.

the jar, the jar mounted on the dowel, and the whole apparatus is put  
weep. Mark the paper where it faces north and leave it exposed for 7  
paper with a clear lacquer and compare the surface of the paper with a  
es per square inch (obtainable from Technical Associates for Industry, Inc.,  
rsey 07656).

o a clean wide-mouth glass jar (1-gallon size). Place a wire screen over  
e the jar outdoors in an exposed place, 5 feet off the ground. Add dis-  
keep the water level up to 1 quart. Rain or snow causes no trouble un-  
s, start again. Freezing should be avoided to prevent the jar from

transfer all the liquid in the jar, a little at a time, into an evaporat-  
carefully to avoid spattering. Scrape the sides of the jar clean, and  
is wash water should also be added to the evaporating dish.

the dish and its contents. Calculate by subtraction the weight of the  
opening (assume that the opening is a circle with an area  $\pi r^2$ ). Calculate  
er square centimeter of exposed area for 30 days. If a time interval  
the necessary adjustment. Measurements of dustfall are commonly expressed  
vs. Use the factor-label (multiplying by unity) method and change your

sol can of air freshener to spray a mist into a beam of sunlight coming  
plets of moisture. Caution! Do not use an insecticide bomb. Make sure  
om during the spraying or for several minutes thereafter.

#### A 6.17 Effect of Oil Pollutants on Plants

Certain particulate pollutants may clog the stomata, or openings, on the leaves. To interfere with the passage of water vapor and other gases in and out of the leaves, a few leaves of a geranium plant can be used to demonstrate this. Vaseline, a pollutant, may be used more effectively to demonstrate the clogging of leaves than leaves on a healthy green plant. Coat them with vaseline, making sure you cover both sides. Observe the condition of these leaves as compared with the uncoated leaves after a certain amount of time. An interesting variation of this experiment would involve coating only one leaf on the top surface only, and one leaf on both sides. What are the results of the experiment?

#### A 6.18 Sulfur Dioxide in Air

Cut a 10-inch length of 6-mm. soft glass tubing. Using a Bunsen flame, heat the tubing until an opening 0.008 - 0.01 inches is attained. Make a right-angle bend in the tubing 1 inch from the open end. Insert the tube through a one-hole stopper containing 10 ml. of distilled water. Using an appropriate pump attached to the open end of the tube, draw water through the tube for at least 10 minutes. Transfer the water through which the air has passed to a flask. If  $\text{SO}_2$  was present in the air sample, the flask will contain 10 ml. of water. The concentration is unknown.

Titrate into the Erlenmeyer flask a 0.01M potassium permanganate solution. Add to the sulfurous acid solution slowly, drop by drop, and with constant stirring. As the titration approaches, a transitory faint brown color may appear. The end point is reached when a permanent brown color appears in the solution in the flask which does not disappear upon stirring. For every mole of sulfurous acid that reacts with 2 moles of permanganate, the concentration of sulfurous acid is determined.

The total number of moles of  $\text{SO}_2$  dissolved in the 10 ml. of water = ml.

#### A 6.19 Total Acids in Air

Connect the stem of a thistle tube to an air pump or aspirator. Over the open end of the tube, attach a piece of wet strength white paper towel by an elastic band. When the paper towel ruptures when wet after the pump is turned on, use a piece of wire screen

## plants

...s may clog the stomata, or openings, on the leaves of green plants and inter-r vapor and other gases in and out of the leaf. Moderately heavy dusting of ant can be used to demonstrate this. Vaseline, though not a particulate pol- ctively to demonstrate the clogging of leaf "pores." Select two or three nt. Coat them with vaseline, making sure that all surfaces are covered. e leaves as compared with the uncoated leaves on the same plant over a period ation of this experiment would involve coating one leaf on the bottom surface face only, and one leaf on both sides. What conclusions can be drawn from ?

...soft glass tubing. Using a Bunsen flame, almost close one end of the tubing inches is attained. Make a right-angle bend in the tubing about 2 or 3 ssert the tube through a one-hole stopper that fits a side-arm test tube con- ater. Using an appropriate pump attached to the side-arm, draw air into the . Transfer the water through which the air has passed to a 250-ml. Erlenmeyer the air sample, the flask will contain 10 ml. of sulfurous acid whose con-

...flask a 0.01M potassium permanganate solution. The  $\text{KMnO}_4$  solution should be olution slowly, drop by drop, and with continual stirring. As the end point nt brown color may appear. The end point is reached when a pink color forms which does not disappear upon stirring. From the fact that 5 moles of oles of permanganate, the concentration of the sulfurous acid may be calcu-

$\text{SO}_2$  dissolved in the 10 ml. of water = ml. of  $\text{KMnO}_4 \times \frac{5 \times 10^{-5}}{2}$

...tube to an air pump or aspirator. Over the open bulb end of the thistle strength white paper towel by an elastic band. If it is found that the paper ump is turned on, use a piece of wire screen to support the paper.

Add one drop of 0.1 percent indicator (1 g. of methyl orange dissolved in 10 ml. of 0.01 sodium bicarbonate buffer (0.94 g./liter) to the paper. More drops of indicator until a yellow color is not apparent. Add, also, a drop of glycerin to keep the paper moist.

When the air pump is started, the acids in the air passing through the paper will cause the color to drop, and the color of the indicator will change from yellow to red. Water has little effect on the indicator, but  $\text{SO}_2$  and other compounds in the air will cause the color to change.

For a preliminary test, draw air from an open bottle of dilute HCl. Use a piece of paper for the color change from yellow to red. Repeat with samples of air from various sources. The time of time needed for the color change is a measure of the relative acidity of the air.

#### A 6.20 Construction of an Electrostatic Precipitator

A description of the construction of an electrostatic precipitator from a coil, induction coil, 6-volt battery, and knife switch is given in Conserving Our Resources, a student manual produced by the American Petroleum Institute and distributed by Holt, Rinehart and Winston. This book, giving essentially the same information, is Scientific Experiments in the Laboratory, published by Holt, Rinehart and Winston.

#### A 6.21 Afterburners

Place a clean cold dish in a candle flame. The soot formed is a result of incomplete combustion of candle fuel. Heating this soot in a hot Bunsen flame causes it to disappear. This is a kind of pollution control might be suggested by this demonstration.

#### A 6.22 Biodegradability of Solids

Prepare 1-inch x 3-inch strips of various solids: paper (colored toilet tissue, facial tissue, paper towel, paper bag, typing paper, label paper from a tin can), aluminum foil, pieces of metal containers), and plastic (saran, polyethylene, candy wrappings, etc.). Measure the average thickness of each strip with a micrometer. Measure the combined thickness of ten sheets and compare with the micrometer reading.

Bury each sample vertically in a deep pan containing garden soil or compost. The top of the sample remains above the soil level. Numbers placed on the projecting ends will help identify the samples. Keep the soil moist by watering it every day.

indicator (1 g. of methyl orange dissolved in one liter of water) and one drop of buffer (0.94 g./liter) to the paper. More drops of indicator may be needed if necessary. Add, also, a drop of glycerin to keep the paper from drying out.

The acids in the air passing through the paper will cause the pH in the paper and the indicator will change from yellow to red. With the buffer present,  $\text{CO}_2$  is not a factor, but  $\text{SO}_2$  and other compounds in the air which produce stronger acids

are removed from an open bottle of dilute HCl. Use a timer to find the elapsed time for the indicator to turn red. Repeat with samples of air from various locations. The length of time is a measure of the relative acidity of the air sample.

#### Electrostatic Precipitator

Construction of an electrostatic precipitator from a cardboard tube, aluminum foil, and knife switch is given in Conserving Our Waters and Clearing the Air, published by the American Petroleum Institute and distributed free to schools. Another source of information is Scientific Experiments in Pollution Control, which is available from Winston.

Experiments with a candle flame. The soot formed is a result of incomplete combustion of the fuel. The soot in a hot Bunsen flame causes it to disappear. Why? What ideas for one experiment can be suggested by this demonstration?

Experiments with various solids: paper (colored toilet tissue, white toilet tissue, paper bag, typing paper, label paper from a tin can, cardboard, etc.), metal (aluminum, tin, etc. containers), and plastic (saran, polyethylene, cellophane, cigarette, and other plastic). Measure the average thickness of each strip with a micrometer. If a sheet is too thick, measure the combined thickness of ten sheets and take one-tenth of the micro-

Use a deep pan containing garden soil or compost so that only about 1 inch of soil is exposed. Numbers placed on the projecting ends will help in identification. Keep the soil moist every day.

If four duplicate samples of each solid are used, a sample may be removed. Variations include the thickness and appearance (extent of decay) of each sample from the most biodegradable to the least biodegradable.

#### A 6.23 Some Problems of Incineration

Prepare samples (about 4cm<sup>2</sup>) of paper, plastic materials, food wraps, fabrics with labels, newspapers, etc. Place a sample on a wire gauze which is centered over a lighted burner beneath the sample and note the time. Observe the sample and note the time again. If smoke is emitted, find out whether or not a second

A tabulated record should be kept for each sample. The data collected may include: mass after heating, the elapsed time of heating, evidences of steam, color, and characteristics of the residue, and other observations such as: burns with a flame, flows, burns like paper.

Distinguish between burning (addition of oxygen) and pyrolysis (decomposition by flame alone). Ask students to evaluate to what degree the sample shows the characteristics of incineration.

Throughout the activity, try to keep the quality and height of the flame constant. Note these variables.

#### A 6.24 Finding the Scrap Value of an Aluminum Can

Have each class member bring in one used 12-oz. beverage can. Use magnets to separate the aluminum cans. Weigh each aluminum can, and find the average mass per can.

Find the number of aluminum cans there would be in a ton. Use the following formula:

$$\frac{2 \times 10^3 \text{ lb.} \times 4.54 \times 10^2 \text{ g./lb.}}{\text{g./can}}$$

Local scrap yards should know the current value for a ton of aluminum scrap. The price per ton (in cents) by the number of cans per ton, will give the scrap value of an aluminum can.

of each solid are used, a sample may be removed each week for 1 month. Observe mass and appearance (extent of decay) of each sample. Prepare a list of the most biodegradable to the least biodegradable.

Procedure

1. Weigh a sample of paper, plastic materials, food wraps, fabrics, cardboard, foil, tin cans, etc. Place a sample on a wire gauze which is centered on a tripod. Place a Bunsen burner under the sample and note the time. Observe the sample until no more changes occur and no smoke is emitted, find out whether or not a second flame will burn the smoke.

2. Record the data for each sample. The data collected may include the mass before and after heating, time of heating, evidences of steam, color, and density of smoke, characteristic observations such as: burns with a flame, burns with a glow, melts and

3. Record the results of the combustion (addition of oxygen) and pyrolysis (decomposition caused by the heat of the sample) to evaluate to what degree the sample shows that it can be disposed of by

4. Adjust the Bunsen burner to keep the quality and height of the flame constant for each sample to elimi-

### Activity 2: Aluminum Can

1. Weigh in one used 12-oz. beverage can. Use magnets to separate any steel cans from each aluminum can, and find the average mass per can.

2. Calculate the number of cans there would be in a ton. Use the following relationship:

$\frac{\text{mass of 1 can}}{\text{mass of 1 lb.}}$

3. Calculate the current value for a ton of aluminum scrap (about \$200/ton). Dividing the value of a ton of scrap by the number of cans per ton, will give the scrap value in cents of an alu-

#### A 7.01 Exhibiting Polymers

Display some polymers such as glass, modeling clay, amber, hair, shellac, gum, resins, spray, nail polish, paper, wood, meat, wool, silk, and plastics. Ask the pupils to see how many can be classified into the same category.

Point out that the items can be subdivided into natural polymer and manmade polymer.

#### A 7.02 Obtaining Casein from Milk

Add rennet (Junket tablet) to a pint of milk (35 - 40°C.) to form curds which coagulate. The milk has "set," filter by suction, and wash the curds. (Use decantation if the curds cannot be separated by a filter.) The dried curds are casein.

When soaked in water, casein powder can form a soft, pliable plastic which can be used for many purposes.

#### A 7.03 Condensation Polymerization

Have a team of pupils build models of two phenol molecules and one formaldehyde molecule. Have them try to join the molecules by following the condensation rules - no more than 1 H or 1 OH can be removed from any molecule and no more than a total of 2 H and 1 O can be removed to form H<sub>2</sub>O.

The condensation products of all the teams can be joined together. If on a single team's product are used, a network can be built up and the rigid structure of a "set" polymer shown.

#### A 7.04 Addition Polymerization

Ball-and-stick models can be used to illustrate the joining of monomers to form long chains.

Have each pupil (or team) make ball-and-stick models for several molecules of acrylonitrile:  $\text{CH}_2 = \text{CH} - \text{CN}$ . Ask the pupils to join their monomers to form one unit, then have pupils

—  
CN

to make Orlon. Point out that inhibitor chemicals are used to determine the length of the chain desired. Hydrogen may be added to complete the final molecule's bonding.

ng clay, amber, hair, shellac, gum, resin, laundry starch, hair, silk, and plastics. Ask the pupils to "guess why" the items

into natural polymer and manmade polymer groups.

ilk (35 - 40°C.) to form curds which contain the casein. When wash the curds. (Use decantation if the curds are too small to are casein.

m a soft, pliable plastic which can be molded.

henol molecules and one formaldehyde molecule. Tell the pupils ensation rules - no more than 1 H or 1 O atom can be removed of 2 H and 1 O can be removed to form H<sub>2</sub>O.

can be joined together. If on a single phenol all linkage sets rigid structure of a "set" polymer shown.

rate the joining of monomers to form long chain polymers.

ck models for several molecules of acrylonitrile monomer, omers to form one unit, then have pupils join their "units"

emicals are used to determine the length of polymer chains e the final molecule's bonding.

A polyethylene model can be made in a similar manner from  $C_2H_4$

A 7.05 Preparation of a Plastic Similar to Bakelite

*Teacher Demonstration*

Simultaneously pour 100 ml. of a saturated solution of aniline and formalin solution into a 300-ml. beaker. Stir with a glass rod and mold. When hardened, the black substance is a plastic similar to bakelite.

A 7.06 Identification of Vinyl Chloride Polymers

Weigh out equal masses of Saran (a vinyl chloride polymer) and polyethylene. Bags are made of polyethylene. Mount an inverted funnel on a retort stand. From the stem of the funnel into a beaker containing 100 ml. of water. Repeat the procedure using polyethylene and a new sample of water. The water contains HCl which produces a lower pH in water than the smoke from Saran.

Test different plastic food wraps, containers, and phonograph records. Point out that some plastics have similar polymer structures.

A 7.07 Testing Fibers

Obtain some samples of cotton, linen, wool, silk, nylon, Orlon, or Spandex. Most fabrics purchased at the local store are blends. Samples be obtained from a mill or chemical company.

Inspect shredded fibers of each type of material under the low power microscope.

Test the combustibility, resistance to 3N HCl, chlorine bleaches, and tensile strength of each fiber. Relate the results to any structure.

A 7.08 Thermoplastics

The properties of a thermoplastic material can be illustrated with a sample of polyethylene.

made in a similar manner from  $C_2H_4$  monomer units.

#### Similar to Bakelite

of a saturated solution of aniline hydrochloride and 100 ml. of 40-percent  
-ml. beaker. Stir with a glass rod. Pour the viscous materials into a sand  
black substance is a plastic similar to Bakelite.

#### Chloride Polymers

Saran (a vinyl chloride polymer) and polyethylene. Most plastic sandwich  
e. Mount an inverted funnel on a ringstand, and connect a piece of tubing  
into a beaker containing 100 ml. of distilled water. Burn the Saran under  
is collected and dissolved in the water. Test the pH of the water. Re-  
polyethylene and a new sample of water. The smoke from vinyl chloride polymers  
a lower pH in water than the smoke from nonchloride containing polymers.

wraps, containers, and phonograph records to determine if they are vinyl  
t that some plastics have similar properties and appearances but different

on, linen, wool, silk, nylon, Orlon, Rayon, and an elastic yarn, such as Lycra  
urchased at the local store are blends of fibers. It is suggested that pure  
mill or chemical company.

each type of material under the low power of a microscope.

sistance to 3N HCl, chlorine bleaches, 1 N NaOH, retention of water, elasticity,  
n fiber. Relate the results to any specific uses of the fiber.

lastic material can be illustrated with sealing wax, a natural resin plastic.

In its normal state, sealing wax is a hard solid. When warmed over a flame, it flows under the pull of gravity. When a blob of molten sealing wax is stamped with the shape of the imprint. As it cools, the wax resets to a plastic and is impressed upon the wax.

A 7.09 Cold-Setting Plastic

Cold-setting plastic can be illustrated by using the "bioplastic" material. Cold-setting plastic specimens. The plastic syrup and catalyst can be purchased from most chemical supply houses.

A 7.10 Identification of Thermosetting and Thermoplastic Materials

Classify a number of plastic materials as thermoplastic or not thermoplastic by boiling in boiling water for several minutes. Those that can be bent or softened are thermoplastics. Include samples of Bakelite, polystyrene, synthetic rubber, plastic "wrap" or bags, and a toothbrush handle. The temperature of boiling water is to identify all thermosets from thermoplastics.

A 7.11 Properties of Plastics

Obtain many samples of plastics used in the home. Some examples are square tiles, old toothbrushes, wrapping products, nylon, yarn, and a broken electric plug.

Classify each according to transparency, color, flammability, hardness, solubility in water, alcohol, nail polish remover, sodium hydroxide, hydrochloric acid.

Relate the uses of the material to any properties observed.

A 7.12 Use of the Geiger Counter

Many schools have rate meters or scalars of the Geiger counter type. The difference between alpha, beta, and gamma emission in terms of the range of the ability of varying thicknesses of different materials to absorb the radiation. Gamma emitters are available commercially in sealed plastic containers for use by students. The Geiger tube is not 100 percent efficient in registering alpha particles, particularly poor for counting gammas. Section 6.05 of the Chemistry Handbook describes the use of the Geiger counter and factors which affect count rates.

ing wax is a hard solid. When warmed over a match, it will melt and flow under  
n a blob of molten sealing wax is stamped with a "seal," the wax flows and takes  
As it cools, the wax resets to a plastic and the pattern of the stamp remains

be illustrated by using the "bioplastic" materials that biologists use in mount-  
ic syrup and catalyst can be purchased from most scientific supply houses.

#### Setting and Thermoplastic Materials

stic materials as thermoplastic or not thermoplastic by immersing the pieces of  
for several minutes. Those that can be bent or are softened by the heat are  
samples of Bakelite, polystyrene, synthetic rubber, sealing wax, polyethylene,  
and a toothbrush handle. The temperature of boiling water is too low to be used  
s from thermoplastics.

astics used in the home. Some examples are squeeze bottles, toys, old jewelry,  
ng products, nylon, yarn, and a broken electric plug.

to transparency, color, flammability, hardness, elasticity, and solubility in  
sh remover, sodium hydroxide, hydrochloric acid, and sulfuric acid.

aterial to any properties observed.

eters or scalers of the Geiger counter type. These can be used to show the  
, beta, and gamma emission in terms of the range of these radiations in air and  
hicknesses of different materials to absorb these radiations. Alpha, beta, and  
able commercially in sealed plastic containers which can be handled safely by  
be is not 100 percent efficient in registering emissions it receives. It is  
unting gammas. Section 6.05 of the Chemistry Handbook has a good discussion of  
unter and factors which affect count rates.

### A 7.13 Counting Geometry

If your school has a Geiger counter with a thin end window, you can show that sharply as the source is moved away from the end window just a few centimeter the source does not actually touch the window at the beginning. Thin end window tubes containing them are expensive.

### A 7.14 The Absorption of Carbon Dioxide by Plants

Seal the pot and soil surface of a geranium with aluminum foil, and place the jar or beaker. With a wire, support a small beaker within 2 inches of the top of the jar. In the beaker place .5g. of dry  $\text{BaCO}_3$  which has previously been mixed with 10 micrograms of carbon 14. This can be done by making a paste of the nonradioactive  $\text{BaCO}_3$  and carbon 14. Allow the mixture to dry in air.

Cover the plant, jar, and beaker with Saran wrap. This should be "airtight." Place a jar directly over the  $\text{BaCO}_3$  container, attach two pieces of cellophane tape across the jar. Insert a pipette through the taped area and inject about 2 ml. of vinegar or dilute hydrochloric acid. The reaction results in  $\text{CO}_2$  being released, and part of it is  $\text{C}^{14}\text{O}_2$ . Seal the jar. Place the entire setup in a fume hood under a strong light for 24 hours. Then remove the jar and an end window tube, count both the upper and lower surfaces of leaves cut from the jar.

Dispose of any excess  $\text{BaC}^{14}\text{O}_3$  by flushing it down the drain with a large quantity of water.

### A 7.15 The Minimum Activity of a Radioisotope Required for Detection

Prepare six 100-ml. solutions of  $\text{P}^{32}$ . These solutions should have a strength of 2.0 $\mu\text{c}$ ., 3.0 $\mu\text{c}$ ., and 3.2 $\mu\text{c}$ .. The total strength of all six solutions must not exceed 10.0 $\mu\text{c}$ ., all combined. Adjust the pH of the solutions so they are brought to just a reaction with the plants.

Remove six 5-week-old bean plants from a culture solution in which they have been growing and place one in each of the six solutions.

Counts should be made frequently when the experiment is started to indicate the activity in the plants; intervals of 15-20, 30-40, 60-75 minutes might be chosen. Take the Geiger counter from the radioactive solution while counting leaves. (Folded Al foil around the counter to shield from radiation.) Care should be taken to duplicate the counting geometry as accurately as possible in counting of successive leaves. Thereafter, further readings after 6-8 hours and

er counter with a thin end window, you can show that the count rate drops very moved away from the end window just a few centimeters. Be careful that lly touch the window at the beginning. Thin end windows are very fragile, are expensive.

#### Dioxide by Plants

face of a geranium with aluminum foil, and place the sealed pot in a glass jar support a small beaker within 2 inches of the top of the jar. Into the small  $\text{BaCO}_3$  which has previously been mixed with 10 microcuries of  $\text{BaCO}_3$  containing one by making a paste of the nonradioactive  $\text{BaCO}_3$  and mixing with it the  $\text{BaC}^{14}\text{O}_3$ . in air.

beaker with Saran wrap. This should be "airtight." On the wrap at a point ontainer, attach two pieces of cellophane tape crossed at right angles. Insert ed area and inject about 2 ml. of vinegar or dilute HCl into the beaker of  $\text{BaCO}_3$ .  $\text{O}_2$  being released, and part of it is  $\text{C}^{14}\text{O}_2$ . Seal the puncture hole with tape. a fume hood under a strong light for 24 hours. Then open the wrapping and with both the upper and lower surfaces of leaves cut from the plant.

$\text{C}^{14}\text{O}_3$  by flushing it down the drain with a large quantity of water.

#### Radioisotope Required for Detection

ions of  $\text{P}^{32}$ . These solutions should have a strength of 0.3 $\mu\text{c}$ ., 0.5 $\mu\text{c}$ ., 1.0 $\mu\text{c}$ ., The total strength of all six solutions must not exceed 10 $\mu\text{c}$ ., if they were pH of the solutions so they are brought to just a red reaction on litmus.

n plants from a culture solution in which they have been growing, rinse them off, the six solutions.

quently when the experiment is started to indicate the first appearance of  $\text{P}^{32}$  of 15-20, 30-40, 60-75 minutes might be chosen. Take great care to shield the lve solution while counting leaves. (Folded Al foil should absorb all beta be taken to duplicate the counting geometry as accurately as possible with the aves. Thereafter, further readings after 6-8 hours and 24 hours would be useful

in determining the maximum uptake. Before and after each set of readings, re This will be useful in establishing the minimum amount of  $P^{32}$  detectable. Th subtracted from each leaf count in order to find the radioactive count due to

#### A 7.16 Simulating the Use of a Radioisotope for Diagnosis

A mailing tube or other paper cylinder can be partly filled with sand or loose gamma source hidden in the tube. Pupils could be told that the tube represents given a radioisotope for diagnosis. Use the Geiger counter to locate the source emits.

#### A 7.17 Measuring a Liquid Level by Using a Radioisotope

Radioisotopes have been used to indicate the varying height of liquids stored. This can be demonstrated by taping a sealed gamma emitter inside an evaporating dish inside an aquarium or battery jar containing a small amount of water. As more water evaporates from the jar, the evaporating dish containing the sealed source moves up in the jar and is detected with a Geiger counter. A sheet of black construction paper can be used to shield the counter from seeing the location of the evaporating dish.

#### A 7.18 Using a Radioisotope to Gauge Thickness

The use of a radioisotope thickness gauge can be demonstrated fairly easily with a sealed source of gamma radiation. Place the counter on a table or desk top, near enough to the counter to make the counter register its maximum rate. The counter should be placed on a cardboard between the source and probe. The counter should show a slightly lower rate as the source is moved through a stack of books of different thickness one at a time through the space. Try an empty beaker and then several filled with different liquids. Thin sheets of various metals and combine some of the sheets to get varying thicknesses. The gamma radiation can be concentrated into more of a beam if the source is in a lead can.

#### A 7.19 Half-life Measurement

Half-life measurements can be made using beta and gamma sources which have simple "geometry" must be the same for all counts made with the counter. Iodine-131, with a half-life of 8.08 days, and phosphorus-32, with a half-life of 14.3 days, have been used. The

before and after each set of readings, record the background count. The minimum amount of  $P^{32}$  detectable. The background count must be subtracted to find the radioactive count due to  $P^{32}$ .

#### for Diagnosis

The jar can be partly filled with sand or loosely folded paper and a sealed source could be told that the tube represents a person who has been exposed. Use the Geiger counter to locate the source from the radiation it emits.

#### Radioisotope

Measure the varying height of liquids stored in large tanks. Place a sealed gamma emitter inside an evaporating dish and floating the dish containing a small amount of water. As more water is poured into the dish, the sealed source moves up in the jar and its movement can be detected. Black construction paper can be used to keep the person operating the Geiger counter from seeing the evaporating dish.

#### Mass

A mass gauge can be demonstrated fairly easily with a Geiger counter and a metal plate. Place the counter on a table or desk top. Put the gamma source just above the counter register its maximum rate. Then pass a piece of metal plate. The counter should show a slightly lower count rate. Next, pass a sheet of thickness one at a time through the space and note the resulting count rate. Then several filled with different liquids, including water. Try to determine the mass of some of the sheets to get varying thicknesses of the metals. This can be used to detect a beam if the source is enclosed in a metal tube or shield.

Using beta and gamma sources which have short half-lives. The counting rates are made with the counter. Iodine-131, which has a half-life of 8.06 days, and Technetium-99m, which has a half-life of 14.3 days, have been used. There are companies which sell

"generators" of barium-137, which has a half-life of only 2.6 minutes. A against the count rate, and when the counting rate is less than half the be read directly from the graph as the length of time necessary for the its initial rate.

A 7.20 Effects of Radioactivity on Living Plants

Many science supply houses sell seeds which have been irradiated. These hour in a chlorine bleach solution (1 part bleach to 8 parts water) to and grow the seeds in moist blotter paper or paper toweling. One technic blotting paper, then put it into a beaker containing a little water so the inside the glass. The seeds are placed between the paper and the glass w

Use nonirradiated seeds as a control, and note the differences between the plants with regard to root length, stem length, number of roots, leaf size

A 7.21 Looking for Radioactive Fallout in Rain and Snow

Collect about 500 ml. of rainwater or melted snow. Evaporate the sample, from an infrared lamp, until only about 2 ml. remain. Take several backg background level of radiation. Repeat the procedure, this time keeping t than 5 centimeters from the concentrated sample. (Because of the reducti weapons in the atmosphere, this activity may not show any appreciable rad

A 7.22 Using a Radioisotope To Determine the Efficiency of a Cleanser

One of the problems involved in using radioisotopes is that of decontamin spilled. As far as possible, the same procedures are used with radioisot material. Spills involving low levels of radiation are mopped up using a the mopping efficiency. Solutions of various soaps and detergents will v up the radioisotopes.

This can be shown if equal small quantities of a short-lived radioisotope beakers, each containing 10 milliliters of water. The activity of each so proceeding. Once the activity of each solution is known and recorded, it of a waxed floor tile, which is available in many schools. A small quantit on the spill and rubbed in with a wooden splint. Equal quantities of soap out beforehand. Each tile should then be wiped dry with paper towels. Ca any of the spill on the hands, and the used towels should be put into a pla

37, which has a half-life of only 2.6 minutes. A graph is made by plotting time and when the counting rate is less than half the initial rate, the half-life can be graphed as the length of time necessary for the activity to drop to one-half of

#### on Living Plants

es sell seeds which have been irradiated. These seeds can be soaked for half an hour in a solution (1 part bleach to 8 parts water) to inhibit fungus growth. Germinate on moist blotter paper or paper toweling. One technique is to make a cylinder of the paper and fit it into a beaker containing a little water so that the paper cylinder is just above the water. The seeds are placed between the paper and the glass wall of the beaker.

As a control, and note the differences between the control plants and experimental plants. Measure root length, stem length, number of roots, leaf size, and rate of germination.

#### Fallout in Rain and Snow

Collect rainwater or melted snow. Evaporate the sample, using either no heat or the heat of a water bath until only about 2 ml. remain. Take several background counts and get an average. Repeat the procedure, this time keeping the counting tube window no more than 1 cm from the concentrated sample. (Because of the reduction in the testing of nuclear activity, this activity may not show any appreciable radiation levels above background.)

#### Determine the Efficiency of a Cleanser

Work done in using radioisotopes is that of decontamination if a radioisotope is spilled. If possible, the same procedures are used with radioisotopes as with any other hazardous material. Low levels of radiation are mopped up using a soap or detergent to increase solubility. Solutions of various soaps and detergents will vary in their abilities to pick

up small quantities of a short-lived radioisotope are measured into several small beakers (10 milliliters of water). The activity of each solution should be checked before use. When the activity of each solution is known and recorded, it can be spilled upon the surface of a sink which is available in many schools. A small quantity of soap can be put directly on the surface with a wooden splint. Equal quantities of soap or detergent should be weighed out. The surface should then be wiped dry with paper towels. Care should be taken not to get hands, and the used towels should be put into a plastic bag for disposal.

After each tile has been wiped dry, the Geiger counter probe should be used and each tile should be placed near the window of the probe for counting. The probe and tile should be kept the same for each tile. The tile which shows the greatest rate decrease should be that for which the soap or detergent was most effective.

It is important that the radioisotope used be one with a fairly short half-life. Radioactivity on both tile and paper towels will decrease quickly. A radioisotope with a longer half-life than the 8 days of iodine-131 should be used for this activity. A generator is an ideal source of radiation. The parent tin-113 has an indium-113 daughter, which is eluted from the parent, has a half-life of 45 minutes, and a generator is commercially available.

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A 8.01 Identification of a Precipitate

Before class, prepare solutions of  $\text{BaCl}_2$  and  $\text{K}_2\text{SO}_4$  (1 g./100 ml.). Label them "A" and "B," respectively.

Have the pupils mix equal quantities of "A" and "B," and try to identify the precipitate. Refer to solubility charts and properties of substances listed in handbooks.

Draw the pupils attention to the large number of possible compounds that precipitate. Note the solubility and inability to precipitate easily.

A 8.02 Separation of Two Precipitated Ions

Prepare (2 g./100 ml.) solutions of  $\text{Na}_2\text{CrO}_4$ ,  $\text{Pb}(\text{NO}_3)_2$ ,  $\text{NaNO}_3$ ,  $\text{Mg}(\text{NO}_3)_2$ . Ask the pupils to find which metallic ions can be precipitated as chlorides. Note which precipitates are soluble in hot water, which in concentrated ammonium hydroxide, and which are affected by light.

Give pupils a solution containing both  $\text{Pb}^{++}$  and  $\text{Ag}^+$  ions, and ask them to perform a confirming test for each.

A 8.03 Identification of Halides by Precipitation

Compare the effect of silver nitrate solution on halogen ions. Repeat with lead nitrate solutions. Observe the behavior of the silver and lead halides in sunlight. Repeat in hot water and dilute  $\text{HNO}_3$ .

wiped dry, the Geiger counter probe should be mounted in a stationary position placed near the window of the probe for counting. The counting distance between kept the same for each tile. The tile which shows the greatest percentage count that for which the soap or detergent was most efficient.

radioisotope used be one with a fairly short half-life, so that the level of le and paper towels will decrease quickly. No radioisotope having a half-life of iodine-131 should be used for this activity. A tin-113/indium-113 isotope source of radiation. The parent tin-113 has a half-life of 115 days, and the which is eluted from the parent, has a half-life of only 100 minutes. This isotope is available.

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### Precipitate

Solutions of  $\text{BaCl}_2$  and  $\text{K}_2\text{SO}_4$  (1 g./100 ml.). Label them "Solution A" and "Solution

equal quantities of "A" and "B," and try to identify the precipitate formed by means of properties of substances listed in handbooks.

Due to the large number of possible compounds that were excluded because of their tendency to precipitate easily.

### Precipitated Ions

Solutions of  $\text{Na}_2\text{CrO}_4$ ,  $\text{Pb}(\text{NO}_3)_2$ ,  $\text{NaNO}_3$ ,  $\text{Mg}(\text{NO}_3)_2$ , and  $\text{AgNO}_3$ , and a 1 M HCl solution. Determine which metallic ions can be precipitated as chlorides or as chromates, which are soluble in hot water, which in concentrated ammonium hydroxide (use the hood), and which

are soluble in solutions containing both  $\text{Pb}^{++}$  and  $\text{Ag}^+$  ions, and ask them to separate the two ions and give the results.

### Separation of Ions by Precipitation

Test silver nitrate solution on halogen ions. Repeat the process using lead nitrate and observe the behavior of the silver and lead halides in sunlight, and compare their solubilities in  $\text{HNO}_3$ .

Ask the pupils to suggest a test for  $\text{Cl}^-$ ,  $\text{Br}^-$ , and  $\text{I}^-$ .

A 8.04 Making a Simple Spectroscope

Obtain a cardboard tube such as found in a roll of wax paper. At one end containing a narrow slit. At the other end, mount a plastic replica grat

In a darkened room, look through the tube to see spectral lines produced in spectral tubes.

A 8.05 Identification of Unknowns by Flame Tests

Have available solutions of each of the following ions:  $\text{Li}^+$ ,  $\text{Sr}^{++}$ ,  $\text{Ca}^{++}$  number of unknown mixtures labeled unknown 1, 2, 3, etc.

- |                                                     |                                                        |
|-----------------------------------------------------|--------------------------------------------------------|
| 1. $\text{K}^+$ , $\text{Na}^+$                     | 5. $\text{Li}^+$ , $\text{Sr}^{++}$ , $\text{Ca}^{++}$ |
| 2. $\text{Li}^+$ , $\text{Ba}^{++}$                 | 6. blank (distilled)                                   |
| 3. $\text{Cu}^{++}$ , $\text{K}^+$ , $\text{Na}^+$  | 7. An ion not in s                                     |
| 4. $\text{Li}^+$ , $\text{Ba}^{++}$ , $\text{Na}^+$ | an excellent f                                         |

Provide the pupils with some glass filters, and ask them to identify as mixture. (Do not expect all ions in all solutions to be identified.) In some results. Only spectrographic analysis can give a positive identification.

A 8.06 Influence of Developers

Several tapered strips of filter paper are cut to fit 6-inch test tubes. end, place a tiny spot of green cake-coloring dye which can be purchased tube, put 1 ml. of distilled water, in another put 1 ml. of n-butanol, and butanol-acetic acid (glacial) - water, 4:1:2 (v/v/v). Insert and suspend end is immersed, but do not allow the color spot to dip into the solvent. polar dye with the solvent front. Relatively nonpolar butanol has no effect marked zones. The polarity of a mixture of water and glacial acetic is

The butanol-acetic acid solvent should be made just before class as the solvent. If too large a spot of dye is used, distinct zones will not be obtained.

r  $\text{Cl}^-$ ,  $\text{Br}^-$ , and  $\text{I}^-$ .

nd in a roll of wax paper. At one end, fasten a piece of cardboard  
ther end, mount a plastic replica grating.

e tube to see spectral lines produced by colored flames or excited gases

#### Tests

f the following ions:  $\text{Li}^+$ ,  $\text{Sr}^{++}$ ,  $\text{Ca}^{++}$ ,  $\text{Ba}^{++}$ ,  $\text{Cu}^{++}$ ,  $\text{K}^+$ , and  $\text{Na}^+$ . Have a  
unknown 1, 2, 3, etc.

5.  $\text{Li}^+$ ,  $\text{Sr}^{++}$ ,  $\text{Ca}^{++}$
6. blank (distilled water)
7. An ion not in standard set up. Indium will give  
an excellent flame.

filters, and ask them to identify as many ions as possible in each  
(in all solutions to be identified.) Interference of colors will obscure  
analysis can give a positive identification.

paper are cut to fit 6-inch test tubes. At about 1 cm. from the tapered  
ake-coloring dye which can be purchased at a grocery store. In one test  
r, in another put 1 ml. of n-butanol, and in the third put 1 ml. of a  
ater, 4:1:2 (v/v/v). Insert and suspend the paper strips so the tapered  
the color spot to dip into the solvent. Highly polar water moves the  
Relatively nonpolar butanol has no effect. The mixture produces well-  
mixture of water and glacial acetic is "reduced" by the n-butanol.

hould be made just before class as the solvent mixture is unstable.

ed, distinct zones will not be obtained.

#### A 8.07 Selection of Solvent and Adsorbent

Since there is no way to predict the best choice of an adsorbent or solvent for the graphic separation of a mixture, the selection must be worked out by experiment.

Select an adsorbent, paper or Silica Gel G layer (See 8.10), preferably a mixture of dyes, such as found in food coloring, a few centimeters apart on a tube, add dropwise a small quantity of solvent and observe any separation. The spot that moves out from the spot. Repeat the process using a different solvent. The best separation should be used on that adsorbent.

If time permits, the process may be repeated using another adsorbent. Probably, the results will show that the same solvent will not give the same separation on both adsorbents.

A piece of glass tubing with one end drawn out into a capillary tube may be used for dropping solvent or spotting the mixture.

Some solvents often used in separations are benzene, benzene-acetone (1:1), benzene-acetone (8:2, v./v.); n-butanol, acetone, methanol, and water.

*Be sure to use the hood for many of the solvents are flammable and/or toxic.*

#### A 8.08 Making an R<sub>f</sub> Table

An R<sub>f</sub> table lists the R<sub>f</sub> values for various substances on a specific adsorbent and solvent used.

Before class, determine the solvent(s) which will separate on a specific adsorbent. (See A 8.07)

Each pupil spots a known dye on the adsorbent, develops the chromatogram. (Remind pupils to mark the solvent front as soon as the adsorbent is removed from the tank.) Have the class list the average R<sub>f</sub> for the dye on the chart. Repeat for other dyes.

The table can be expanded by repeating the above but using a different solvent and a second column.

nt

the best choice of an adsorbent or solvent to be used during the chromatography. The selection must be worked out by trial and error.

silica Gel G layer (See 8.10), preferably. Put several tiny drops of a mixture of food coloring, a few centimeters apart on the adsorbent. From a capillary tube draw a quantity of solvent and observe any separation which may occur as the solvent moves through the process using a different solvent on each spot. The solvent giving the best separation is used on that adsorbent.

The process may be repeated using another adsorbent with the solvents previously tested. It should be noted that the same solvent will not give the best separation of the mixture on

all adsorbents. A glass tube drawn out into a capillary tube makes an excellent pipette for drawing up the mixture.

Common solvent ratios are benzene, benzene-acetone (8:2, v./v.); petroleum ether, ethyl alcohol, butanol, acetone, methanol, and water.

*of the solvents are flammable and/or have toxic vapors.*

for various substances on a specific adsorbent when different solvents are used.

Identify the component(s) which will separate on a specific adsorbent a mixture of known dyes.

Using the same adsorbent, develop the chromatogram, and calculate the  $R_f$  value. Stop the solvent front as soon as the adsorbent is removed from the developing dish or calculate the average  $R_f$  for the dye on the chart. Repeat the process to obtain values

for other substances repeating the above but using a different solvent. The data obtained makes a

Remind pupils that the title of the table must mention the general class of substance while each column of values must be labeled with the solvent system used to obtain them.

If time permits, unknown mixtures containing one or more dyes can be separated and identified on the basis of the  $R_f$  values.

#### A 8.09 Thin Layer Chromatography

Silica Gel G makes a very satisfactory thin-layer adsorbent. It can be purchased in plastic sheets which can be cut into small strips for pupil use.

The Gel can also be purchased in powder form, slurried, and spread on microfilm made by mixing 1 part of Silica Gel G with 2 parts (by weight) of distilled water. The amount of the slurry is put on one end of the slide and quickly spread by drawing a stirring rod across the slide. With a little practice, fairly uniform layers can be dried in air in several minutes or in an oven at  $110^{\circ}\text{C}$ . for 10 minutes.

Since Silica Gel G contains a binder of plaster of paris, the slurry should be well mixed.

With a sharp pencil point or pin, prick the film about 1 cm. from the edge of the slide. This mark will show the starting point, and a drop of mixture should be applied. After the spot has dried, stand the film in a screw-cap jar or 250-ml. beaker containing solvent. Cover the container to keep the atmosphere saturated with solvent. After the solvent has risen  $3/4$  of the height of adsorbent, remove the film and mark the solvent front.

The  $R_f$  value of each component can be calculated:  $R_f = \frac{\text{distance component moved}}{\text{distance solvent moved}}$

By comparison with  $R_f$  tables for the solvent-adsorbent system listed in most chemistry handbooks, or comparison with known samples run along with the mixture on the film, the components can be identified.

TLC can be used to separate chlorophyll and xanthophyll components of plants. The materials can be obtained from the Biology Handbook.

Mixtures of dyes or amino acids are also separated by TLC. Amino acids are detected on a developed chromatogram with ninhydrin reagent which can be obtained in aerosol spray supply companies.

e of the table must mention the general class of substances and the adsorbent, must be labeled with the solvent system used to obtain the values.

xtures containing one or more dyes can be separated and some components identi- values.

atisfactory thin-layer adsorbent. It can be purchased ready to use as a film on cut into small strips for pupil use.

ed in powder form, slurried, and spread on microscope slides. The slurry is silica Gel G with 2 parts (by weight) of distilled or de-ionized water. A small on one end of the slide and quickly spread by drawing or rolling a glass de. With a little practice, fairly uniform layers can be made. The films are utes or in an oven at 110°C. for 10 minutes.

a binder of plaster of paris, the slurry should be spread as soon as it is

r pin, prick the film about 1 cm. from the edge of the narrow width of the strip how the starting point, and a drop of mixture should be placed on it. After the film in a screw-cap jar or 250-ml. beaker containing a shallow layer of solvent. the atmosphere saturated with solvent. After the solvent has traveled about ent, remove the film and mark the solvent front.

ent can be calculated:  $R_f = \frac{\text{distance component moved from starting point}}{\text{distance solvent moved from starting point}}$

s for the solvent-adsorbent system listed in most chromatography texts or by es run along with the mixture on the film, the components can be identified.

chlorophyll and xanthophyll components of plants. Directions for extracting ed from the Biology Handbook.

cids are also separated by TLC. Amino acids are detected by spraying the ninhydrin reagent which can be obtained in aerosol cans from most scientific

#### A 8.10 Amino Acid Separation

Prepare air dried silica gel layers, and spot with the amino acid on the film. (See Activity A 8.09 for preparing, spotting the adsorbent. Develop the film in a chamber containing a mixture of n-butanol/glass (volume). When the solvent has moved about 10 cm. from the initial solvent front, and dry the film in air. Then heat the film in an oven warm, dried film with ninhydrin reagent. (Reheat if necessary to develop spots.)

Handle all films by the edges to avoid adding contaminating amino acids.

Pupils may encounter difficulty in identifying amino acids from  $R_f$  values the values are affected by concentration. A more positive identification "spots" with those obtained by simultaneously running chromatograms.

Pupils may find a challenging laboratory experience in separating fresh cucumber juice or tree sap.

#### A 8.11 Determining the Amount of CO<sub>2</sub> in a Substance

Assemble a gas generator and apparatus for collecting a gas by displacement in a vessel for collection of the gas. In the interests of safety, wrap the vessel in tape and use a thistle tube.

Check the volume of water displaced in the collecting vessel as 10 ml. generator. The displaced volume caused by any solution being added from any gas volume.

Place a tablet or powder of an effervescing antacid substance used as a gas generator. Add the 100 ml. of water, and collect the CO<sub>2</sub> produced.

Find the factors that affect the amount of gas formed.

Vary the amount and temperature of the water added to the generator and the collecting apparatus. This should give an opportunity to discuss variables except the one being investigated in an experiment.

el layers, and spot with the amino acid mixture about 1-2 cm. from the edge of  
8.09 for preparing, spotting the adsorbent, and developing a chromatogram.)  
ber containing a mixture of n-butanol/glacial acetic acid/water (4:1:1 by  
t has moved about 10 cm. from the initial spot point, remove the plate, mark the  
e film in air. Then heat the film in an oven at 110°C. for 10 min. Spray the  
hydrin reagent. (Reheat if necessary to bring up the color reaction with the

edges to avoid adding contaminating amino acids from the skin.

difficulty in identifying amino acids from  $R_f$  values found in reference tables, since  
ly concentration. A more positive identification can be made by comparing the  
ed by simultaneously running chromatograms of known amino acids on the same plate.

g laboratory experience in separating and identifying the amino acids found in  
ree sap.

#### CO<sub>2</sub> in a Substance

and apparatus for collecting a gas by displacement of water. Use a calibrated  
the gas. In the interests of safety, wrap the generator bottle with a towel or  
tube.

r displaced in the collecting vessel as 100 ml. of water are added to the  
d volume caused by any solution being added to the generator should be subtracted

of an effervescing antacid substance used for stomach disorders into the dry  
ml. of water, and collect the CO<sub>2</sub> produced.

Effect the amount of gas formed.

perature of the water added to the generator and the temperature of the water in  
s. This should give an opportunity to discuss the necessity for controlling all  
e being investigated in an experiment.

#### A 8.12 Making a Series of Dilutions

In a 100-ml. volumetric flask containing about 75 ml. of hot water, dissolve the crystals. Cool the solution, and adjust its volume to 100 ml. Label it.

Make the first dilution. Transfer by a volumetric pipette 10 ml. of the solution to a 100-ml. volumetric flask. Add water to adjust the volume to 100 ml. Label it.

The second dilution is made by using the same technique to transfer 10 ml. of the first dilution to a 100-ml. volumetric flask. Add water to increase its volume to 100 ml. Label this solution 0.002 g./ml.

Successive dilutions are made until the eye can no longer distinguish the color of the solution.

Use the dilutions to demonstrate a simple colorimeter. Compare 10-ml. portions of an unknown concentration of the same solute. The unknown concentration is compared to the standard which most closely matches the color of the unknown.

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containing about 75 ml. of hot water, dissolve 20 grams of copper sulfate and adjust its volume to 100 ml. Label this solution 0.2 g./ml.

Transfer by a volumetric pipette 10 ml. of the 0.2 g./ml. solution to a 100-ml. flask and adjust the volume to 100 ml. Label this solution 0.02 g./ml.

Using the same technique to transfer 10 ml. of 0.02 g./ml. solution and label this solution 0.002 g./ml.

Continue until the eye can no longer distinguish any color to the solution.

Use a simple colorimeter. Compare 10-ml. samples of the dilutions with 10 ml. of the same solute. The unknown concentration will be approximately equal to the one which matches the color of the unknown.

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## APPENDIX B - BIBLIOGRAPHY OF CHEMISTRY REFERENCE MATERIALS

Among the many reference books available, the following may be used by teachers for

### General

- Crespin, F. S. *Dictionary of technical terms*. New York. D. Bruce. 1948.
- Grant, J. S. *Hackh's chemical dictionary; 3d ed.* New York. Blakiston. 1944.
- Gray, C. H. *Laboratory handbook of toxic agents*. Prentice-Hall. 1961.
- Manufacturing Chemists' Association, Inc. *Guide for safety in the chemical laboratory*. Van Nostrand. 1954, 1962.
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- Nebergall, W. H., Schmidt, F. C., & Holtclaw, H. F. *General chemistry*. Boston. 1961.
- Sanderson, R. T. *Chemical periodicity*. New York. Reinhold. 1963.
- Sienko, M. J. & Plane, R. A. *Chemistry*. New York. McGraw-Hill. 1965.

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- Biddle, H. C. & Floutz, V. W. *Chemistry for nurses*. Philadelphia. Davis.
- \_\_\_\_ *Chemistry in health and disease*. Philadelphia. Davis. 1963.
- Campaigne, E. A. *Elementary organic chemistry*. Prentice-Hall. 1962, 1963.
- Fieser, L. F. & Fieser, Mary. *Basic organic chemistry*. Boston. Heath.

#### Area 5

- Fitch, N. K. & Francis, C. A. *Foods and principles of cookery*. Prentice-Lowe, Belle. *Experimental cookery*. New York. Wiley. 1955.

#### Area 6

- American Petroleum Institute. *Conserving our waters and clearing the air*.
- American Public Health Association, American Water Works Association, and (Joint publication). *Standard methods for the examination of water and wastewater*. American Public Health Association. 1965.
- Education Committee, Mid-Atlantic States Section, Air Pollution Control Association. *Standard methods for the examination of water and wastewater for junior and senior high school science classes*. Pennsylvania. Air Pollution Control Association.
- Lewis, H. R. *With every breath you take*. New York. Crown Publishers. 1963.
- McKinney, R. E. *Microbiology for sanitary engineers*. New York. McGraw-Hill. 1963.
- Monroe County Conservation Council. *Study report by committee on air and water quality*. Daily Record Corporation. 1970.
- New York State Department of Health. *Laboratory procedures for wastewater analysis*.
- \_\_\_\_ *Manual of instruction for water treatment plant operators*. Albany.

*Chemistry for nurses.* Philadelphia. Davis. 1963.

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*Organic chemistry.* Prentice-Hall. 1962, 1965.

*Basic organic chemistry.* Boston. Heath. 1959.

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*Textbook for sanitary engineers.* New York. McGraw-Hill. 1962.

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### Area 7

- Brady, G. S. *Materials handbook; 9th ed.* New York. McGraw-Hill. 1963
- Chase, G. D. & Rabinowitz, J. L. *Principles of radioisotope methodology*
- Cook, J. G. *The miracle of plastics.* New York. Dial Press. 1964.
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- Holum, J. R. *Elements of general and biological chemistry.* New York.
- Melville, H. R. *Big molecules.* New York. Macmillan. 1958.
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- New York State Education Department. *Nuclear survival - a resource hand*
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\_\_\_\_ *Understanding the atom series*. Oak Ridge. The Commission. Each booklet suggested references including books, articles, and motion pictures. The series "Reading Resources in Atomic Energy."

#### Area 8

Block, R. R., Durrum, E. B., & Sweig, G. T. *A manual of paper chromatography and related techniques*. New York. Academic Press. 1958.

Randerath, K. K. *Thin layer chromatography*. New York. Academic Press. 1965.

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U. S. Government Printing Office. 1959.

e. The Commission. Each booklet concludes with a list of  
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*A manual of paper chromatography and paper electrophoresis.*

New York. Academic Press. 1965.

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APPENDIX C - FILMS AND FILMSTRIPS

Among the many films and filmstrips which may be used are the following:

AREA I - Similarities and Dissimilarities of Matter

Films:

- Cor Chemical bonds and atomic structure
- Chemistry Laboratory techniques series:
  - Introduction to the Chemistry Laboratory
  - Bunsen burner
  - Glass tubing
  - The test tube
  - The reagent bottle
  - Solids
- Cor Elements, compounds, and mixtures
- Cor The halogens (2d ed.)
  - M Family of halogens
  - SM Fun in metals
- Cor Ionization
- BU Magic of sulfur
- Cor Metals and nonmetals
- Cor Preparation and properties of halogens
- Cor The sodium family
- Cor Solutions
- Cor Sulfur and its compounds

Film loops:

- E Chemistry Laboratory Technique Series
  - Bunsen burner
  - Heating solids
  - Heating liquids
  - Weighing on a two-pan balance
  - Filtration
  - Use of a burette
  - Use of a pipette
  - Working with glass

Filmstrips:

- EBF Electron arrangement and chemical bonds
- EBF Ionic and covalent bonds
- EBF Ionization and dissociation

AREA II - The Preparation of Compounds

Films:

- EBF Electrolysis
- EBF Oxidation-reduction
- M Oxidation-reduction
- Cor Properties of acids
- Cor Properties of bases
- Cor Standardization
- M Structures of acids and bases

Filmstrips:

- M Chemical reactions
- M Equations
- M Laboratory techniques
- M Periodic table

AREAS III and IV - Properties of Matter

Films:

- S Crude oil
- Cor Hydrocarbons
- P Make materials
- S Refining
- BU Story of oil

Filmstrips:

- M Hydrocarbons

AREA V - Chemistry

Films:

- A Effect of acids and bases

AREA VI - Environmental Chemistry

Films:

- NM Air pollution (3 parts)

K C - FILMS AND FILMSTRIPS

may be used are the following:

er AREA II - The Preparation and Separation of Substances

Films:

es: EBF Electrochemistry  
EBF Oxidation and reduction  
ratory M Oxidation - reduction  
ion Cor Properties of water  
Cor Properties of solutions  
Cor Standard solutions and titrations  
wpipe M Structure of water

in the Filmstrips:

ratory M Chemical formula  
M Equations  
M Laboratory techniques  
M Periodic table

AREAS III and IV - Organic Compounds

Films:

ns S Crude oil distillation  
Cor Hydrocarbons and their structure  
P Make me useful  
S Refining oil for energy  
s BU Story of gasoline

Filmstrips:

M Hydrocarbons

AREA V - Chemistry in the Home

Films:

A Effect of heat on milk

AREA VI - Environmental Pollution

Films:

nds NM Air pollution: take a deep deadly breath  
(3 parts)

EC Better water for Americans  
 PHS Control of air pollution MIS 676  
 PHS Effects of air pollution MIS 678  
 IS Endless search (scrap processing)  
 EC Finding out about the water cycle  
 PHS George Washington's river MIS 525  
 Cor Hard water  
   A It's your decision - clean water  
 EC Municipal sewage treatment processes  
 BR New water for a thirsty world  
 MT Pure water and public health  
 RH Role of ion exchange  
 EC Sanitary landfill - open dump conversion  
 PHS Sources of air pollution MIS 677  
 EC Take a deep breath  
   S The river must live  
 NM The third pollution (Land pollution)  
 AP To clear the air  
 EC Wise use of water resources  
 EC With each breath

F Of mer  
 BT Physic  
 AEC Radiat  
 AEC Radioi  
 DN Report  
 BU Silver  
 AEC The ne  
 AEC Unders  
 Alph  
 Rad  
 Prop

AREA VIII - Chem

Films:

AEC Art of  
 M Princ

Filmstrips:

W Environmental pollution...our world in  
   crisis

AREA VII - Some Modern Materials

Films:

AEC Art of separation (radio-chromatography)  
 AEC Atomic cities  
 US Blast furnace  
 UC Case of the fantastic plastic  
 BU Copper, the oldest modern metal  
 FM FMC Fibers and films  
 AEC Isotopes (production and handling)  
 USA Lead from mine to metal  
   G Magic touch (polymerization)  
 AEC Man and radiation (application)  
   C Manufacturing reinforced plastics  
   R New world of chemistry  
   G New world of rubber

for Americans  
air pollution MIS 676  
air pollution MIS 678  
ch (scrap processing)  
about the water cycle  
ngton's river MIS 525  
cision - clean water  
wage treatment processes  
r a thirsty world  
nd public health  
exchange  
dfill - open dump conversion  
r pollution MIS 677  
breath  
st live  
lution (Land pollution)  
air  
water resources  
eath

F Of men and molecules  
BT Physical chemistry of polymers  
AEC Radiation in perspective (radiation hazard)  
AEC Radioisotopes - safe servants of industry  
DN Report on DuPont elastomers  
BU Silver  
AEC The new power (power reactor)  
AEC Understanding the atom series:  
Alpha, beta, gamma Detection by  
Radiation and matter ionization  
Properties of radiation Detection by  
scintillation  
Nuclear reactions

AREA VIII - Chemical Analysis

Films:

AEC Art of separation (chromatography)  
M Principles of chromatography

pollution...our world in

terials

tion (radio-chromatography)

antastic plastic  
ldest modern metal  
and films  
duction and handling)  
e to metal  
polymerization)  
tion (application)  
reinforced plastics  
chemistry  
rubber

## KEY TO SOURCES

The companies listed in the key below lend the films in Appendix request, supply complete lists of their films.

- |                                                                                                                                                      |                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <p>(A) Association Films<br/>347 Madison Ave.<br/>New York, N.Y. 10017</p>                                                                           | <p>(BT) Bell Tel<br/>(contact)</p>                                                 |
| <p>(AEC) U.S. Atomic Energy Commission<br/>New York Operations Office<br/>Public Information Service<br/>376 Hudson St.<br/>New York, N.Y. 10014</p> | <p>(BU) Bureau of<br/>United States<br/>Graphic<br/>4800 Forbes<br/>Pittsburgh</p> |
| <p>(AP) American Petroleum Institute<br/>Committee on Public Affairs<br/>1271 Avenue of the Americas<br/>New York, N.Y. 10020</p>                    | <p>(C) Carborundum<br/>Attn.:<br/>Niagara</p>                                      |
| <p>(Cor) Coronet Films<br/>42 Midland Rd.<br/>Roslyn Heights, N.Y. 11577</p>                                                                         | <p>(EBF) Encyclopaedia<br/>38 W. 32nd<br/>New York</p>                             |
| <p>(D) Disraeli Films<br/>P.O. Box 343 - Cooper Station<br/>New York, N.Y. 10003</p>                                                                 | <p>(EC) New York<br/>Film Library<br/>50 Wolf<br/>Albany, N.Y.</p>                 |
| <p>(DN) DuPont de Nemours and Co., Inc.<br/>Motion Picture Section<br/>Advertising Dept.<br/>1007 Market St.<br/>Wilmington, Del. 19898</p>          | <p>(F) Farm Film<br/>1425 H Street<br/>Washington, D.C.</p>                        |
| <p>(E) The Ealing Corp.<br/>Cambridge, Mass. 02140</p>                                                                                               | <p>(FM) FMC Corp<br/>American<br/>Product<br/>1617 John<br/>Philadelphia</p>       |
| <p>(BR) Bureau of Reclamation<br/>Office of Chief Engineer<br/>Building 67<br/>Attn.: D-841<br/>Denver Federal Center<br/>Denver, Colo. 80225</p>    | <p>(G) Goodyear<br/>A.V. Dept.<br/>Akron, Ohio</p>                                 |

## KEY TO SOURCES

They below lend the films in Appendix C. Many of these companies will, upon request, lend their films.

- (BT) Bell Telephone Company  
(contact local telephone office)
- (BU) Bureau of Mines  
United States Department of Interior  
Graphic Services  
4800 Forbes Ave.  
Pittsburgh, Pa. 15213
- (C) Carborundum Co.  
Attn.: Mr. W. Evans  
Niagara Falls, N.Y. 14302
- (EBF) Encyclopaedia Britannica Films  
38 W. 32nd St.  
New York, N.Y. 10001
- (EC) New York State Environmental Conservation Dept.  
Film Library  
50 Wolf Road  
Albany, N.Y. 12201
- (F) Farm Film Foundation  
1425 H St., N.W.  
Washington, D.C. 20005
- (FM) FMC Corporation  
American Viscose Division  
Product Information  
1617 John F. Kennedy Blvd.  
Philadelphia, Pa. 19103
- (G) Goodyear Tire and Rubber Co.  
A.V. Department  
Akron, Ohio 44316

- (IS) Institute of Scrap Iron and Steel  
Public Relations Department  
1729 H St., N.W.  
Washington, D.C. 20006
- (M) McGraw Hill  
330 W. 42nd St.  
New York, N.Y. 10036
- (MT) Modern Talking Picture Service  
122 West Chippewa St.  
Buffalo, N.Y. 14202
- (NM) National Medical Audiovisual Center (Annex)  
Station K  
Atlanta, Ga. 30324
- (P) Pure Oil Co.  
Film Library  
200 E. Golf Road  
Palastine, Ill. 60067
- (PHS) Public Health Service  
Communicable Disease Center  
Atlanta, Ga. 30300
- (R) Reichhold Chemicals, Inc.  
Att.: L. Welles, A.V. Department  
525 N. Broadway  
White Plains, N.Y. 10602
- (RH) Rohm and Haas Company  
Redstone Research Lab  
Huntsville, Ala. 35807
- (S) Shell Oil Company  
Film Library  
149-07 Northern Blvd.  
Flushing, N.Y. 11354
- (SM) American Society for Metals  
Attn.: Mr. T. C. DuMond  
Metals Park, Ohio 44073
- (UC) Uniroyal Chemical  
Public Relations Dept.  
Chemical Division  
Naugatuck, Conn. 06770
- (US) United States Steel Corporation  
New York Film Distribution Center  
71 Broadway  
New York, N.Y. 10006
- (USA) United States Audiovisual Center  
National Archives and Record Servi  
Washington, D.C. 20409
- (W) Wards Natural Science Establishmen  
Rochester, N.Y. 14603