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ABSTRACT

This volume contains the lesson plans and appropriate teacher background information for a 43-lesson sequence on the subject of respiration. Associated materials, contained in separate volumes, include a student text and a student laboratory manual. Each lesson outline includes a rationale, objectives, sequence of student text lessons and laboratory activities, suggestions, teaching notes, and materials necessary for teaching each lesson. (Author/RE)

BIOMEDICAL SCIENCE

UNIT I

RESPIRATION IN HEALTH AND MEDICINE

RESPIRATORY ANATOMY, PHYSIOLOGY AND PATHOLOGY; THE BEHAVIOR OF GASES; INTRODUCTORY CHEMISTRY; AND AIR POLLUTION

INSTRUCTOR'S MANUAL
REVISED VERSION, 1975

THE BIOMEDICAL INTERDISCIPLINARY CURRICULUM PROJECT

SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION

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INTRODUCTION

Perhaps the most important characteristic of the Biomedical Science course is the broadly interdisciplinary nature of its approach to learning. In itself, the course is a combination of those basic principles of biology, chemistry and physics needed for an understanding of health and medical topics. But beyond this, the science course is linked to courses in mathematics and social science which approach the subjects of health and medicine from their own respective points of view. And, although the course is not a vocational one in the traditional sense of the word, every attempt is made to introduce the student to potential career opportunities in the health and medical fields.

As the subtitle indicates, this opening unit is concerned with the anatomical structures and the physiological processes involved in respiration and how these structures and processes can be affected by various respiratory distresses. The latter information is introduced through a series of fictional case histories, which are included in the Student Text. It is hoped that the end result will be a thorough understanding of respiration and a basic knowledge of the symptoms, first aid, treatment and prevention of the various respiratory distresses presented in the unit.

The problem of air pollution, and smoking as a form of self-induced air pollution, is also presented in the unit. The topic is approached by first identifying the classes of air pollutants and their sources and the meteorological phenomena that contribute to the problem. The effects of air pollutants on the respiratory system are then examined, and finally corrective measures are discussed.

In addition to the biomedical and environmental studies, the student is exposed to certain fundamental principles of physics and chemistry that relate to the process of respiration. These include an understanding of the behavior of gases and the gas laws, the atomic theory of matter, molecular formation and the basis for chemical reactions.

This volume contains the lesson plans and appropriate teacher background information for a 43-lesson sequence on the subject of respiration. Associated materials, contained in separate volumes, include a student laboratory manual and a student text.

Your students may need some explanation of the numbering system used for laboratory activities and sections of the Student Text. For example, the laboratory manual begins with Laboratory Activity 2, there is no Section 7 in the Student Text, etc. The numbers of the laboratory activities and sections of the Student Text are keyed to the lesson numbers of this volume. Such a numbering

system makes it possible to see at a glance how the two student volumes are organized in relation to one another. In addition, we have given in each lesson a suggested sequence of presentation. For example "ST-1; LA-1" indicates that Section 1 of the Student Text should precede Laboratory Activity 1.

A point that cannot be made too strongly is that what is called a "lesson" here is not necessarily a classroom "day." The pacing of these materials is entirely up to you and the needs of your students (and, to some extent, the other two members of your team). Our experience has been that on the average five of our "lessons" require approximately seven double-period days in the classroom.

We wish to stress the importance of maintaining close contact with the other members of the Biomedical teaching team. For this particular unit, your pacing and the pacing of the mathematics instructor must be closely coordinated. There are three specific instances in which data collected in the science laboratory are to be transferred to the mathematics class for analysis. For this reason, the following events <u>must</u> occur.

LA-15 must precede Math Lesson 19
LA-16 must precede Math Lesson 20
LA-18 must precede Math Lesson 22

In addition, the science materials depend heavily upon concepts and skills developed in the mathematics course. In particular, dimensional algebra, ranges of imprecision, graphing and scientific notation are all used in the science course following their initial development in the mathematics course.

For Unit I, there should be no special pacing requirements in relation to the social science course. It should be pointed out, however, that the social science instructor will be partially dependent on you for input on the indentification of interdisciplinary review problems near the end of the unit.

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INTRODUCTORY LESSON:

ORIENTATION TO THE BIOMEDICAL CURRICULUM

SUGGESTIONS:

The two purposes of this lesson are to inform students of the basic structure and intent of the Biomedical Curriculum, and to demonstrate to students that their three instructors are working as an interdisciplinary team. To accomplish this, you and your two colleagues should meet with the students for the first class period of the semester. If Science is the first of the three classes scheduled, all three instructors may still have a full class period to dispose of administrative details. If this is not the case, you may be able to arrange schedules so that each of you will have at least some of your own class time with the students. Although arranging schedules so that three teachers are free during the same period may be difficult, starting the course with this joint orientation will go far toward encouraging you and your students to approach curricular topics with an interdisciplinary perspective.

This first meeting can be organized in a number of ways. An essential ingredient is the provision for student questions. This will allow students to see how you and your colleagues interact as a team. Each of you may wish to react to the entire program from your own perspective, thus allowing students the opportunity to see how different perspectives can and should be applied to a central topic such as health.

Specifically, your team may be able to locate an article in the local newspaper which will allow each of you to indicate how your teaching area can provide a perspective on the topic. For example, a drought or famine in some area of the world, accidents, coronary heart disease, or organ transplants are appropriate for analysis by the mathematician, the natural scientist and the social scientist. A statement about changes in the health characteristics of a population, such as an increase in the frequency of an illness, or an increase in the proportion of persons over sixty-five, is also appropriate for analysis from all three perspectives. A health care delivery topic, such as a shortage of equipment or a financial dilemma, can be used to illustrate how all three perspectives may be applied.

Other examples will occur to you and your colleagues as you plan for this meeting, or you may want to use another approach. The organization of this initial lesson is not as important as the results you are able to obtain in orienting the students to the curriculum in an interdisciplinary manner.

In the next class session each of the three teachers may have time to pursue in greater depth the perspective each course can supply for a health topic. If students come to understand that the three courses will seldom be totally related to each other on specifics, but will often be related to each other on general topics, they will begin the course of study with the appropriate interdisciplinary approach.

LESSON 1: (A) WHAT IS A BIOMEDICAL CURRICULUM?

(B) WHY A BIOMEDICAL CURRICULUM?

RATIONALE:

ST-1 consists of an introduction to the entire biomedical curriculum. It is intended to give the students an idea as to why such a curriculum was written as well as an overview of how the curriculum is organized in terms of content and sequence.

OBJECTIVES:

The student will explain how a biomedical curriculum can help to improve the general health of people in the United States.

The student will state the importance of an interdisciplinary approach to the solution of health-care problems.

SUGGESTIONS:

1. In discussing the need for more resources (both material and human) in the health field you might make the point that disease is still a serious problem by giving out the following statistics: the life expectancy of people past the age of 40 has not changed significantly since the early 1900's. This information is often shocking to people who believe that the health situation in the United States must be much better than it was previously. However, despite the advances which have been made, this statistic still prevails. Possibly, the explanation lies in the fact that although the incidence of infectious diseases has decreased, that of degenerative conditions such as coronary disease has increased. Thus, there is still an immense amount of work to be done.

2. There is no laboratory activity associated with ST-1. However, suggestions for a possible LA-1 are appended.

3. You may wish to conduct an open discussion on the reasons why the students have enrolled in the biomedical program. What are their interests, their career aspirations? What do they want to get out of the program? Such a

discussion should help the students to become acquainted with each other. You might also talk about the requirements necessary to reach some of the students' goals and ways in which the curriculum may be of help.

4. Consider procuring a fetal pig which could be used throughout the year for demonstration of the various anatomical structures as they are introduced in the Text.

5. Free brochures and other information on various respiratory disorders are available from such organizations as the American Cancer Society, the Easter Seals Foundation, the Asthma Foundation, etc.

6. You might wish to have the students maintain a collection of the meanings of prefixes, roots and suffixes from the Latin and Greek as they come up in the curriculum.

7. A field trip to the inhalation therapy section of the local hospital would be very useful near the end of the unit.

8. See Lessons 20 and 21. Both contain suggestions that would have to be arranged for well in advance.

9. WARNING. LA-34 calls for students to make a finger puncture with a lancet. You may wish to make sure well in advance that there are no community or state laws prohibiting this procedure. Finger punctures are called for a number of times in later units, as well.

GENERAL INTRODUCTION TO LABORATORY ACTIVITIES:

The information on laboratory activities given in this volume is presented under the following headings.

TEACHING NOTES:

1. The first note gives the purpose of the activity.

2. The second note provides an estimated time for completion of the activity.

3. Additional notes provide other hopefully useful information. When it is not obvious, an indication is given as to where an activity may be stopped and resumed the next day.

MATERIALS:

1. The materials lists given in the student procedures are for one complete set-up. The materials lists given here are for a specified number of set-ups

(usually 10 or 15). The quantities indicated may be adjusted for any other number of set-ups as desired.

2. Note that the spirometers used in LA-18 will require considerable advance preparation.

3. An organized list of materials for ordering purposes, including sources of unusual items, will be provided separately from the volume.

PREPARATION OF REAGENTS (OR EQUIPMENT):

Unless otherwise indicated, it may be assumed that a prepared reagent may be stored indefinitely at room temperature in a closed transparent bottle.

ANTICIPATED RESULTS:

While most of the procedures include a sample data table or sheet to help the students organize their data, it is assumed that you will make your own specifications as to the nature of lab write-ups in general.

ANSWERS TO DISCUSSION QUESTIONS:

These questions may be used for discussion, or you may wish to require written answers.

SUGGESTIONS FOR LABORATORY ACTIVITY 1:

TEACHING NOTES:

1. The purpose of this activity is to acquaint students with the names, uses, and proper care of some commonly used laboratory equipment.

2. Anticipated time: 1 period

3. The following is an outline of suggested demonstrations and activities which you could perform for the class. Some equipment and techniques are elaborated on in the student activities as appropriate. Basic knowledge of names of equipment, proper lab behavior, safety and first-aid procedures is important before the students begin working in the lab. You could provide a list of names of the equipment and have the equipment set out at various stations in the room. The students could rotate from station to station trying to guess the names of each piece and give uses for it. After the student experience, review the names and uses.

4. You may wish to add to this outline the location of equipment in the laboratory, the assignment of lockers and/or equipment to students and other pertinent information.

5. Since the program is heavily lab-oriented, it is suggested that the students be provided with some basic equpment if storage space (lockers or cabinets) permits. Such space also provides for individual storage of any lab materials which must be kept overnight for observation, drying etc. Suggested equipment is as follows: (for 2 to 4 students) glass marking pencil, 5 (or more) test tubes to fit colorimeter test well, test-tube brush and cleanser, test-tube rack or jar to hold test tubes, slides and coverslips, medicine dropper, box of Kimwipes, and any other commonly used equipment which is not needed elsewhere. Also, suggest that the students bring a bar of hand soap and towel from home if they are not available in the lab.

MATERIAL	DEMONSTRATION, USES
Beaker	Mixing, heating, approximate measurements.
Graduated cylinder	Measuring, collar for protection against falls.
Pipet	Measuring, calibration.
Medicine dropper	Dispensing small amounts, clean with pipe cleaner used as small test tube brush.
Erlenmeyer flask	Swirl to mix solutions.
Test tube and holder	Use holder when heating test tube.
Test-tube rack	Pegs to invert test tubes for drying.
Slide and coverslip	Differences in size and use.
Gas burner	How to light, adjust flame, hottest part of flame. Boil water showing proper technique. Demonstrate water shooting out of test tube if heat is applied incorrectly. Hold test tube so that mouth is not pointing towards anyone.
Matches or striker	Use in lighting gas burner.
Ringstand, ring and wire gauze	Heat beaker of water which can be used as a hot water bath. A hot water bath is used when chemicals in the test tubes are flammable, when chemicals need to be kept at a specified temperature for a period of time, when many tubes need to be heated, or when dangerous chemicals are heated to avoid chance of spattering.
Glass tubing and glass cutter	How to cut glass and fire polish ends. How to bend tubing--(optional).
One-hold stopper	How to safely insert glass tubing into a stopper. Water or glycerine used as a lubricant.
Parafilm	When and how to use.
Eyecup--(optional)	Where stored, how and when to use.

MATERIAL	DEMONSTRATION, USES
Glass-marking pencil	Writes on dry glassware. Will not easily wash off painted-on label spaces that some glassware has.
Funnel and filter paper	How to fold paper.
Volatile liquid	How to smell safely.
Fire blanket or extinguisher (optional)	Location.
Shower and/or eyewash fountain (optional)	Location, how and when to use.

LESSON 2: THE BALANCE AND BIOMEDICINE

RATIONALE:

This begins a series of six lessons intended to acquaint the students with some of the properties of matter and units of measure used in biomedicine. A knowledge of these properties and the instruments used to measure them will be of great help to the student in subsequent lessons and laboratory activities. This first section introduces the properties of mass and weight and the instruments employed to measure them: balances and scales, respectively. The accompanying laboratory activity will give the students some experience in the use of the balance to determine the mass of solids and liquids.

OBJECTIVES:

The student will describe at least two ways in which the balance is used in biomedicine.

The student will define the terms mass and weight.

The student will define the units kilogram and gram and give the abbreviations used for each.

The student will point out the following parts of a balance and explain the function of each: weighing pan, riders, indicator scale, pointer and adjustment screw.

The student will demonstrate how to "zero" a balance.

The student will demonstrate the weighing of a solid and a liquid.

The student will state the reason for using a tare and scoopula when weighing a solid.

SEQUENCE: ST-2; LA-2

SUGGESTIONS:

1. It would be most helpful to be able to show that weight does indeed change under varying conditions. You may do this "on paper" by providing the students with figures for the relative strengths of gravity on different planets. For example, on the Moon a person's weight would be 16.3 per cent of what it is on the Earth, on Mercury it would be 40.0 per cent and on Jupiter, 269 per cent. However, if the same person's mass was determined on a balance it would still take the same amount of mass to bring the balance into equilibrium irrespective of the location.

2. Another demonstration of how weight changes with conditions is to have students obtain a scale and determine their weight as they ride up and then down in an elevator. If the elevator accelerates sufficiently, the weight reading can be seen to increase as the elevator ascends and decrease as it descends.

3. A demonstration of the use of a microbalance may be of interest, if one is available.

INFORMATION ON LABORATORY ACTIVITY 2:

TEACHING NOTES:

1. The purpose of this activity is to introduce the students to the components of the balance, proper care of the balance and proper techniques for its use in determining the mass of solids and liquids.

2. Anticipated time: one period or more.

3. If sand is not available for use as a solid, sodium chloride, table sugar or similar compounds could be used. Scoopulas could be replaced with plastic spoons. Small baby food jars or other similar containers could be used instead of the 50-ml beakers. Paper tares are available from supply houses, but waxed paper or scratch paper cut into about 10-cm squares work just as well. It is best not to use paper toweling since some compounds stick to the rough surface.

4. You may want to instruct the students on carrying the balance with two hands, holding the pan so that it doesn't swing. Your balances may have a lever which secures the pan in place. If so, this should be pointed out to the students. You may also want to provide any pertinent instructions about sharing of balances, if they are in short supply, and about storage.

5. If there are too few balances available for the entire class to perform the activity, Part II of LA-3 could be done by part of the class (after a reading of ST-3). If platform balances are available, the activity could be done using them. Differences between balances should be pointed out.

6. Students often have difficulty understanding why the mass of the tare or beaker must be subtracted to obtain the mass of the solid or liquid being weighed. You may need to reinforce this point.

7. Note that the discussion of the balance ignores the torsion balance on the assumption that it is not likely to be in use in a high school laboratory.

MATERIALS: (for 15 set-ups)

- 15 balances
- 30 beakers, 50-ml
- 15 scoopulas or plastic spoons
- 500 ml sand
- 15 paper tares
- 15 medicine droppers

LESSON 3: (A) THE ACCURACY AND PRECISION OF MEASUREMENTS

(B) VOLUME AND ITS MEASUREMENT

RATIONALE:

In ST-2 the students were introduced to the use of the balance to measure the mass of solids and liquids. In taking such measurements it is important to keep in mind that error is inherent in all measurements. This is the first topic covered in ST-3. In connection with error, the terms precision and accuracy are defined and distinguished.

In the last portion of ST-3 a second property of matter is introduced: the fact that it occupies space. Volume, a measure of the space that a mass occupies, and some of the units in which it is expressed are discussed. In LA-3 the students will become acquainted with the use and precision of two instruments that are used to measure volume: the graduated cylinder and the graduated pipet.

OBJECTIVES:

The student will state why it is important to know the amount of error involved in the taking of measurements.

The student will differentiate between accuracy and precision.

The student will give an example of how a measurement may be very precise and yet inaccurate.

The student will describe the procedures used to test the accuracy and the precision of a balance.

The student will define the terms volume, liter, milliliter and meniscus.

The student will measure out a specified volume of water using both a graduated cylinder and a graduated pipet.

SEQUENCE: ST-3; LA-3

SUGGESTIONS:

1. The difference between accuracy and precision could be demonstrated using two balances that are similar to each other in precision except that the zero setting in one could be changed so as to be about 0.1 g off. Measurements made on both balances would be similar as far as precision was concerned, but the measurements made on the one that is incorrectly zeroed would be much more inaccurate.

2. It would also be possible to determine the precision and accuracy of a particular balance by taking a series of measurements (precision) and weighing a set of standard masses (accuracy).

INFORMATION ON LABORATORY ACTIVITY 3:

TEACHING NOTES.

1. The purpose of this activity is to introduce techniques for the proper measurement of volume using a graduated cylinder and a pipet and to compare the precision of the two instruments.

2. Anticipated time: one period or more.

3. The materials list for Part II was inadvertently omitted. It should read: 10-ml pipet, 1-ml pipet, 2 50-ml beakers, Kimwipes (or other tissues).

4. The following changes in equipment can be made. The beakers can be replaced with small baby food jars or other containers. If 100-ml graduated cylinders are not available, 50-ml or 200-ml can be used.

5. You may wish to show the students the proper placement and purpose of a collar on a graduate.

6. In later activities, pipetting of dangerous chemicals will be necessary. Either in this activity or when the need arises, give the students experience in alternate ways of using the pipet. One method is to attach a syringe to the top of the pipet with a short (3 to 5 cm) piece of rubber tubing. Another method is to attach a rubber bulb to the top of the pipet. If syringes are available, they are easier to use than the rubber bulb.

7. Part II points out that the pipet is graduated with the numbers running from top to bottom. This, of course, is not always true. If your pipets are graduated in the opposite direction, some discussion will be needed.

8. In Part II, Step 6, it may be necessary to explain why the pipet is touched to the inside of the beaker.

MATERIALS: (for 15 set-ups)

15 graduated cylinders, 10-ml
15 graduated cylinders, 10-ml
30 beakers, 50-ml
15 balances
15 pipets, 10-ml
15 pipets, 1-ml
15 medicine droppers
Kimwipes (or other tissues)

ANSWERS TO DISCUSSION QUESTIONS:

PART I:

1. 1 ml of water has a mass of 1 gram.

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2. Find the volume of water by weighing it.

PART III:

1. Because not all the water can be poured out; therefore leaving the water in the beaker would increase accuracy (unless the beaker was weighed "empty" each time).

2. The pipet is better because almost all the liquid can be blown out.

3. Otherwise liquid running down the outside of the pipet could cause an error in volume.

LESSON 4: (A) DENSITY

(B) AVERAGING MEASUREMENTS

RATIONALE:

In this section density, another of the properties of matter, is introduced, and its importance in biomedicine is discussed. Since a calculated density is an average, the subject of averaging data is taken up; and the effect of averaging on accuracy and precision is discussed.

In LA-4 the students are asked to determine the densities of several solids and liquids. This activity also provides for the reinforcement of techniques learned in LA-2 and LA-3, since measurements of both mass and volume are necessary to determine the density of matter.

OBJECTIVES:

The student will define the terms density and mean.

The student will list two ways in which density may be expressed.

The student will give one example of the use of density measurements in biomedicine.

Given a set of four density values, the student will calculate the mean density.

The student will determine the densities of solids and liquids by measuring their masses and volumes.

SEQUENCE: ST-4; LA-4

SUGGESTIONS:

1. You may wish to present some of the following questions to the class for consideration.

a. Given a liquid and a solid, how could you determine which of the two is denser without resorting to measurements of mass and volume? (Denser objects sink, lighter ones float.)

b. Why does a piece of dry wood usually float while the same piece of wood may sink after remaining in the water for a long period of time? (The average density of dry wood, containing many air spaces, is less than that of water. If this same piece of wood becomes waterlogged, i.e., the air spaces become filled with water, the average density may increase to such a degree that it becomes greater than that of water. Some woods are denser than water to start with.)

c. Why do ships made of steel float if the density of steel is greater than that of water? (The volume of water that the ship displaces is not all replaced by steel. Most of the volume is occupied by the air inside a ship's hull, making the average density of the mass displacing the water less than that of water.)

d. Why do some people have more buoyancy in water than others? (People are made up of a number of different types of mass, some denser than others. The average density depends on the relative proportions of these different types of mass. For example, fat is less dense than muscle and bone. If two people were identical except for the percentage of fat, the person with the greater percentage of fat would be more buoyant.)

e. Why is it easier to float in sea water than in fresh water? (Sea water is denser than fresh water.)

2. The students may be interested in the densities of some of the commonly known elements. In g/ml,

magnesium = 1.74	tin = 7.3	lead = 11.4
carbon = 2.26	nickel = 8.9	mercury = 13.6
aluminum = 2.70	copper = 8.96	gold = 19.3
chromium = 7.19	silver = 10.5	platimun = 21.4

The most dense element is osmium at 22.6 g/ml.

INFORMATION ON LABORATORY ACTIVITY 4:

TEACHING NOTES:

1. The purpose of this activity is to calculate the density of several solids and liquids from measurements of mass and volume.

2. Anticipated time: One period or more.

3. It is suggested that you make dishwashing soap and pipe cleaners available for use in washing the cooking oil from the pipets and other glassware.

4. The following variations can be made in the equipment. The rubber stoppers can be solid, one- or two-holed as long as they fit easily into the graduate. Glass tubing can be substituted for glass rods. 10 to 15 paper clips, small washers, pennies, or other small-sized metal objects can be substituted for the nails. Any small glass container can be used instead of the 50-ml beakers.

5. As time permits, you might make other materials available for the students to use to find densities. Solids with densities less than 1 g/ml, such as cork or styrofoam, should be interesting.

6. If calculators are available or if students know how to use slide rules, they might be used for the calculations.

7. The class could be divided with half doing Part I while the other half does Part II first.

MATERIALS: (for 15 set-ups)

15 graduated cylinders, 100-ml

15 balances

30 pipets, 10-ml

30 beakers, 50-ml

Kimwipes (or other tissues)

The following materials can be shared. Enough for 5 set-ups is given.

10-15 rubber stoppers (any size that fits into graduate)

10-15 glass rods

10-15 nails

75 ml alcohol, denatured

75 ml cooking oil

75 ml corn syrup (or molasses)

ANSWERS TO DISCUSSION QUESTIONS:

PART I:

1. Make the anchor out of the most dense material since it will sink and hold the boat best.

2. The volume determination is less precise.

PART II:

1. Water is the most dense; alcohol the least dense.

2. Only the mass of the liquid is needed. The material in the beaker will not affect the mass of the material added. It is important that the mass of the beaker and any material in it be known before adding more, however.

3. Oil is on top because it is less dense than water.

LESSON 5: (A) LENGTH, AREA AND VOLUME

(B) DETERMINING VOLUMES

RATIONALE:

In biomedicine the determination of area, volume and specific gravity is often called for in diagnostic testing. The significance of these measures and their calculation is the topic of this section. Since area is calculated from length measurements, length is introduced at the beginning of ST-5. The various units used to designate length and their relationship to one another are discussed. This is followed by a treatment of area (and square length units) and volume, this time in cubic length units. LA-5 provides an opportunity for the student to make practical determinations of mass, surface area, volume and density.

OBJECTIVES:

The student will state one reason why length is an important dimension in biomedicine.

The student will define the term meter and state the meaning of the prefixes "kilo-," "deci-," "centi-," "milli-," and "micro-."

The student will define area and give one example of its importance in biomedicine.

Given the length of one side of a square in meters, the student will calculate the area in square meters and square centimeters.

Given the length of one edge of a cube in meters, the student will calculate the volume of the cube in cubic meters and in cubic centimeters.

The student will state the relationship between one milliliter and one cubic centimeter.

The student will define specific gravity.

The student will distinguish between specific gravity and density.

The student will state one use of specific gravity in medicine.

The student will determine the surface area and volume of a cylinder.

The student will determine the volume of an irregular object.

SEQUENCE: ST-5; LA-5

SUGGESTIONS:

1. In Section 4 a test for measuring the density of blood was mentioned. You might point out that what is actually being tested for is the specific gravity of the blood. The blue solutions which are used are copper sulfate solutions of known specific gravities. By determining in which solutions the blood sinks or remains suspended, the approximate specific gravity of the blood is estimated. A low specific gravity may be a sign of anemia while a high one could be due to infection or some other disease process.

2. Specific gravity measurements of urine are also of clinical importance in medicine. Too high or too low a specific gravity could indicate that the kidneys are not functioning properly in diluting or concentrating the urine. A high specific gravity may also be the result of sugar in the urine (a symptom of diabetes) or too much protein (often a symptom of kidney disease).

3. In connection with specific gravity it was mentioned that water occupies a minimum volume at 39 °F. The fact that water expands as it solidifies into ice at 32 °F is a very unusual property. The students are probably aware of the fact that water expands as it freezes, but they may not be aware that it is the only liquid (so far as we know) that behaves in this fashion. You might discuss some of the ecological implications of this property of water. For example, it accounts for the formation of ice at the top rather than the bottom of bodies of water. This fact is of paramount importance to the survival of aquatic organisms that are "bottom-feeders."

4. Water has a number of other special properties which make it uniquely appropriate for the existence of life. If any of the students wish to learn more about this substance you might refer them to the books listed below. Water will be discussed further in Unit II.

A.D. Giese. Cell Physiology. W.B. Saunders Co., Philadelphia, 1968, pp. 173-7.

L.J. Henderson. Fitness of the Environment. Macmillan Co., N.Y., 1927.

W.T. Keaton. Biological Science. W.W. Norton & Co., N.Y., 1972, p. 26.

5. The instrument used to measure specific gravity of liquids is called a hydrometer. It is basically a tube that can be filled with a specified volume of

the liquid to be measured. The tube is then placed in water so that it floats. The level at which it floats is a measure of the specific gravity. One project which you might suggest to the students is to construct a crude hydrometer. This would necessitate the fashioning of a container that would float in water when a given amount (say 15 ml) of water was added to it. The "water line" could then be determined for a number of liquids of known density, including water, and the scale on the hydrometer calibrated accordingly.

INFORMATION ON LABORATORY ACTIVITY 5:

TEACHING NOTES:

1. The primary purpose of this activity is to help the students to distinguish clearly between length, area and volume. In addition, it provides further experience with mass and volume measurements and the concept of density. The activity asks them to find the mass, surface area, volume, and density of a rectangular solid, to find the surface area and volume of a cylinder from two measurements of length, and to find the volume of an irregular solid that is too large to fit inside a graduate.

2. Anticipated time: one period or more.

3. Prior to starting the activity, it may be well to determine how much review is needed for the students to find surface area and volume from linear measurements.

4. The rectangular solid and the irregular solid should both be made of the same substance. Blocks of wood from the school woodshop are one possibility.

5. There are at least three possible approaches to finding the volume of the irregular solid.

a. Find a container large enough to submerge the solid. Mark the water levels before and after submersion and determine the volume of water between the two levels.

b. Find the mass of the entire solid. Then break off a small chunk and find its mass. Find the volume of the small chunk, and determine its density. Use the density to calculate the volume of the entire solid.

c. Same as "b" except omit two steps by assuming that the density is the same as it was for the rectangular solid. Note that this solution requires that both solids be made of the same substance.

6. The diameter of the graduate could be checked by providing the students with a compass. Have them open the distance between the two points to the diameter and then measure the distance between them.

MATERIALS: (for 15 set-ups)

15 graduated cylinders, 100-ml
15 balances
15 millimeter rulers
15 rectangular solids
15 irregular solids
15 pieces of scratch paper, 15 cm x 15 cm or larger
assorted containers (beakers, buckets, etc.) for determining volumes in Step 14

ANTICIPATED RESULTS:

Graduated Cylinder:

diameter: 2.6 cm

height: 19 cm

calculated radius: 1.3 cm

calculated volume: approximately 100.9 cu cm

calculated total surface area of 100 ml of water: approximately 165.8 sq cm

ANSWERS TO DISCUSSION QUESTIONS:

1. a. Direct measurement in ml (for powdered or granular solids).

   b. Water displacement (for small solids).

   c. Measurement of linear dimensions and calculation.

2. Calculation from linear measurements is likely to be least precise, because it is based on three different measurements.

3. Total body volume would best be determined by submersion in a tank of appropriate size.

LESSON 6: TEMPERATURE SCALES AND THERMOMETERS

RATIONALE:

In this section temperature is discussed as another property of matter. The origin and relationship of the Fahrenheit and Celsius temperature scales is covered. The principle on which a thermometer works is pointed out, and the difference between the laboratory thermometer and the clinical thermometer is discussed.

LA-6 provides an opportunity for the student to familiarize himself with the proper use of the laboratory thermometer.

OBJECTIVES:

The student will convert a temperature stated in °F to °C and vice versa.

The student will state the relationship between the volume of mercury in a thermometer and the temperature of the matter that is being measured.

The student will explain why a fever thermometer must be shaken before it can be reused, and will state the usefulness of this property.

The student will measure the temperature of a liquid.

The student will demonstrate the expansion of a volume of gas and of a liquid with increase in temperature.

SEQUENCE: ST-6; LA-6

SUGGESTIONS:

1. The measurement of body temperature is one of the most commonly used diagnostic tests in disease in medicine. This stems from the fact that almost all diseases are accompanied by a rise, or less commonly, a fall in body temperature. The topic of temperature regulation in health and disease is one of great importance and interest. If some of your students with high reading levels wish to do some research on this subject you might suggest the following references.

T.R. Harrison, et. al., Eds. Principles of Internal Medicine. McGraw-Hill Book Co., 1966, pp. 50-2.

W.F. Ganong. Review of Medical Physiology. Lange Medical Publications, California, 1973, pp. 168-72.

2. As indicated in Part II of LA-6, the students could build a functioning water thermometer or gas thermometer to measure the temperature of the laboratory. Such an instrument could be calibrated over a period of time by means of a mercury thermometer.

INFORMATION ON LABORATORY ACTIVITY 6:

TEACHING NOTES:

1. The purpose of this activity is to introduce the student to proper techniques for temperature measurement. In addition, the procedure contains a good deal of information on the principles underlying thermometry.

2. Anticipated time: one period.

3. The activity is divided into two parts. The class can be divided so that half do Part I and half do Part II first. This should reduce the amount of equipment needed, except for gas burners which are needed in both parts. Parts I and II could be done on separate days.

4. The amount of salt needed could be reduced if the students saved their solutions and shared them with others. Be sure the solutions are labeled, expecially if kept overnight.

5. Be sure to provide the students with safety glasses or goggles, if required by the health and safety codes of your school district.

6. If you have not done so earlier, it will be necessary to provide instruction in how to set up, light and adjust the gas burner and in proper technique for inserting glass tubing into stoppers.

7. If beaker tongs are available, they should be provided for the students to use in moving the heated beakers. If not, several layers or paper toweling, potholders or asbestos gloves will suffice.

8. Questions 11 and 12 refer to a hole in the top of the thermometer through which a piece of string or bent paper clip can be attached to suspend the thermometer. If your thermometers do not have this hole, the students should be told.

9. The students may need to be told that numerals in parentheses indicate that a written answer is expected.

10. A discussion of the effect of altitude on the boiling point of water may be of interest following the activity.

11. Some students might be interested in finding out how far the freezing and boiling points of water can be changed by adding NaCl until the solution is saturated. The results should be about -11 °C and 103 °C (assuming you are near sea level).

12. The students should be cautioned about handling mercury if a thermometer should ever break. Mercury can enter the body through the skin and is a cumulative poison. Care should be taken when cleaning up spills.

MATERIALS: (for 15 set-ups) *Parts I and II both

15 thermometers

*15 beakers, 250-ml

15 beakers, 50-ml

*15 ring stands

*15 ring-stand rings

*15 wire gauzes

*15 gas burners

*matches or 15 strikers

15 stirring rods

15 scoopulas or plastic spoons

15 Erlenmeyer flasks, 125-ml, with one-hole stopper

15 glass tubes, at least 30 cm long

15 medicine droppers

ice

500 g sodium chloride

clock with second hand

beaker tongs (optional)

ANSWERS TO QUESTIONS IN PROCEDURE:

1. will vary
2. The mercury would expand until it broke the glass.
3. The mercury would contract until it was all in the bulb of the thermometer.
4. will vary
5. Yes, eye position affects the reading.
6. will vary
7. will vary
8. yes
9. will vary
10. Hold the bulb in the center of the liquid.
11. Hole at top of thermometer.
12. Suspend the thermometer over the liquid by attaching it to a ring or clamp above the container of liquid.
13. will vary
14. Ice water = 2 ± 2 °C.
15. The glass could easily be broken.
16. The freezing point should be lowered about 2 °C.
17. Boiling water = 97 ± 2 °C.
18. Water molecules that attain temperatures greater than the boiling point leave the container as steam.
19. The boiling point should be increased about 1 °C.

20. Bubbles appear at end of glass tube. Heat from hands heated air in flask, causing it to expand.

21. Water would have entered the glass tube.

22. Otherwise, air would be lost from the system when the temperature went down.

23. Suspend the flask from a ring or clamp. Possibly glue the stopper in. Calibrate with a mercury thermometer. Add water to beaker over time to compensate for evaporation.

24. Any situation involving temperatures outside this range.

25. As the water heats up, the water level rises.

26. Water, as mercury, expands when heated.

27. The useful range of a water thermometer is limited to temperatures above 4 °C and below 100 °C.

28. Methyl alcohol freezes at -137 °F and boils at 149 °F. Essentially all shade temperatures are within this range.

LESSON 7: (A) INTRODUCTION TO THE BIP

(B) SKIN TEMPERATURE BEFORE AND AFTER EXERCISE

RATIONALE:

Between one and two periods will be occupied at this time to accomplish two things. First the student will be introduced to the BIP (Biomedical Instrumentation Package). This instrument will be used extensively in the activities throughout the curriculum and it is desirable that the students become acquainted with it at an early stage. Secondly, the students will be introduced to a second method for determining temperature, in this case the temperature of the skin under two different conditions (body at rest and after exercise). A brief set of review problems covering Lessons 1 through 6 is included in the text.

OBJECTIVES:

The student will demonstrate the ability to program and use the BIP to measure skin temperature.

The student will demonstrate that skin temperature near the torso of the body is higher than that of the extremities.

The student will determine the effect of exercise on skin temperature.

INFORMATION ON LABORATORY ACTIVITY 7:

TEACHING NOTES:

1. In this activity, the students are introduced to the BIP (Biomedical Instrumentation Package), which is used to measure temperature electronically. By measuring the skin temperature of various parts of the body, the students demonstrate that

a. skin temperatures near the torso are higher than those farther from the torso (legs, feet and hands), and that

b. exercise can raise the skin temperature.

2. The temperature-sensing element used with the BIP is called a thermistor. A thermistor is an electronic device whose electrical resistance is a function of the ambient temperature. The BIP measures the amount of current flowing through the thermistor, which is converted by means of a table into the proper temperature reading. (See the BIP manual for further information.)

3. Anticipated time: one period--perhaps slightly longer.

4. The activity may be split at the ened of Part I.

5. The transfer of heat from the skin to the thermistor can be maximized by the application of a suitable heat transfer agent, such as petroleum jelly.

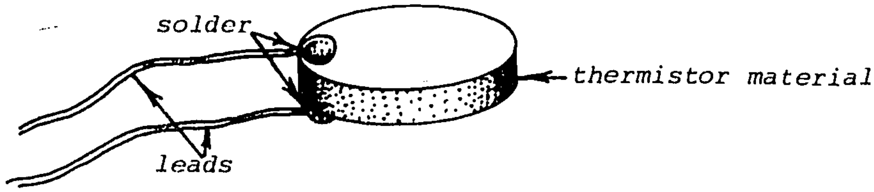
MATERIALS: (for 10 set-ups)

10 BIP's
10 thermistor components
programming wire
5 wire cutter-strippers
10 thermometers
10 screwdrivers
cotton

PREPARATION OF MATERIALS:

The thermistor recommended for use with the BIP is made by the Fenwal Company (#KP41J2). They can be obtained through most electronic supply stores, usually by special order. The thermistor comes with two short wire leads which should be removed using a soldering iron. Two lengths (at least 2 feet each) of programming wire are then soldered to either side of the body of the thermistor. The thermistor should be dipped into urethane varnish (thinned with 1 part solvent to 5 parts varnish) to protect it from moisture.

Note: Thermistors provided by BICP as BIP accessories will not require this treatment.



ANTICIPATED RESULTS:

Skin temperatures vary considerably depending upon the room temperature and particular individual being tested. Temperatures between 23 and 36 °C should be expected. The armpit temperature is almost invariably between 35 and 36 °C. Temperatures of areas farther away from the torso tend to be lower than those near the torso as shown in the following sample results.

	TEMPERATURE (°C)	
	Before Exercise	After Exercise
Behind Knee	32.4	32.4
Calf	30.9	32.1
Ankle	28.0	30.4
Toe	25.0	25.0

The elevated skin temperatures following exercise are caused in part by increased blood flow to the area, and in part by metabolic reactions occurring in muscle tissue which produce heat.

ANSWERS TO DISCUSSION QUESTIONS:

1. See "Anticipated Results."

2. See "Anticipated Results."

3. Significantly different temperatures on the two sides of the body is a symptom of circulatory impairment.

KEY--REVIEW SET 7:

1. Answers should center around both the career aspects and the need, on the part of everyone, for a better understanding of health and ways of preventing illness.

2. Mass is a measure of the quantity of matter in an object and does not change with location. Weight is a measure of the force with which gravity acts on an object and therefore changes with location.

3. See definitions on p. 13 of ST.

4. a. kilogram (and gram); b. meter; c. square meter; d. cubic meter (the liter is not a "basic" unit); e. degree Celsius

5. mass and volume

6. larger: kilo-; smaller: cente-, micro- and milli-

7. a. one-hundredth; b. one thousand; c. one-millionth; d. one-thousandth

8. See definition on p. 22 of ST. Specific gravity has no units.

9. Definitions of units are based on decisions of individuals. They have no fundamental basis in nature.

LESSON 8: (A) WHAT IS RESPIRATION?

(B) INHALED AIR AND THE PROPERTIES OF OXYGEN

RATIONALE:

The previous lessons were of an introductory nature, intended to acquaint the students with a number of concepts, instruments and laboratory techniques that will be of use to them throughout the course. The central focus of the remainder of this unit will be the function and malfunction of the respiratory system.

ST-8 defines respiration and gives a short analysis of the components of the air we breathe. The case history introduces the protagonist of a series of case histories which will serve to exemplify respiratory ailments throughout the unit. In LA-8 the students will generate oxygen gas and test some of its properties.

OBJECTIVES:

The student will give two definitions of respiration.

The student will list four components of clean air.

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The student will describe the ways in which an incubator helps maintain the life of a premature baby.

The student will describe at least three properties of oxygen gas.

SEQUENCE: ST-8; LA-8

SUGGESTIONS:

1. You may wish to present the class with some of the following statistics on respiratory disease.

a. Some eight per cent of all deaths in the U.S. have respiratory ailments as their primary cause. In addition, some 15 per cent of persons aged 45 to 64 have definite physical limitations resulting from respiratory disease.

b. The death rate from lung cancer more than doubled between 1950 and 1970 (13 per 100,000 vs. 30 per 100,000 population). More than 60,000 persons now die each year in the U.S. from this disease.

c. Death and disability from emphysema have increased at an even greater rate than lung cancer. Emphysema is a disease which may compromise the functioning of the lungs to such an extent that even simple physical chores become impossible to perform.

2. To illustrate what it feels like to have a respiratory impairment, distribute a soda straw to each student and instruct them to breathe exclusively through the straw. After they have done this for a few minutes while sitting quietly, have them perform some exercise, such as running in place, still breathing only through the straw. The resulting feeling of suffocation is very similar to what someone with a respiratory impairment feels when he attempts a simple task that a healthy person could perform with ease.

3. Points to bring out on the case history:

a. Tommy's primary difficulty is that he lacks sufficient muscular development and strength to do the work of breathing. He cannot breathe often enough or deeply enough to obtain sufficient oxygen.

b. Tommy's bluish cast is a symptom of insufficient oxygen.

c. Each breath taken by Tommy in the incubator (50 per cent oxygen) will supply him with 2.5 times the oxygen he would receive outside of it.

INFORMATION ON LABORATORY ACTIVITY 8:

TEACHING NOTES:

1. The purpose of this activity is to generate and test oxygen gas, a substance of vital importance to the respiration process. Some of the simple properties of oxygen are investigated, and the percentage of oxygen present in the atmosphere is measured. Although detailed chemistry is not presented, the students are introduced to the basic concept of a chemical reaction--that certain substances combine to form new substances.

2. Anticipated time: one and a half periods (plus time later for completion of Part III).

3. The generation of oxygen gas may be represented as in the following chemical equation.

$$2\ KClO_3 \xrightarrow[\Delta]{MnO_2} 2\ KCl + 3\ O_2$$

Potassium chlorate is reduced to potassium chloride. Heat and manganese dioxide catalyze the reaction.

4. The use of safety glasses or goggles, if available, is recommended during the generation of oxygen in Part I. (Potassium chlorate does not ignite or explode in air. This occurs only when it is mixed with substances which can be readily oxidized, e.g., carbon, sulfur or cloth.)

5. Of the six tubes of oxygen collected in Part I, only four are needed for Parts II and III. Thus the student has two additional tubes in the event that a procedural error is made or a repeat test is desired.

6. The gas-generating apparatus set up in Part I may be saved and used in LA-9 for the generation of carbon dioxide gas. (The large test tube should be cleaned after its use in LA-8--this is easily accomplished since the potassium chloride residue is quite soluble in water.)

7. The oxidation of the steel wool in Part III requires approximately one week to complete.

8. Discussion Questions 1, 2 and 3 may be treated immediately. Questions 4, 5 and 6 should be deferred until completion of Part III.

9. "Oxidation" is the term usually associated with reactions of oxygen. In many cases, these reactions are simple combustion as represented by the splint

test. The oxidation of sugars by the reaction

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

is not discussed until ST-27. However, you might wish to mention at this point that cellular respiration is also an oxidation process.

10. Parts II and III are designed to show that oxygen can react with substances in a variety or ways, not necessarily by rapid combustion. The slow oxidation of steel wool (rusting) may be contrasted with rapid oxidation by burning steel wool in oxygen. This may be demonstrated by heating a small piece of steel wool to glowing in a burner flame, and then thrusting it into a test tube containing oxygen gas. Other examples of simple combustion which may be demonstrated include the burning of red phosphorus, magnesium metal ribbon or calcium metal.

11. Items marked with an asterisk in the materials list may be shared.

MATERIALS: (for 15 set-ups)

100 g potassium chlorate ($KClO_3$)
5 g manganese dioxide (MnO_2)
15 test tubes, 25 x 200 mm
15 rubber stoppers, one-hole, #4
75 cm glass tubing, 6 mm O.D. (cut into 5-cm lengths)
11.25 m rubber tubing, 3/16" I.D. (cut into 75-cm lengths)
15 ring stands
15 ring-stand clamps
90 test tubes, 16 x 125 mm
90 stoppers, cork, #4
15 gas burners
15 matchbooks or strikers
*15 balances
*15 scoopulas
*15 spatulas
15 large pans
several steel wool balls (Grade 000 to 1)
15 glass-marking pencils
0.1 g phenol red (phenolsulfonephthalein)
15 medicine droppers
30 wooden splints
15 beakers, 150-ml
15 graduated cylinders, 10-ml
*15 millimeter rulers

PREPARATION OF REAGENT:

Phenol red indicator: Add 0.1 g of phenol red (phenolsulfonephthalein) to 250 ml of water. Stir to dissolve. The solution should be adjusted so that it changes from red to yellow after the absorption of very small amounts of carbon dioxide. The indicator may be tested as explained in Step 13 of LA-9. Adjust the pH of the solution using small amounts of weak acids and/or bases. (This recipe provides enough solution for both LA-8 and 9.)

ANTICIPATED RESULTS:

Part II Observations:

oxygen + glowing splint: splint bursts into flame

oxygen + phenol red: phenol red does not change color

air + phenol red: phenol red does not change color

phenol red + gas resulting from burning splint in oxygen: phenol red solution changes from red to yellow

Part III Data:

initial volume of gas: approximately 18 ml (depends on quantity of steel wool)

final height of water level: approximately 25 mm

final volume of gas: approximately 14.2 ml

calculated volume of gas consumed: approximately 3.8 ml

calculated precentage of gas consumed: $\frac{3.8 \text{ ml}}{18 \text{ ml}} \times 100 \approx 21\%$

PART III Observations:

The water rises most rapidly and to the highest level in the tube containing pure oxygen. The water in the tube containing air rises approximately one-fifth of the way up the tube. The tube that contains no steel wool should show little or no change.

ANSWERS TO DISCUSSION QUESTIONS:

1. Combustion occurs much more vigorously in pure oxygen than in air.

2. Oxygen and air have no effect on the phenol red indicator. The gases resulting from the burning splint cause the phenol red to change color.

3. Since pure oxygen has no effect on phenol red, it may be assumed that the change in color is due to some other substance or condition resulting from the burning. There is no direct evidence to indicate that oxygen is <u>not</u> produced, although it may seem obvious that oxygen is consumed rather than produced.

4. The tube that does not contain steel wool demonstrates that steel wool is necessary for any pronounced change in the level of the water. It serves as a control since it demonstrates to what extent the change in water level is due

to influences other than the gases in the tubes (for example, the effects of pressure, temperature and evaporation of water).

5. The gas combines with the steel wool, thereby changing from a gaseous to a solid state. The gas consumed is evidently oxygen.

6. The value obtained is roughly the percentage of oxygen present in the atmosphere.

LESSON 9: (A) THE MECHANICS OF RESPIRATION
(B) EXHALED AIR AND THE PROPERTIES OF CO_2

RATIONALE:

In ST-8 respiration was defined as breathing. In this section the gross mechanics of how the body gets air into and out of the lungs is discussed. The difference in the composition of inhaled and exhaled air is also presented as evidence of the function of breathing, i.e., to acquire oxygen for bodily processes and expel the waste product, carbon dioxide. In LA-9 the students will generate and test CO_2 and compare its properties to those of O_2.

OBJECTIVES:

The student will state two ways in which the lungs can be caused to expand.

The student will define the terms expiration and inspiration.

The student will state the function of the diaphragm in respiration.

On a drawing of the respiratory system, the student will label the following structures: trachea, bronchi, pleural spaces and diaphragm.

The student will state the function of respiration to be the intake of oxygen and the elimination of carbon dioxide.

The student will describe two tests which could be used to distinguish oxygen from carbon dioxide.

SEQUENCE: ST-9; LA-9

SUGGESTIONS:

1. Although the bell-jar model is pictured and discussed in ST-9, it is recommended that a functioning model be purchased or built for use in the classroom.

2. Have the students name the parts of the model analogous to the structures of the respiratory system named in Figure 2 on p. 35 of the text. Ask

how the model and the human system differ. (The model has rigid walls, no partition at the center and an inordinately large "pleural" space.)

3. Conduct an open-ended discussion of why the movement of the diaphragm (human and rubber) affects the inflation of the lungs and balloons. (This question is not fully resolved until Lesson 19.)

INFORMATION ON LABORATORY ACTIVITY 9:

TEACHING NOTES:

1. This activity serves as a continuation of LA-8. Carbon dioxide, another gas important to the respiration process, is generated; and its properties are contrasted with those of oxygen.

2. Anticipated time: one period.

3. The reaction for the gas generation is as follows.

$$CaCO_3 + 2\ HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

4. Other sources of carbon dioxide which may be demonstrated or mentioned include soft drinks, dry ice, certain fire extinguishers and a mixture of vinegar and baking soda ($NaHCO_3$). If time permits, cellular respiration may be demonstrated by mixing a small quantity of yeast (1/2 teaspoon) with approximately 100 ml of a 20% sugar solution. After about 45 minutes, carbon dioxide is produced, which may be detected by bubbling the gas through limewater.

MATERIALS: (for 15 set-ups)

- 100 g marble chips ($CaCO_3$)
- 42 ml concentrated HCl
- 10 g lime powder (CaO)
- 100 ml household ammonia
- phenol red indicator solution (from LA-8)
- 60 beakers, 50-ml (other sizes may be substituted)
- 90 test tubes, 16 x 125 mm
- 45 stoppers, cork #4
- 15 balances
- 15 medicine droppers
- 15 scoopulas
- 15 glass-marking pencils
- 15 wooden splints
- 15 matchbooks or strikers
- 15 gas-generating set-ups (from LA-8)

PREPARATION OF REAGENTS:

Hydrochloric acid 1.0 M: To approximately 200 ml of water add 42 ml of concentrated hydrochloric acid (HCl). Dilute with tap water to 500 ml total volume.

Limewater (calcium hydroxide solution): Mix 10 g of calcium oxide powder (CaO) with 500 ml of tap water. Stir and allow to stand for several minutes. Filter and save the clear solution.

Ammonia water: Dilute 100 ml of household ammonia to 500 ml with tap water.

ANTICIPATED RESULTS:

Observations after:	1 min	5 min	15 min
carbon dioxide over tap water	Change in water level slight to none over this short a period.		
carbon dioxide over limewater	Milky white precipitate apparent soon after tube is immersed.		
carbon dioxide over ammonia water	Most of tube should be filled with liquid after five minutes.		

Other observations:

carbon dioxide + glowing splint: Extinguishes splint.

carbon dioxide + phenol red: Color change from red to yellow.

exhaled air + phenol red: Color change from red to yellow.

ANSWERS TO DISCUSSION QUESTIONS:

1. Oxygen causes a glowing splint to burst into flame, while carbon dioxide extinguishes the glow.

2. It doesn't appear to support combustion at all.

3. Oxygen and air have no effect on phenol red, while carbon dioxide turns it yellow.

4. Exhaled air contains either carbon dioxide or some other substance in sufficient quantity to change the color of phenol red.

5. Tap water appears to have little or no effect on carbon dioxide. Since the volume of carbon dioxide declines quickly when it is placed over ammonia water, the gas must be entering the liquid. (The students have no way of knowing whether this is a chemical reaction of merely dissolving. In fact, it is both. The product is a solution of ammonium carbonate.)

6. Since limewater standing open to the atmosphere does not turn milky, one can presume that air has no effect on it. The fact that air is one-fifth oxygen suggests that oxygen has no effect on limewater. This could be verified, however, only by a test.

7. Oxygen causes a glowing splint to burst into flame and has no effect on phenol red. Carbon dioxide extinguishes a glowing splint and causes phenol red to change its color to yellow. In addition, carbon dioxide turns limewater milky and rapidly enters ammonia water.

LESSON 10: (A) CROUP AND THE ANATOMY OF THE UPPER RESPIRATORY TRACT

(B) ORGANS, TISSUES AND CELLS

(C) DISSECTION OF THE RESPIRATORY SYSTEM

RATIONALE:

ST-9 provided a view of the gross anatomy of the respiratory system. ST-10, via the discussion of croup, provides a more detailed examination of the upper respiratory tract. The last portion of the text presents the idea that the structure and function of the human body may be studied on many levels, each of which provides different types of information.

LA-10 concerns the dissection and examination of the tissues of the respiratory system. The activity introduces dissection technique as well as the use of the microscope to examine tissue samples obtained in the course of dissection.

OBJECTIVES:

Given a diagram of the upper respiratory tract, the student will label the following parts: pharynx, epiglottis, glottis, larynx, trachea.

The student will state the function of the epiglottis.

The student will list the symptoms of bacterial croup, and the reasons for its development.

The student will list two differences between bacterial and viral croup.

The student will state the relationship between the location of a croup infection and one of its symptoms, a barking cough.

The student will describe the first-aid measures which may be taken to relieve breathing impairment as a result of croup.

The student will state the function of a tracheostomy in relieving impaired breathing resulting from blockage of the upper respiratory tract.

Given a drawing of the human body, the student will label the anterior, posterior, ventral and dorsal portions.

Given a dissected specimen of a respiratory tract, the student will point out the trachea, bronchi, bronchioles, pleura, pleural space and lobes of the lung.

The student will determine the density of specimens of cartilage, fat, lung and esophagus tissue.

When presented with a microscope, the student will demonstrate the use of each of its parts.

The student will make microscopic observations of tissue specimens of cartilage, fat, lung and esophagus and draw a diagram depicting the cellular organization of each type of tissue.

SEQUENCE: ST-10; LA-10. Note that LA-10 is expected to extend over at least three days.

SUGGESTIONS:

1. Have the students indicate the site of the impairment caused by croup on the bell-jar model.

2. Diphtheria is a disease similar to croup that at one time was the cause of death of many thousands of people. Diphtheria epidemics were dreaded, but apparently unavoidable. Today a vaccine exists and deaths due to it are very uncommon. Perhaps one of your students would be interested in researching the history of diphtheria epidemics in Europe and the U.S. and the path followed by medical and other scientists which led to the discovery of the vaccine.

3. Project a 35-mm slide of Hemophilus influenzae.

BACKGROUND INFORMATION ON CROUP:

Croup is a condition arising from a variety of causes. It is characterized by inflammation and swelling of tissues in the vicinity of the larynx and epiglottis and is accompanied by a "croupy" cough.

The most common causes of croup are infections by certain respiratory viruses and a bacterium, Hemophilus influenzae. Diphtheria was once a frequent cause of croup. A foreign body lodged near the epiglottis or larynx can also cause croup.

Viral croup is usually of gradual onset and without high fever. H. influenzae croup is of more sudden onset with high fever. The white blood cell count is usually high in bacterial croup and normal or low in the viral form.

Treatment of croup depends on the cause and severity of respiratory distress. Tracheostomy (insertion of an endotracheal tube) is necessary if severe respiratory distress is not relieved by steam or mist (steam is useful, but the cool humidification of mist is preferable), suction and/or ventilatory assistance.

Antibiotics are used in Hemophilus croup. Oxygen is generally not used. With a lodged foreign body, instrumental removal by a specialist may be necessary.

The prognosis for viral croup is good, but the illness may last for days because there is no specific treatment. Hemophilus croup can be fatal, but prompt intensive antibiotic treatment is usually effective. Croup caused by diphtheria is rare in the United States.

PHYSIOLOGICAL RESPONSES LEADING TO THE CONDITION:

Inflammation. A specific tissue response to injury, characterized by vascular dilation, fluid exudation and/or accumulation of leukocytes. In the case record the inflammation is confined to the region of the larynx and epiglottis and is a response to the infective agent, Hemophilus influenzae.

Increased Mucus Production. In general, inflammation or irritation of a mucus surface is marked by increased production of mucus.

Cough. A reflex response integrated in the medulla oblongata. It is initiated by irritation of the lining of the respiratory passages. The glottis closes and a strong contraction of the respiratory muscles builds up intrapulmonary pressure, whereupon the glottis suddenly opens, causing an explosive discharge of air (velocities up to 75 to 100 mph). The rapidly moving air usually carries with it any foreign matter that is present in the bronchi or trachea.

Fever. A body temperature above the usual range of normal. Causes include infectious diseases, tumors, dehydration, toxins, and allergic responses. In most types of fever, the rise in body temperature is not a result of a breakdown of the body temperature regulating system. The system behaves normally except that the body temperature "set-point" appears to be increased. Many proteins, breakdown products of proteins, and certain other sybstances, such as toxins secreted by bacteria, can increase the "reference temperature." Substances that cause this effect are called pyrogens. When the body temperature "set-point" becomes increased to a higher level than normal, all the mechanisms for raising the body temperature are set into play, including heat conservation and increased heat production. It is not known whether the pyrogenic substance has a direct or indirect action on the body temperature "set-point." There is some evidence that fever plays a protective role in combating infection.

ASSOCIATED ANATOMY:

Pharynx. The region in the back of the mouth. It serves as a passageway for both food and air. Outgrowths of this area are the tonsils and the adenoids.

The pharynx ends at the glottis, the opening into the trachea. The glottis is a narrow slit varying in length between men and women. The vocal cords form the rim of the glottis. Above the glottis is the epiglottis, a flap-like structure that closes the glottis during swallowing.

Larynx. A triangular chamber just below the glottis, which forms the upper portion of the trachea. It is composed of cartilage plates. The larynx is often referred to in men as the Adam's apple.

Trachea. Below the larynx, the trachea is composed of alternating bands of muscle and cartilage. The inner walls are lined with ciliated epithelium containing mucus-secreting goblet cells. In addition to its function as a lubricant, the mucus serves to trap foreign particles, bacteria, etc., which are then carried upward by ciliary action to the pharynx and swallowed.

INFORMATION ON LABORATORY ACTIVITY 10:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to dissect a fresh trachea and lung; to compare at least three different types of tissue in appearance, feel, density, and microscopic appearance; to learn to use a compound microscope; and to prepare slides for use with the microscope.

2. Anticipated time: four periods.

3. To obtain a fresh sheep or beef lung you should contact a local office of the United States Department of Agriculture, Animal and Plant Health Inspection Service. This office should be able to give you the names of federal inspected slaughter houses. (Many states also have "state inspected" slaughter houses. You might try the state Food and Agriculture Department for state inspected slaughter houses.) You should state that you are a teacher and that the specimen will be used for educational purposes only (not consumption). Some inspectors may require proof that you are a teacher. You will need to fill out form MP-403-10 either before or upon receiving the specimen.

4. Be sure to specify that you want the trachea and both lungs. The cost varies with the slaughter house. The specimens also will vary. Some slaughter houses leave the larynx and/or esophagus attached, some cut the lungs for inspection and some will include the heart. You will probably have to pick up the specimen yourself.

5. The lung can be kept for long periods in the freezer or stored in the refrigerator for 7 to 10 days at the most before spoiling. If kept refrigerated this long, it is recommended that the specimen be rinsed well with cold tap water to wash away blood and blood clots. The lung should be used as soon as possible after obtaining it and disposed of as soon as possible after use to avoid spoilage.

6. Dispose of the specimen by placing in a plastic bag. Contact the school custodian for instructions on disposal. Small pieces of tissue and fluids will spoil in trash cans. Caution the students not to throw small pieces in the trash or sinks and to clean up the blood and fluids at the end of each lab period.

7. Tubing to inflate the lungs may vary with the specimen. Tubing or pipe made of any rigid material will work (garden hose, glass, PVC, etc.). If the lungs are badly cut from the inspection process, smaller tubing may be necessary to insert into the bronchus or bronchioles.

8. The lungs are quite large. If you do not have a dissecting pan large enough, a tray from the cafeteria or the "vegetable" drawer from a refrigerator will work.

9. The activity is long because it has four parts. There are a couple suggestions for organizing class activities. Any of the parts can be done independent of the others except that Part I must be done before Parts II, III and IV-D because it is observation of the undissected lung. Part II is the dissection of the lung tissues and should precede Parts III and IV-D. Part III is study of the density of tissues and should be completed in one day since it involves tissues which are perishable and considerable equipment and mess. Part IV is learning to use the microscope and microscopic study of tissues. The first three sections on working with the microscope do not involve any perishable materials and can be done days or even weeks before the lung dissection. The microscopic study of the tissues is best done the day after the density studies since this will give overnight to freeze the tissues. Freezing makes the lung tissue easier to slice. Freezing is not as critical in working with the other tissues. If the section on density and microscopic studies are to be done on the same day, freeze some lung tissue the day before for the class to use. A piece the size of a golf ball should be more than enough for the class. It is a good idea to freeze three or four pieces in separate containers and bring them from the freezer at different times during the class since they will thaw rather quickly.

10. a. The instructor or lab assistant could demonstrate Part I to small groups of students while the others read Part IV-A, "Parts of the Microscope." Then the specimen could be dissected and used for the remaining three parts of the activity.

b. If more than one specimen is available, the class could be divided into smaller groups to work with each specimen. The instructor would be free to circulate among the groups and assist them.

11. Read Part IV-A on the microscope before class. Any differences between the microscopes available to the students and the microscope discussed in the text should be pointed out to the students before they read the section.

12. The small pieces of tissue that the students keep overnight for further study can be stored in Petri dishes, plastic bags or beakers capped with parafilm. If kept over a weekend, freeze if possible. Small sections will thaw in a few minutes at room temperature.

13. Diagrams and models are optional materials. If charts or diagrams of the anatomy of human or other species are available, they could be made available for the students to use as reference or as an introduction or follow-up to the activity. Other books which have appropriate drawings and diagrams could also be made available to the students.

14. If some students complete the activity and have time, they could

a. dissect out several subdivisions of bronchioles from a larger section of lung,

b. look up in an anatomy or histology book the cellular structure of epithelial tissue lining the trachea, of cartilage, of muscle, of fat or of lung. Have them make drawings and do a report on their findings.

15. The first part of the activity has instructions for the student to "feel" and "pinch" the tissues. It is hoped that the students will follow these instructions and realize that many of their senses are involved in learning. Also, it is hoped that the students realize that dissection and study of tissues is more than just looking and cutting.

16. A large number of slides are called for. Fewer will be needed if the students are told to wash the slides and reuse them. The washing will take a little more time.

17. Part I-4 refers to the esophagus. If the specimen you obtain does not have the esophagus, mention this to the students. If any heart muscle is attached, this muscle can be used instead of the esophagus for comparative density and microscope studies. If no muscle is attached to the specimen, you can choose whether to eliminate the comparison of muscle tissue or to buy a small piece of meat at the grocery store.

18. The students may be able to see some cilia in the cross-section of the epithelium they prepare. Cilia are not discussed until ST-38. You may wish to explain what cilia are and their purpose during discussion of this activity.

19. To check the students' proficiency with the microscope, a series of tests could be set up. You can do one or more things to set up the microscope and/or slide improperly and ask the students to identify the mistake. For example, don't click the objective into position, turn the mirror so that no light comes through the stage, place a prepared slide upside down on the stage and ask the students to focus under low and high power, or turn the coarse adjustment so that the objectives are as far away from the stage as possible.

20. No data sheet is included with the activity. You could suggest that the students make four tables as given below to record data for finding densities. The students could be asked to keep notes and/or drawings of their other observations.

SAMPLE DATA TABLE, PART III--DENSITY

Tissue:	Mass: ________g
Final volume	
Initial volume	
Volume of tissue	

Density: __________g/ml

MATERIALS: (for 15 set-ups)

- 1 (or more) beef or sheep lungs, fresh
- tube, 4 cm diameter, at least 20 cm long (rubber, plastic, or glass)
- 15 scalpels or razor blades (single-edged)
- 15 Petri dishes (not sterile)
- 15 balances
- 15 graduated cylinders, 100-ml
- 15 beakers, 50-ml
- 15 compound microscopes

150 glass slides

150 coverslips

15 medicine droppers

15 scissors

15 forceps

30 dissecting needles, straight

lens paper

Kimwipes or other tissue

piece of newsprint from classified section

piece of colored picture from a magazine

3 to 5 balls of cotton or equivalent

1.48 g methylene blue crystals

100 ml 95% ethyl alcohol

15 dropper bottles (to dispense stain)

models, charts, diagrams of respiratory system--optional

PREPARATION OF REAGENT:

200 ml methylene blue stain: Dissolve 1.48 g methylene blue crystals in 100 ml 95% ethyl alcohol. Label this "Stock Solution." Dilute the stock solution by mixing 20 ml stock solution and 180 ml tap water. Save the remaining stock solution in a capped bottle for later use.

LESSON 11: BACTERIAL AND VIRAL RESPIRATORY DISEASES

RATIONALE:

In the preceding lesson the topic of respiratory diseases was introduced. In this section some of the most common bacterial and viral respiratory diseases are discussed. Influenza is singled out to illustrate one of the methods used to predict epidemics and the implications of such predictions in safeguarding the health of the population. A few differences between bacteria and viruses are also covered.

OBJECTIVES:

The student will list four bacterial and four viral disease of the respiratory tract.

The student will state two differences between bacteria and viruses.

The student will define the term epidemic.

Given a graph drawn from the survey of pneumonia-influenza deaths over a specific time period, the student will state whether an epidemic is likely to occur.

The student will state the reason for continuous surveillance of diseases such as influenza.

SEQUENCE: continuation of LA-10; ST-11

SUGGESTIONS:

1. If you can obtain prepared microscope slides or 35-mm slides of the bacteria mentioned in the Student Text the students would be able to observe them when they are discussed in class. Such slides are available from biological supply companies such as Carolina Biological.

Also, the students might be interested in hearing someone speak on how bacterial cultures are done in hospitals to ascertain what type of organism is the cause of an infection. If you do find a speaker ask him or her to bring some samples of actual cultures that have been worked up. Presenting a case history and the cultures that go with it would be very effective. The best place to look for such a speaker is your own local hospital.

2. If any of the students are interested in reading more about epidemics and epidemiology, the following references are suggested.

> Zinnser, H. Rats, Lice and History. Little, Brown and Co., Boston, 1935.
>
> Roueché, Berton. Eleven Blue Men. Berkley Pub. Corp., N.Y., 1955. (Berkley Medallion Book N1622)

INFORMATION ON INFLUENZA:

Influenza is an acute, contagious viral disease of the respiratory tract. It is usually accompanied by fever, headache and muscular aches.

"Influenza" is an Italian word meaning "influence." In most non-English speaking countries, the disease is referred to by the French word "grippe." Influenza was uncommon in Europe until the pandemic of 1889. From that time on the frequency and severity of epidemics increased, culminating in the disastrous pandemic of 1918, which caused an estimated 20 to 40 million deaths. The pandemic of 1957 was perhaps the most thoroughly studied and documented major epidemic in the annals of medicine.

The isolation of influenza virus (type A) in 1933 led to the development of simple diagnostic tests which have greatly advanced knowledge of the disease. A second type of virus (type B) was isolated in 1940, and a third virus (type C) in 1950. The discovery, by Burnet (1940), that influenza viruses could be cultivated readily in the chick embryo led to the development of vaccines.

Influenza occurs in three distinct antigenic types designated A, B and C. Type A virus has been further subdivided into three strains (A_0, A_1 and A_2). Type B virus has two subgroups but the strains have not been named. No major antigenic variation of type C virus has been discovered.

The viruses are all of medium size (approximately .08 μm in diameter) and by conventional electron microscopy appear spherical or filamentous in form. The nucleic acid of the viruses is ribonucleic acid (RNA).

Influenza type B and C viruses are associated primarily with young people in schools and military camps. Type A viruses are the cause of major epidemics. The epidemics are cyclic, occurring at intervals of two to four years in the winter months. The factors responsible for this periodicity are the decline in effective immunity of a population in interepidemic periods and the emergence from time to time of new or mutated strains of viruses. Influenza type A epidemics start abruptly, reach a peak in two to three months and subside almost as rapidly. The number of immune individuals determines how rapidly the case rate will rise and if and when epidemic proportions will be reached. Experiences from the 1957 pandemic proved conclusively that crowding is the major factor predisposing to epidemics. The opening of schools in September brings a highly susceptible population into close proximity and facilitates rapid spread of the disease. School children are the primary focus and disseminators of infection in the United States.

Influenza is primarily an infection of the epithelium in the upper and middle portion of the respiratory tract. The trachea is the anatomical structure most strikingly involved. The chief complications of influenza are secondary bacterial infections of the sinuses, middle ear, bronchi and lungs. The most potentially lethal complications are derived from infection of the lung. Infants, the aged, pregnant women, and individuals with pre-existing cardiac or pulmonary disease are must vulnerable to pulmonary complications of influenza.

Influenza is transmitted directly from person to person under conditions of close contact via the respiratory tract. The incubation period is usually 18 to 36 hours but may be as long as three days. The most frequent initial symptom is a severe headache with pain in the legs, lower back and abdominal muscles. Fever and chilly sensations usually follow. Prostration of some degree is almost invariable. Vomiting and diarrhea are rare and there is no evidence that

influenza viruses infect the gastrointestinal tract (the term "intestinal flu" is a misnomer). Patients with influenza almost invariably cough, experience a dryness or soreness of the throat, and have some nasal discharge. Complete recovery from uncomplicated influenza takes from 10 to 14 days.

There is no specific treatment for influenza. General treatment consists of aspirin for the pain and codeine for the cough. In addition, drinking liquids frequently and resting are recommended.

Influenza may be prevented by inoculations with influenza vaccine. The vaccine is made up of representative strains of viruses (usually the A types) that have been inactivated. The pain felt following an inoculation is the result of a toxic reaction involving the viral antigens in the vaccine and the antibodies in the body.

LESSON 12: REVIEW

RATIONALE:

This time slot is intended to be used for the completion of LA-10 and a review of the material covered in Lessons 8 through 11.

SEQUENCE: LA-10; Review Set 12

KEY--REVIEW SET 12:

1. Premature infants are not fully developed when they are born. Three systems which are problems due to this lack of development are the respiratory system, the digestive system and the temperature regulatory center. To aid the infant, an incubator is used. This provides an atmosphere rich in oxygen so that obtaining sufficient oxygen is not so taxing on the respiratory system. The incubator also keeps the air warm so that the infant does not have to work too hard to maintain a normal body temperature. Feeding is accomplished subcutaneously to avoid using the poorly developed digestive system. (Note: Intravenous feeding is not feasible due to the small and fragile nature of the blood vessels.)

2.

	Bacterial Croup	Viral Croup
Cause	Bacteria	Viruses
Symptoms	Fever	Little or no fever. Develops more slowly and may last longer.
Treatment	Antibiotics Antipyretic (aspir[illegible])	No antibiotics. Usually no need for antipyretic.

3. Nose, pharynx, epiglottis, glottis, larynx, trachea, bronchi, bronchioles (aveoli not yet introduced).

4.

	Inspiration	Expir[illegible]
Muscle movement	Diaphragm moves down.	Diaphragm moves up.
Volume of chest cavity	Increases	Decreases
Volume of lungs	Increases	Decreases
Composition of air	O_2 = 20.7%, CO_2 = 0.03 % water vapor = 1.2%	O_2 = 13.1%, CO_2 = 5.3% water vapor = 6.2%

5. The three levels are organs, tissues and cells. Organs are composed of tissues which are in turn composed of cells. (A fourth level is the organ system.)

6. Air is a mixture of gases. (Composition given on p. 36 of text.)

7. Public health workers conduct surveys on the number of people affected by various diseases over time. By analyzing these data statistically they can sometimes predict where and when a disease may reach epidemic proportions. This type of information is helpful in preventing or reducing the magnitude of epidemics because steps can be taken to curtail the spread of the disease, such as administering "flu" vaccines during certain months of the year when epidemics of this disease are most likely to occur.

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LESSON 13: PRESSURE

RATIONALE:

In order to understand how the respiratory system functions (or fails to function properly) it is necessary to have a good grasp of the concept of pressure. In the next four sections, pressure is defined and its connection with the physiology of the respiratory system is discussed.

OBJECTIVES:

The student will define pressure.

The student will differentiate between force and pressure.

The student will state the equation used to calculate pressure from measurements of force and area.

The student will state the equation for determining the pressure exerted by a column of liquid of known density.

The student will explain how the equation for the pressure of a liquid (p = hD) can be used to measure the pressure of a gas.

The student will define the terms manometer and sphygmomanometer.

The student will demonstrate the effects of changing force and area on pressure.

SEQUENCE: ST-13; LA-13

SUGGESTIONS:

1. A demonstration of how a manometer works would be helpful to the students' understanding of this instrument. One way of doing this is to use a short piece of rubber tubing to connect a syringe to a U-tube containing water. By pushing down or pulling up on the plunger you can change the pressure of the air in the syringe and obtain various readings on the manometer.

2. Use a thumbtack to demonstrate the effect of area on pressure. If a thumbtack is squeezed between thumb and forefinger, the force exerted on the two sides is the same. On one side we feel pain because the area over which the force is exerted is quite small and thus the pressure quite large. To push a thumbtack into hardwoods, such as oak, requires the application of huge pressures. To determine roughly how much pressure is exerted in such cases, we performed the following experiment, which could be duplicated in the classroom if you have a hand calculator or slide rule available.

First we determined that we could exert at least 35 lb of force on a bathroom scale with one thumb. Then we measured the diameters of the head and the point of a thumbtack with the aid of a hand lens. The following data and calculations were the result.

$$F = 35\ \text{lb} \approx 15.9\ \text{kg}$$

HEAD	POINT
$d = 1.00$ cm	$d = 0.025$ cm
$r = 0.5$ cm	$r = 0.0125$ cm
$A = \pi r^2 \approx 0.7854$ sq cm	$A = 0.00049$ sq cm
$P = \frac{F}{A} \approx 20$ kg/sq cm	$P \approx 32{,}000$ kg/sq cm
≈ 290 lb/sq in	$\approx 460{,}000$ lb/sq in
	≈ 230 tons/sq in

The results are also shown in lb/sq in because some of the students should have some "feel" for these units from filling bicycle or automobile tires. Note that even with these huge pressures, we can push a thumbtack only part way into hardwood. There are two reasons for this. As the point goes in, the area of contact with the wood increases rapidly, the pressure decreases proportionally and friction builds up. In addition, the wood around and below the point is compressed, thus becoming even "harder."

INFORMATION ON LABORATORY ACTIVITY 13:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to work with the concept of pressure. The activity should give the students experiences by which they will understand that pressure is the amount of force per unit area. The procedure provides tangible experiences as an introduction to the concept of pressure in gases which is further developed in later lessons.

2. Anticipated time: one period or more.

3. Girls should be warned the preceding day not to wear pantyhose since the bare foot is dipped into water.

4. The students could be encouraged to obtain their body weight before coming to class to eliminate waiting to use the scale.

5. The pan or tray to hold water should be large enough to hold a large foot but may be quite shallow.

6. All sheets of paper should come from the same stock. Different weights of paper would make the proportionality in Step 14 meaningless. Avoid paper that is very light weight. Standard mimeograph paper is a good choice. Also note that Step 14 is based on 8.5 x 11 inch paper.

7. When the students cut out the imprints, they may or may not find the toe prints to be separate from the remainder of the foot. They should have some guidance on whether to cut out the separate areas or to include the small spaces between the toes and the foot to make a one-piece footprint. You might decide for the class or have each student decide which to do.

8. Wet paper will affect the results significantly. If there is not enough time to dry the prints in an oven, leave the prints overnight (out of the oven) and complete the activity the next day.

9. The calculations in Step 14 can be eliminated by drawing a graph with area on the horizontal axis and mass on the vertical axis. The following two points can be plotted: (0,0) and (603 cm^2, y) where y is the mass of a full sheet of paper. The students could then interpolate to find the area of their footprints.

10. The calculations can be done in class or as an assignment. Access to a calculator would reduce the work greatly. If any students know how to use a slide rule, they sould be encouraged to do so. To simplify the calculations, the students could round the "mass of sheet" to the nearest 10 sq cm.

11. To eliminate the possibility of communicating disease through the pan of water, fungicide could be added to the water at the strength recommended on the label.

12. To obtain visual evidence of pressure change using the body, it is suggested that a box of wet sand, clay or similar material be provided. The box should be large enough for a person to stand in and 2 to 3 inches deep. Have a student stand in the sand or clay and measure the depth of the footprints. Smooth the surface and have the student stand in the box again. This time have him hold a weight (several heavy books). Measure the depth of the footprints. Repeat this adding more weights. The depth of the footprints should increase as the pressure increases. Have the student stand on two feet, one foot and on the toes of one foot.

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MATERIALS: (for 15 set-ups)

bathroom scale

15 (or less) trays or pans, large enough to hold one foot

bottle of food coloring

15 scissors

15 balances

60 sheets of 8.5 x 11 inch paper (4 per student)

drying oven, set at low

ANSWERS TO DISCUSSION QUESTIONS:

1. Pressure exerted on two feet is half the pressure exerted while standing on one foot.

2. Variations exist depending on the area of the feet in contact with the floor.

3. Pressure.

4. Shoes should increase the area of contact and reduce the pressure.

5. Standing on tiptoe on one foot, because the area is the smallest.

6. A 700-lb gorilla.

7. The force is exerted over a greater area while lying down, causing less pressure to be exerted on the ice in any given place.

8. The worst situation is on horesback, since not only is the area of contact small, but the force is the weight of the horse and the rider. Skis and snowshoes are both superior to boots because of the larger area of contact.

LESSON 14: (A) PRESSURE, PULMONARY CIRCULATION AND CHEST PAIN

(B) AEROBIC CAPACITY AND PHYSICAL FITNESS

RATIONALE:

In this section the chest pain which Tommy experienced in his race (ST-13) is explained in terms of an increase in pressure due to increased pulmonary circulation. Aerobic capacity, or the maximum rate at which the body can use oxygen, is discussed as a measure of physical fitness.

LA-14 provides the students with an opportunity to test their physical fitness by determining their aerobic capacity.

OBJECTIVES:

Given a diagram of the detailed structure of a lung the student will label the following parts: bronchiole, alveolus, alveolar capillaries.

The student will state the two structures involved in the transfer of oxygen from the lung to the bloodstream.

The student will define the terms pulmonary and aerobic capacity.

The student will state one cause of pulmonary edema and describe how this condition impairs the function of the lungs.

The student will define aerobic capacity and describe its relationship to physical fitness.

The student will determine his or her aerobic capacity.

SEQUENCE: ST-14; LA-14

SUGGESTIONS:

1. You may want to discuss various factors that affect the distensibility of the blood vessels. Perhaps the most important one is atherosclerosis which hardens the vessel walls, making them much less distensible. How would such a reduction in flexibility affect a person's ability to perform strenuous activities? (The volume of blood that could be pumped through the pulmonary vessels per unit time without incurring chest pain would decrease. This would lessen a person's capacity for strenuous exercise.)

2. A good way to increase the significance of the results is to encourage the students to begin physical fitness programs following the activity. In Lesson 25, after two to three weeks of conditioning, the Fitness Index may be re-measured. The results should indicate the effectiveness of the program in improving physical fitness. Some students may participate actively in after-school sports and will not require special additional training. Other students desiring physical fitness programs may be referred to sources such as the following.

A Health Enhancement Program. Preventive Medicine Center, Palo Alto, Calif., 1970.

Cooper, Kenneth H. The New Aerobics. Bantam Books (#553-04667), New York, 1970.

Royal Canadian Air Force. Exercise Plans for Physical Fitness. Simon and Schuster, Inc., New York, 1962.

A copy of the first of these programs is included at the end of this lesson. The other two are available in paperback at almost any local bookstore.

Some students may wish to formulate their own programs. The relative success of these programs could then be compared. For example, a regimen of push-ups and sit-ups will not increase the fitness index as markedly as a program of jogging.

Students that are unable or unwilling to participate in a physical fitness program may be used as controls when the fitness index is re-measured.

Another possibility is to see whether any of the smokers in the class would be willing to quit for three weeks to see whether this would produce any salutory effects.

INFORMATION ON LABORATORY ACTIVITY 14:

TEACHING NOTES:

1. In this activity the students are given an opportunity to measure their physical fitness, which is expressed in terms of aerobic capacity per unit of body weight. The aerobic capacity is determined by performing a step test, just as is done in health-testing programs. In addition, a nomogram is introduced as a device used to simplify mathematical calculations.

2. The Fitness Index values should be saved for use in LA-25. These data may also be useful in LA-18, where the vital capacity of the lungs is determined and compared to various body measurements.

3. The BIP may be programmed to provide either audible or visible signals (see the BIP manual for details). Audible signals must be loud enough for students to hear over the noise generated by the activities of the procedure. An electric metronome with a volume control is one possibility. Alternatively, a conventional metronome might be tape-recorded and played back in the classroom with the volume increased. A cassette tape recording may be particularly useful if the activity is performed in a location that is distant from a wall outlet.

4. Anticipated time: one period (not including calculations).

5. A few students who are in excellent condition might be off the bottom of the aerobic capacity scale, but still want to arrive at a numerical result. You might help them to extrapolate the scale. 7.0 should lie about 8 mm below 6.0, while 8.0 should lie about 5 mm below 7.0. Another possibility is to have such students repeat the test at an increased step rate.

MATERIALS:

bathroom scale

clock with second hand (visible to entire class)

source of timed signals

2 or more meter sticks

step, 30 to 35 cm high, of sufficient width or in sufficient number to accommodate perhaps 10 to 12 students

ANSWERS TO DISCUSSION QUESTIONS:

1. The answer depends upon individual results. Imprecision in the pulse rate measurement could change the final fitness category.

2. Depends upon results of other students.

3. Physical fitness may be improved through consistnet vigorous exercise, particularly exercise that strengthens the heart and lungs.

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HEALTH ENHANCEMENT THROUGH PHYSICAL ACTIVITY*

I.

THE IMPORTANCE OF PHYSICAL ACTIVITY

Patterns of modern living have channeled the average American into an increasingly sedentary existence. Man, however, was designed and built for movement, and it appears that physiologically he has not adapted well to this reduced level of activity. Regular exercise is necessary to develop and maintain an optimal level of health, performance, and appearance. It can increase an individual's physical working capacity by increasing muscle strength and endurance; by enhancing the function of the lungs, heart and blood vessels; by increasing the flexibility of joints; and by improving the efficiency or skill of movement. For many adults with sedentary occupations, appropriate physical activity provides an outlet for job-related tensions or mental fatigue. It also aids in weight control or reduction, improves posture, contributes to a youthful appearance, and increases general vitality.

Recently medical research has demonstrated that more active individuals have fewer heart attacks than less active individuals. Furthermore, if an active individual does suffer an attack, it probably will be less severe and his chances of survival are greater. Appropriate exercise may reduce the frequency and severity of heart attacks by improving the capacity and efficiency of the heart, blood vessels, and lungs as well as favorably altering blood chemistry, blood pressure, and body weight.

It has been estimated that more than 50 per cent of lower back pain or discomfort is due to poor muscle tone and flexibility of the lower back and to inadequate abdominal muscle tone. In many instances this disability could be prevented or corrected by proper exercise. And finally, it now appears that much of the degeneration of bodily functions and structure associated with premature aging can be reduced by frequent participation in a program of proper exercise.

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II.

PHYSIOLOGICAL BASIS OF PHYSICAL ACTIVITY

An individualized physical activity program to supplement the normal daily activities of most adults is considered essential from a health standpoint. There is a sound physiological basis for such a program. Physical inactivity results in reduced efficiency and function of the cardiovascular, respiratory, and muscular systems. On the other hand, increased physical activity promotes and enhances the efficiency and functions of these systems. Prolonged or endurance types of activities, e.g., jogging, bicycling and swimming, have been demonstrated to be the most efficient means of attaining these ends.

The physiological changes which generally occur as a result of an increased activity program are summarized in Table 1. The magnitude of change in each of these measurements is dependent on the types of activities pursued, their frequency and duration, and the degree of effort put into the activity.

Each of the measurements in Table 1 is important in evaluating the overall health status and performance capability of the individual. Several selected measurements, however, are regarded as being of greatest importance and provide the most information about your health and fitness status. Each of these measurements is briefly described along with their normal values.

RESTING HEART RATE

Heart rate is simply a measure of the frequency of the heart contraction during a certain period of time, i.e., beats/minute. The resting heart rate is of significant value in assessing the efficiency and condition of the cardiovascular system because it indicates the energy demands being made upon the heart. The slower its resting rate, the more efficient is the heart.

TABLE 1

PHYSIOLOGICAL CHANGES RESULTING FROM ENDURANCE TYPE PHYSICAL CONDITIONING

HEART

Reduced resting heart rate
Reduced heart rate for standardized submaximal exercise
Increased rate of heart rate recovery after standardized exercise
Increased blood volume pumped per heart beat (stroke volume)
Increased size of heart muscle (myocardial hypertrophy)
Increased blood supply to heart muscle
Increased strength of contraction (contractibility)

BLOOD VESSELS AND BLOOD CHEMISTRY

Reduced resting systolic and diastolic arterial blood pressure
Reduced risk of hardening of the arteries (arteriosclerosis)
Reduced serium lipids, i.e., cholesterol, triglycerides
Increased blood supply to muscles
Increased blood volume
More efficient exchange of oxygen and carbon dioxide in muscles

LUNGS

Increased functional capacity during exercise
Increased blood supply
Increased diffusion of respiratory gases
Reduced non-functional volume of lung (residual volume)

NEURAL, ENDOCRINE, AND METABOLIC FUNCTION

Increased glucose tolerance
Increased enzymatic function in muscle cells
Reduced body fat content (adiposity)
Increased muscle mass (lean body mass)
Reduced strain resulting from psychological stress

Adults in poor physical condition may have resting heart rates as high as 100 beats per minute, while some superbly conditioned endurance athletes have rates as low as 35 to 40 beats per minute. The ability to reduce the resting heart rate as a result of physical conditioning is primarily due to the heart's ability to increase the volume of blood it pumps with each contraction (stroke volume).

ELECTROCARDIOGRAM

When the heart is stimulated by the nervous system, a contraction results. The pattern of this electrical stimulation can be recorded and is referred to as the electrocardiogram. People who have suffered heart attacks or other cardiac disorders will frequently demonstrate abnormal resting electrocardiograms. Recently it has been demonstrated that people who do not have outward manifestations of heart disease, including a normal resting electrocardiogram, may show marked electrocardiographic abnormalities during or following an exercise test of moderate intensity. These electrocardiographic abnormalities during exercise have a rather high positive correlation with the future development of heart and vascular disease.

RESTING BLOOD PRESSURE

Blood pressure is the force or pressure exerted against the blood vessel wall by the blood as it is propelled through them with each beat of the heart. Blood pressures measured in the clinic setting are typically arterial pressures and are usually expressed by a pair of numbers, e.g., 120/80 millimeters of mercury pressure. The higher of these two numbers is referred to as the systolic pressure and represents the pressure during the contraction phase of the heart's cycle. The lower value is the diastolic pressure and represents the relaxation phase of the heart's cycle. Normal blood pressure values will vary considerably due to a number of factors, including age. In a 40-year-old man, a blood pressure of 140/90 is in the

normal range, while a pressure of 150/95 would be considered somewhat high.

OXYGEN UPTAKE

All living cells in the human body require oxygen in order to function properly. An adult man in bed requires about 300 milliliters, or less than a pint, of oxygen per minute to meet his body's energy needs. When he increases his muscular activity, the oxygen demand of his body increases proportionately. This transportation of oxygen to the tissue cells throughout the body is met by the combined function of the lungs, heart, and blood vessels.

Every individual has a finite limit as to the quantity of oxygen he can deliver to his tissues during maximal or exhaustive exercises, such as running or cycling. This upper limit is referred to as the individual's maximal oxygen uptake. Theoretically, those individuals with larger maximal oxygen uptakes have greater cardiorespiratory efficiency and fitness. This ability to deliver more oxygen to the tissues during maximal exercise implies a greater available energy source, increased endurance, and better developed lungs, heart, and vascular system.

An individual's maximal oxygen uptake will increase significantly as a result of endurance-type training or conditioning. Likewise, endurance athletes have much larger values than normal individuals. Therefore, the maximal oxygen uptake can be used to differentiate between people of varying degrees of cardiovascular efficiency and endurance, making it possible to classify individuals into groups according to their cardiorespiratory fitness. The data presented in Table 2 represents an estimate, based on previous research, of varying fitness categories for adults according to age and sex. The oxygen uptake values are expressed relative to body weight; i.e., milliliters of oxygen consumed per kilogram of body weight per minute (ml/kg/min.).

This compensates for the fact that oxygen uptake capacity is directly related to the size of the individual.

TABLE 2

CARDIORESPIRATORY FITNESS CLASSIFICATION

Age Group, Years	Maximal Oxygen Uptake, ml/kg/min. Low	Fair	Average	Good	High
MEN					
20-29	25	25-33	34-42	43-52	52
30-39	23	23-30	31-38	39-48	48
40-49	20	20-26	27-35	36-44	44
50-59	18	18-24	25-33	34-43	43
60-69	16	16-22	23-30	31-40	40
WOMEN					
20-29	24	24-30	31-37	38-48	48
30-39	20	20-27	28-33	34-44	44
40-49	17	17-23	24-30	31-41	41
50-59	15	15-20	21-27	28-37	37
60-69	13	13-17	18-23	24-34	34

RESIDUAL LUNG VOLUME

Residual Lung Volume refers to the volume of air remaining in the lungs following a maximal expiration; i.e., the lungs never fully collapse during a maximal expiration. This volume then becomes one which has no positive value relative to the individual's functional respiratory capacity. It does, however, have considerable value in detecting respiratory abnormalities, especially chronic lung disease. Large residual volumes relative to the total capacity of the lungs normally indicate pulmonary insufficiency or disability.

BODY FAT

Body fat, or the fat content of the body, is most meaningful expressed as a percentage of the total body weight. A value of 10% body fat indicates that 10% of the body weight, or 10 out of every 100 lbs., is fat. Men should aim for a body fat content between 10-15%. Women are given a somewhat liberal allowance of 20-25%, so the essential female contour is maintained. A value of 25% for men and 35% for women is considered borderline obesity.

III.

GENERAL GUIDES TO A PHYSICAL ACTIVITY PROGRAM

When an inactive individual begins a physical activity program, there are several very basic and important factors which need to be considered. The following guides are included to assist you in maintaining a successful and enjoyable activity program.

CLOTHING

The choice of clothing will obviously be dependent upon the weather and the activity in which you plan to participate. However, clothing should always be comfortable, reasonably loose, and heavy or light enough to insure protection from heat, cold, and wind. Women should avoid restrictive support garments or clothing that restrict either free movement or blood flow. In conditioning activities such as jogging, men don't need to wear athletic supporters, as they frequently cause skin irritations.

Do not wear rubberized or plastic clothing while exercising. The increased sweat loss doesn't result in a permanent loss in body weight, and this practice can be very dangerous. The rubberized or plastic clothing doesn't allow the body sweat to evaporate, which is the principal mechanism for temperature regulation in humans during exercise. The result can be a dramatic rise in body temperature, excessive dehydration

and salt loss, and eventual heat stroke or heat exhaustion.

SHOES

The type and proper fit of shoe is important for any activity program. A good quality of tennis, basketball or gym shoe is recommended for most types of activities. For programs of running, jogging or walking, however, special shoes are recommended which have been designed specifically for these activities. These shoes should not fit tightly; the soles should be firm and the tops pliable; and they should have good arch support. Ripple or crepe soles are excellent for use on hard surfaces. It is important to remember that good shoes and socks are the best prevention against blisters, and soreness and aching of the feet, ankles, and knees.

RUNNING SURFACES

For those individuals including walking, running or jogging in their activity program, the matter of running surfaces should be given careful consideration. Beginners and individuals who are overweight or who have a history of foot, ankle, or knee problems should avoid hard surfaces such as cement or asphalt. Running tracks and grass or dirt paths usually provide good surfaces. Golf courses, parks, or rights-of-way along parkways can provide good variations in scenery and terrain. During bad weather use can be made of the local YMCA, school, or church gymnasium, under protected areas aroung shopping centers, and sometimes even around your home.

WHEN TO EXERCISE

Almost any time of the day is acceptable for exercising, except for an hour or two following a meal and during hot and humid weather. Since man seems to be a creature of habit, a specific time of day should be set aside for the activity program. Early morning before breakfast is often the best time for many people.

ILLNESS OR INJURY

The individual's physical activity program should be modified or temporarily stopped during any illness, injury, or infection which might be aggravated by such a program. Use of proper footwear and socks, and taking it easy at the beginning will help avoid many potential foot and leg problems. Also, switching to an activity that does not require you to support your weight while exercising, such as swimming or bicycling, will help eliminate foot or leg problems without losing your fitness. Any persistent illness or injury should be brought to the attention of your personal physician.

MOTIVATION

Physical activity programs are usually started with the best of intentions, but all too often the individual's enthusiasm tends to wane after a short period of time. Since the physical activity program is intended to be a lifetime pursuit, it is important that the individual be properly motivated. Several helpful suggestions are listed below in an effort to overcome the motivation problem.

- Either select activities you enjoy or learn to enjoy the activities in which you feel you must participate.
- Exercise at a regular time of the day and make this a part of your daily routine.
- Exercise with a partner or become a member of a formal group. However, don't get talked into competition.
- Take selected physiological and medical measurements and attempt to chart your improvement on each of these. Several simple tests are described in the section on "Self Evaluation Procedures" in this booklet.
- Become educated in what you are doing. By reading, attending lectures or seminars and by group discussion, attempt to understand the importance of a physical activity program relative to

your total life.

IV.
SELF-EVALUATION PROCEDURES

There are several simple tests which you can perform to gain an estimate of your improvement in cardiorespiratory function and efficiency as a result of your health enhancement program. These tests, while somewhat limited, will give you an indication of your progress from week to week.

RESTING PULSE RATE

The resting pulse rate is a sensitive indicator of changes in cardiorespiratory efficiency and function that result from physical conditioning. The resting rate can be reduced by one or more beats per minute each week during the first few months of even an endurance conditioning program of moderate intensity. During the first three or four months of such a program an individual with a resting heart rate of 80 to 85 beats per minute could expect to drop down to approximately 70 beats per minute.

To obtain an accurate resting pulse rate, the rate should be taken under standardized conditions. The best time of day is probably upon awaking in the morning while still reclining in bed or in the mid-evening while resting comfortably in a semi-recumbant position. The resting rate is sensitive to changes in posture (standing up increases the rate), recent food or beverage intake, room temperature, mental anxiety, and fatigue, so be sure to keep these conditions reasonably constant from one time to the next. To determine your pulse rate accurately:

1. Locate your carotid, temporal, brachial or radial pulse.
    a. Carotid artery - just to the side of the larynx (voice box) in the neck region.
    b. Temporal artery - in the temple regions of the head usually

along the hairline.

c. Brachial - on the inside of the upper arm behind the biceps muscle and just beneath the axilla (armpit).

d. Radial artery - on the palm side of the wrist directly in line with the thumb.

2. Place the tips of your middle and/or index fingers over the region of the arterial pulses and press lightly.

3. Take the pulse count for a 30-second period, counting the first pulse as zero and starting your 30-second interval at that time.

4. Convert your 30-second pulse to a minute count and record this on Figure A. of your permanent record sheet.

Record your resting pulse rate at least once a week and plot it on Figure A.

POST-EXERCISE PULSE RATE

One of the more sensitive measures of improvement in cardiorespiratory function and efficiency is the pulse rate recovery from a standard period of exercise. With increased function and efficiency, the rate of recovery becomes more rapid. To evaluate this, simply follow these directions.

1. Select a stool or step that is approximately 12 inches high. Be sure this is stable enough to support your weight during a stepping activity.

2. Step at a rate of _____ per minute; e.g., all the way up and back down every ______ seconds. Perform this exercise rhythmically, and make a complete ascent and descent each step.

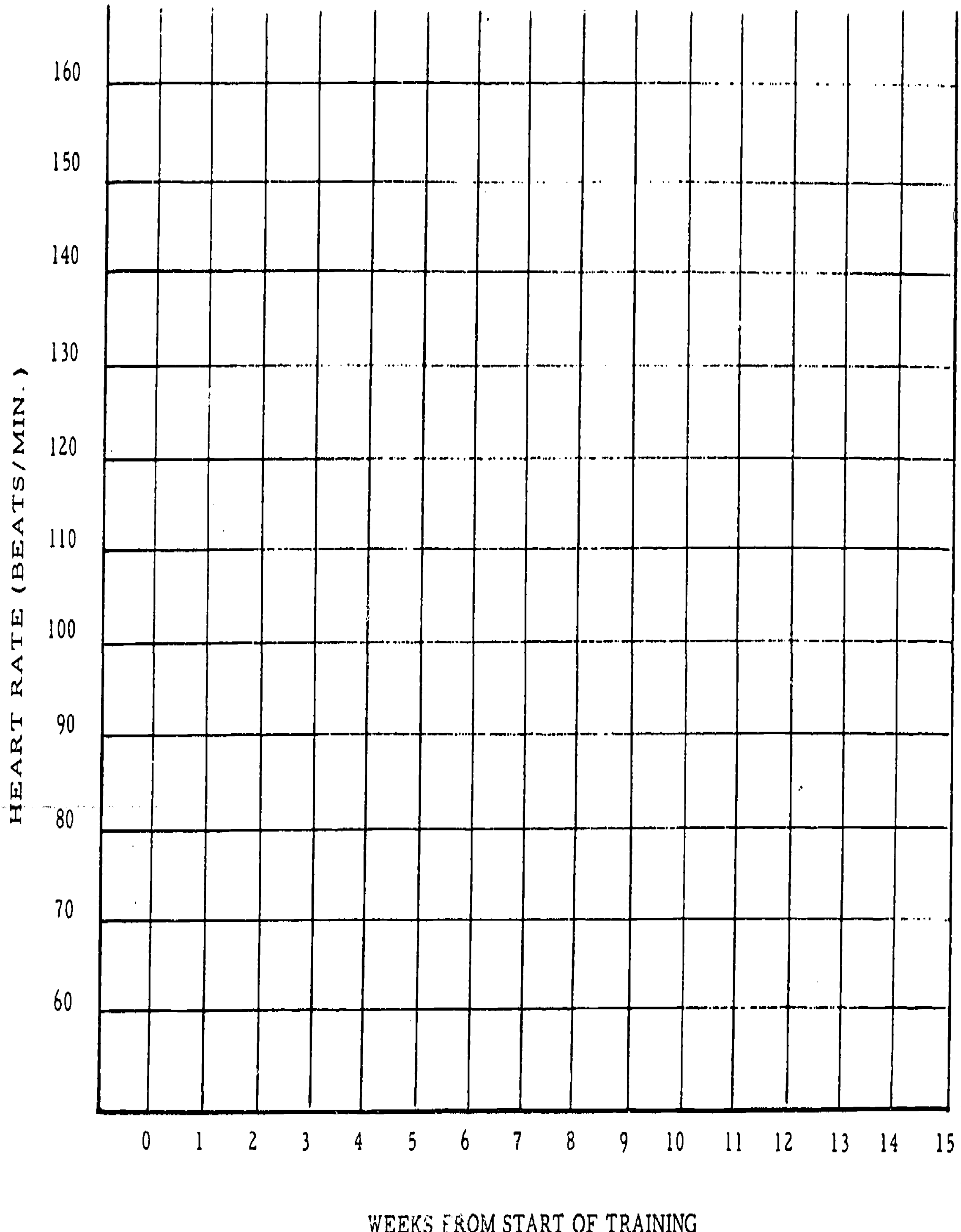
3. Exercise at your prescribed cadence for exactly two minutes.

4. Take your post-exercise recovery pulse rate for 30 seconds beginning exactly at 30 seconds and ending exactly at 60 seconds post-exercise. Double this value and plot it on Figure A.

The submaximal step test should be performed every week or two under the same standardized conditions as given for the determination of resting pulse rate. Both the resting and the post-exercise recovery values should

FIGURE A

RESTING AND POST-EXERCISE HEART RATE RECORD



be plotted graphically on Figure A. to highlight your progress over time.

V.

ENERGY EXPENDITURE AND PHYSICAL ACTIVITY

The amount of oxygen you consume is directly proportional to the energy you expend in physical activity. At rest you use approximately 3.5 milliliters of oxygen per kilogram (2.2 lbs.) of your body weight per minute (ml/kg/min.). When walking slowly at 2 mph you use about 9.0 milliliters, and 24 milliliters when walking rapidly at 5.0 mph. The amount of oxygen necessary to perform an activity is referred to as that activity's oxygen requirement. Thus, all physical activities can be classified according to their intensity as determined by their oxygen requirement.

THE MET SCORE SYSTEM

A simplified system for classifying physical activities has been developed for you using the concept of "metabolic equivalents" or METS. One MET is equal to your resting oxygen uptake, or approximately 3.5 milliliters of oxygen per kilogram of body weight per minute (ml/kg/min.). An activity that is rated as two METS would therefore require two times your resting oxygen consumption or 7 ml/kg/min. and for an activity to be rated as 4 METS it would have to require approximately 14 ml/kg/min. (4 x 3.5 = 14).

For those individuals who would like to keep a record of their physical activity or select activities that have similar energy requirements, the MET system lends itself nicely to this purpose. A suggested way of doing this is to give yourself the MET value of a particular activity for each 30 minute period you perform the activity. As an example, if you performed a 4 MET activity for 30 minutes give yourself four points. If you perform this same activity for 15 minutes it would be worth two points.

This would be only an approximation of your energy expenditure, but it does provide a simple means of quantifying what you do. A number of activities and their MET values are presented in Table 3. It should be noted that these values are only approximations due to the variations in metabolic efficiency both within and between individuals.

TABLE 3

SELECTED ACTIVITIES AND THEIR RESPECTIVE MET VALUES

SELF-CARE ACTIVITIES

ACTIVITY	METS
Rest, supine	1.0
Sitting	1.0
Standing, relaxed	1.0
Eating	1.0
Conversation	1.0
Dressing, undressing	2.0
Washing hands, face	2.0
Propulsion, wheelchair	2.0
Walking, 2.5 mph	3.0
Showering	3.5
Walking downstairs	4.5
Walking, 3.5 mph	5.5
Ambulation, braces and crutches	6.5

HOUSEWORK ACTIVITIES

ACTIVITY	METS
Handsewing	1.0
Sweeping floor	1.5
Machine sewing	1.5
Polishing furniture	2.0
Peeling potatoes	2.5
Scrubbing, standing	2.5
Washing small clothes	2.5
Kneading dough	2.5
Scrubbing floors	3.0
Cleaning windows	3.0

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Table 3 (Continued)

HOUSEWORK ACTIVITIES (Con't.)

ACTIVITY	METS
Making beds	3.0
Ironing, standing	3.5
Mopping	3.5
Wringing by hand	3.5
Hanging wash	3.5
Beating carpets	4.0

OCCUPATIONAL ACTIVITIES

ACTIVITY	METS
Sitting at desk	1.5
Writing	1.5
Riding in automobile	1.5
Watch repairing	1.5
Typing	2.0
Welding	2.5
Radio assembly	2.5
Playing musical instrument	2.5
Parts assembly	3.0
Bricklaying, plastering	3.5
Heavy assembly work	4.0
Wheeling barrow 115 lbs., 2.5 mph	4.0
Carpentry	5.5
Mowing lawn by hand	6.5
Chopping wood	6.5
Shoveling	7.0
Digging	7.5

PHYSICAL CONDITIONING ACTIVITIES

ACTIVITY	METS
Level walking, 2 mph (1 mile in 30')	2.5
Level cycling, 5.5 mph (1 mile in 10' 54")	3.0
Level cycling, 6 mph (1 mile in 10' 15")	3.5
Level walking, 2.5 mph (1 mile in 24')	3.5
Level walking, 3 mph (1 mile in 20')	4.5

Table 3 (Continued)

PHYSICAL CONDITIONING ACTIVITIES (Con't.)

ACTIVITY	METS
Calesthenics	4.5
Level cycling, 9.7 mph (1 mile in 6' 18")	5.0
Swimming, crawl, 1 ft./sec.	5.0
Level walking, 3.5 mph (1 mile in 17')	5.5
Level walking, 4.0 mph (1 mile in 15')	6.5
Level walking, 5.0 mph (1 mile in 12')	7.5
Level cycling, 13 mph (1 mile in 4' 37")	9.0
Level running, 7.5 mph (1 mile in 8')	9.0
Swimming drawl, 2 ft./sec.	10.0
Level running, 8.5 mph (1 mile in 7')	12.0
Level running, 10.0 mph (1 mile in 6')	15.0
Swimming crawl, 2.5 ft./sec.	15.0
Swimming drawl, 3.0 ft./sec.	20.0
Level running, 12 mph (1 mile in 5')	20.0
Level running, 15 mph (1/4 mile in 1')	30.0
Swimming crawl, 3.5 ft./sec.	30.0

RECREATIONAL ACTIVITIES

ACTIVITY	METS
Painting, sitting	1.5
Playing piano	2.0
Driving car	2.0
Canoeing, 2.5 mph	2.5
Horseback riding, walk	2.5
Volleyball, 6 man recreational	3.0
Billiards	3.0
Bowling	3.5
Horseshoes	3.5
Golf	4.0
Cricket	4.0
Archery	4.5
Ballroom dancing	4.5
Table tennis	4.5
Baseball	4.5
Tennis	6.0
Horseback riding, trot	6.5
Folk dancing	6.5
Skiing	8.0
Horseback riding, gallop	8.0

Table 3 (Continued)

RECREATIONAL ACTIVITIES (Con't.)

ACTIVITY	METS
Squash rackets	8.5
Fencing	9.0
Basketball	9.0
Football	9.0
Gymnastics	10.0

SELECTED READING LIST

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BE FIT FOR LIFE. Rodahl, K. New York: Harper & Row Publishers, 1966.

PHYSICAL FITNESS: HOW TO GET IT AND KEEP IT. U.S. News and World Report, Inc., Washington, D.C., 1970.

LESSON 15: (A) HIGH ALTITUDE AND HYPOXIA

(B) PRESSURE AND TEMPERATURE IN A GAS

(C) EFFECT OF TEMPERATURE ON THE VOLUME OF A GAS

RATIONALE:

The ability of the body to use oxygen depends not only on the health of the respiratory and circulatory systems but is also a function of the amount of oxygen available. Using the air at high altitudes as an example, ST-15 discusses the effect of pressure and temperature on the amount of oxygen available to us. The three phases of matter and the molecular bases of pressure and temperature also come into the discussion, as does hypoxia and some of its causes and symptoms.

In LA-15 data are collected on the relation between the temperature and volume of a gas at constant pressure. These data will be used in the mathematics class to derive Charles' Law.

OBJECTIVES:

The student will define hypoxia and list at least three of its possible causes and two of its symptoms.

The student will state three ways in which the air changes with an increase in altitude.

The student will compare a solid, a liquid and a gas in terms of molecular motion and the average distance between molecules.

The student will state the cause of pressure in a gas.

The student will explain in terms of the pressure of the overlying atmosphere, why air is "thinner" at higher altitudes.

The student will define temperature as a measure of molecular activity.

SEQUENCE: ST-15; LA-15

SUGGESTIONS:

1. The idea that molecules in the air exert a force can be demonstrated in two ways. Have the students take a syringe and position the plunger midway inside the tube. Then, after stoppering the syringe by placing a finger over the end, have the students push down on the plunger until it becomes difficult to go any farther. Now, have them release the plunger; it should return approximately to its starting position. The air inside the syringe had to exert a force for this to happen. When the plunger stopped moving the upward force produced by the molecules inside the syringe equaled the downward force due to the molecules in the atmosphere. In other words, the pressure on both sides of the syringe was the same. This same principle can be shown by stoppering the end of the syringe,

pulling the plunger up and then releasing it. Again it will return to the starting point. This time however, the greater force was produced by the air molecules outside the syringe.

This demonstration can be related to the changes in pressure that occur with change in altitude. At higher altitudes the force of the "outside atmosphere" is less and the air molecules may become more widely dispersed. The pressure they exert on any one given area then becomes less. At sea level, where the atmosphere is exerting a greater force, the air molecules are closer together and the pressure they exert on a given area is greater.

2. You might also discuss the question, "Why do you turn blue when you suffer from hypoxia?" The answer to this question has to do with the difference in the color of blood that carries oxygen and that which has given up that oxygen to the tissues of the body. Oxygenated blood is red in color while hemoglobin that has given up its oxygen is a bluish color. In hypoxia, the hemoglobin loses its oxygen and it is not replaced. When this occurs in blood vessels near the surface of the skin, the skin appears bluish due to this "reduced" hemoglobin.

3. If any of the students have done any climbing, backpacking or performed other activities at high altitudes, you may wish to have them share some of their experiences with the class. How did altitude affect the rate at which they could perform activities?

INFORMATION ON LABORATORY ACTIVITY 15:

TEACHING NOTES:

1. The objective of this activity is to collect data on the relationship between the temperature and volume of a gas at constant pressure. These data will be used in the mathematics class to derive Charles' Law.

2. The student data sheets should be collected and given to the mathematics instructor prior to Mathematics Lesson 19.

3. The accuracy of the results is improved by treating the glass tubing with a 1% silicone solution. The silicone coating reduces the adhesion to the glass of polar solvents such as water, ethylene glycol and alcohol. A thin film of ethylene glycol on the walls of the tubing limits the accuracy of the length measurements that are taken. A silicone coating inhibits the formation of this film, and generally reduces the friction of the moving solvent inside the tubing.

"Siliclad" is available from Van Waters and Rogers (#57452-002), and must be diluted with tap water by a factor of 100 before use. The tubes are soaked briefly in the solution and then allowed to dry for 24 to 48 hours. Note: Only the tubing that is used for the length measurements needs to be treated.

4. Ethylene glycol is readily obtainable from chemical supply houses. A technical grade is suitable. Antifreeze serves as a completely acceptable substitute since it contains 80 to 90 per cent ethylene glycol. It has the added advantage of being colored deep green, which makes it easily visible inside the apparatus.

5. The jacket tubing, available from local plastics dealers, is normally called "extruded" clear acrylic tubing. It has the advantages of being easy to cut (as with a hacksaw) and relatively unbreakable. Glass tubing is also acceptable, and although less expensive, is more difficult to cut.

6. The tube containing the trapped air may also be sealed by melting the end in a burner flame. This will eliminate the time required for the silicone rubber cement to cure. If the tubes are to be sealed by melting the end, it is essential that they be made of soft (flint) glass. Hard (Pyrex or Kimble) glass is virtually impossible to melt in typical student burners.

7. Students may need some instruction in clamping the leveling tube without breaking it. Several thicknesses of paper towelling or cloth may help.

8. Most of the ethylene glycol can be recovered for use in later years, if desired. Have students disassemble the apparatus over a large collecting basin.

9. Anticipated time: 1st day--one-half period; 2nd day--one period.

MATERIALS: (for 15 set-ups)

9.75 meters glass tubing, 6 mm O.D.

7.5 meters rubber tubing, 3/16" I.D.

15 rubber stoppers, #4, two-hole

silicone rubber cement

200 ml ethylene glycol ($HOCH_2CH_2OH$) or antifreeze

15 pinch clamps

15 pieces acrylic tubing, 30 cm long, 7/8" I.D.

15 thermometers, 0 to 100 °C

15 ring stands

45 ring-stand clamps

15 millimeter rulers

30 beakers, 250-ml

15 medicine droppers

5 lbs ice

glycerine

masking tape

ANSWERS TO DISCUSSION QUESTIONS:

1. The pressure at the open end of the leveling tube is atmospheric. If the two menisci are at the same level, the pressure on the other side (exerted by the confined gas) must also be atmospheric.

2. The temperature of the jacket tube will be closer to room temperature than the temperature of the water (and confined gas).

3. Temperature: ± 0.25 °C; length: ± 0.025 cm.

4. $V = \pi r^2 h$

$\approx 3.14(.2)(.2)h$

$\approx 0.1256 \text{ h cu cm}$

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LESSON 16: (A) ABSOLUTE AND ATMOSPHERIC PRESSURE

(B) ADAPTATION TO HIGH ALTITUDE

(C) EFFECT OF PRESSURE ON THE VOLUME OF A GAS

RATIONALE:

ST-16 introduces the barometer and atmospheric pressure in order to develop the concept of absolute pressure, which is needed for the derivation and use of Boyle's Law and the Combined Gas Law in the mathematics course and for the treatment of the Universal Gas Law in ST-36. In addition, the section explains the connection between smoking and Tom's hypoxia on Mt. Whitney. The section concludes with a discussion of the mechanisms by which people adapt to high altitude.

In LA-16 the students collect data on the relation between the pressure and volume of a gas at constant temperature. Once again the data are transferred to the mathematics class, where they will be used to derive Char[illegible] Law.

OBJECTIVES:

The student will define gage pressure, absolute pressure and atmospheric pressure and state the relationship between them.

The student will state the relationship between 1 atmosphere, 1 mm Hg and 1 torr.

The student will differentiate between a common manometer and a barometer.

The student will explain how cigarette smoking reduces the ability of the blood to carry oxygen.

The student will list three ways in which the body adapts to high altitude.

SEQUENCE: either LA-16; ST-16 or the reverse.

SUGGESTIONS:

1. One of your students might like to research and report on the use of the barometer in the study of weather.

2. Above certain elevations the body's compensatory mechanisms break down and the situation does not improve or even remain stable, but steadily deteriorates. The students might be interested in finding out what effects these facts have had on mountaineering in such mountain ranges as the Alps, the Andes and the Himalayas, as well as what measures can be taken to counteract such effects.

INFORMATION ON ACCLIMATIZATION TO ALTITUDE:

The human body can adjust, within limits, to high altitude. This acclimatization is gradual. As one becomes acclimatized to lower gas pressures than

usually experienced, there are fewer deleterious effects on the body, and it becomes possible to work harder or to ascend to still higher altitudes. Acclimatization occurs by five main mechanisms.

1. Increased hemoglobin in the blood

Hemoglobin is carried by red blood cells. Hypoxia is the principal stimulus for red blood cell production.

After complete acclimatization to high altitude the hematocrit (the percentage of the blood that is cells) increases from a normal value of about 40 to 45 (per cent cells) to an average of about 50 to 60.

After acclimatization there is an increase in the number of red blood cells. The result is an increase in hemoglobin concentration from about 14 to 17 gram-per cent (14 to 17 g hemoglobin per 100 ml of blood) to about 20 gram-per cent.

Acclimatization to high altitude increases the amount of blood in circulation by as much as 20 to 30 per cent.

All the above can result in a 40 to 70 per cent increase in circulating hemoglobin.

This increase is a very slow process. It takes two to three weeks to detect any change at all. The process is halfway developed after about a month, but takes several years to become fully developed.

2. Increased efficiency of oxygen utilization at the cellular level

Cells require oxidative enzymes to use oxygen for respiration. Certain cellular oxidative enzyme systems are more plentiful in natives of very high altitudes.

These "elevated oxidative enzyme systems" are either very slow in developing, or they are genetic differences selected over many generations at high altitude.

3. Increased pulmonary ventilation

(Note: all but the first sentence of this section is for your information only. The chemical regulation of breathing will be taken up later in the unit.)

Immediately upon exposure to low oxygen pressure, pulmonary ventilation may increase as much as about 65 per cent, because of stimulation of the

respiratory center. This occurs because of the decrease in aortic oxygen levels which stimulates the carotid and aortic chemoreceptors. After several days at low oxygen pressure, ventilation will increase still further.

A larger increase in pulmonary ventilation is not possible at first because increased ventilation blows off excessive CO_2, increasing blood pH, and inhibiting the respiratory center. After three to five days at low oxygen pressures, changes in kidney activity permit a return of the blood pH toward normal levels. When respiratory inhibition from high blood pH no longer opposes hypoxic stimulation by the carotid and aortic bodies, a great increase in alveolar ventilation occurs.

4. Increased vascularity of the tissues

Months or years of living at high altitude result in increased vascularity of many tissues, e.g., increased numbers and sizes of capillaries. Increased vascularity may explain what happens to the 20 to 30 per cent increase in blood volume mentioned under heading 1.

Increased vascularity brings oxygen-carrying blood into closer contact with the tissues, making oxygen more available to the cells.

5. Increased diffusing capacity of the lungs

Acclimatization over long periods to low oxygen pressure can cause a threefold increase in the oxygen-diffusing capacity.

Increased capillary blood volume expands the capillaries surrounding the alveoli. The alveolar membranes expand in response to increased ventilation. This increases the surface through which oxygen can diffuse into the blood.

INFORMATION ON LABORATORY ACTIVITY 16:

TEACHING NOTES:

1. The objective of this activity is to collect data on the relationship between the pressure and volume of a gas at a constant temperature. The data and graphs developed here are subjected to further analysis in the mathematics class in order to derive Boyle's Law.

2. All data, calculations and graphs should be collected and given to the mathematics instructor in time for Mathematics Lesson 20.

3. In order to determine the total pressures, the mathematics instructor will also need the local barometric pressure on the day this activity is conducted. If the school has a barometer (e.g., in the physics laboratory), it is suggested that you send a student delegation to obtain the reading. Otherwise, a telephone call to the local weather station or airport should provide the information. The reading will be either in millimeters of mercury or inches of mercury. Convert it to g/sq cm as follows, and send it along with the other materials.

mm Hg x 1.35 = g/sq cm   in Hg x 34.4 = g/sq cm

4. Note that this activity consists of two entirely separate procedures. If the syringe-platform instruments are available (Part I), they should be used in preference to the Part II procedure because they will produce a much wider range of data. The syringe-platform instruments might well be available in the physics department of your school. They may be purchased from Macalaster Scientific Co., Box R, Department CSM, Nashua, N.H. 03060 (catalog #30220).

5. (Part I only) Each set-up will require 10 to 12 lb or identical weights (books, etc). A single weight should not exceed 1000 grams. You will need to provide the students with the weight (to the nearest gram) of a single weight. If different students are using different types of weights, you will need to make a number of weighings prior to class.

6. (Part I only) The calculations and subsequent treatment in the mathematics class are based on the assumption that the cross-sectional area of the syringe interior is 4.4 sq cm. If you use any other syringe than the one recommended in Note 4, it will be necessary to determine its cross-sectional area and amend the presentation in the calculation portion of the activity. The area can

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be found by measuring the distance from the zero mark to a specific volume (the larger the better) and using the relation V = Ad. For example, if

$$\text{volume (V)} \approx 35 \text{ cu cm}$$

$$\text{and distance (d)} \approx 7.9 \text{ cm}$$

$$A = \frac{V}{d} \approx \frac{35}{7.9} \approx 4.4 \text{ sq cm}$$

7. (Part II only) The sodium bromide solution should not be mouth-pipetted.

8. (Part II only) Most of the NaBr solution could be recovered for use in future years (with suitable readjustment of the density).

9. Anticipated time:

Part I--one period plus calculation and graphing time.

Part II--one-half period on 1st day; one period on 2nd day (plus calculation and graphing time).

PART I MATERIALS: (for 15 set-ups)

- 15 plastic syringe-platform instruments
- 15 sets of identical weights
- glycerine
- 15 balances

PART II MATERIALS: (for 15 set-ups)

- 750 ml NaBr solution, density 1.5 g/ml
- 22.5 meters rubber tubing, 3/16" I.D.
- 9.75 meters glass tubing, 6 mm O.D.
- 15 ring stands
- 15 ring-stand clamps
- 15 beakers, 50-ml
- 15 pipets, 10-ml
- 15 millimeter rulers
- 15 wooden dowels or sticks, at least 120 cm long
- several meter sticks
- silicone rubber cement
- tape

PREPARATION OF REAGENT (Part II):

Sodium bromide solution: Dissolve 540 ± 1 g anhydrous NaBr in 585 ± 5 ml tap water. This will provide approximately 750 ml of solution. Test the density and, if necessary, adjust to a density of 1.50 ± .01 g/ml. NaBr is somewhat hygroscopic, a property which may cause the initial density obtained to deviate from 1.50 g/ml. Stopper tightly to prevent evaporation. The solution will keep indefinitely.

LESSON 17: (A) THE RESPIRATORY CENTER

(B) RESPIRATORY RESPONSE TO COLD

RATIONALE:

When Tom was on Mt. Whitney and he was not able to obtain sufficient oxygen because of the atmospheric pressure, he responded by breathing more deeply and more frequently. In this section the respiratory center which controls such responses is discussed, and the way in which this center responds to cold is covered in some detail.

LA-17 demonstrates the increase in respiration and CO_2 production at low external temperatures.

OBJECTIVES:

The student will state the location and function of the respiratory center.

The student will list three types of events that can cause the respiratory center to change the breathing rate.

The student will list two conditions that may impair the function of the respiratory center to such an extent that breathing ceases.

The student will explain how the respiratory center responds to cold and the advantage of such a response.

The student will define the terms homeothermic and poikilothermic and give two examples of animals that belong to each of these categories.

SEQUENCE: ST-17; LA-17

SUGGESTIONS:

1. You might lead a discussion on hibernation in certain animals. This is a response to extreme cold in which the breathing rate does not speed up, but rather it slows down tremendously (along with all other bodily processes). In this way many animals survive the winter on a minimum of food and air. Some questions you might bring up for further research and discussion are as follows. Have any studies been done on the possibilities of inducing hibernation in astronauts during space travel? If so, what were some of the results? What problems would be encountered in such a project?

2. If you have a fetal pig on hand you may wish to show the students the location of the respiratory center (medulla).

INFORMATION ON LABORATORY ACTIVITY 17:

TEACHING NOTES:

1. The purpose of this activity is to determine the effect of external

temperature on the respiration rate of mammals. This is accomplished by comparing the relative amounts of carbon dioxide produced in six minutes by a mouse at 20 °C and at 10 °C. The increased breathing rate at the lower temperature corresponds to a similar response in humans.

2. Anticipated time: one period.

3. The principle behind the procedure is somewhat complicated since several factors are operating simultaneously. It should be emphasized that the mice are not competing against each other. Rather, the change in fluid level is caused by the pressure difference between the two flasks. This pressure difference is a result of the absorption of carbon dioxide by the soda lime. (This point could be brought out by asking the students to decide which mouse expires the greater amount of carbon dioxide. Since the two mice are similar and subjected to the same conditions, they expire approximately the same amount.)

4. It should also be noted that the change in the level of the manometer fluid is <u>not</u> a direct measurement of the amount of carbon dioxide produced.

a. The soda lime cannot absorb the carbon dioxide perfectly (or completely). In addition, it also absorbs a slight amount of water vapor.

b. The mice may differ slightly in their response to temperature changes.

c. The manometer is not a constant-pressure instrument (as in the Charles' Law activity). Therefore, the change in fluid level is a slightly inaccurate reflection of the change in volume of the gas in the experimental flask.

Although these factors prevent accurate quantitative measurement, they do not significantly interfere with the qualitative result of the procedure: that a reduction of ambient temperature increases the rate of respiration in homeothermic animals.

5. The soda lime is a mixture of sodium hydroxide and calcium hydroxide. The sodium hydroxide, in particular, has a great affinity for carbon dioxide.

6. The students should be instructed to handle the mice in a humane manner. The mice may be held by the tail without causing injury. The experimental mouse may chew on the bag. This behavior is apparently not due to any discomfort resulting from the soda lime. Rather, the texture of the cheesecloth seems to be responsible for their interest. If a double thickness of cheesecloth is used, the soda lime should not spill out.

7. It is important that the two mice be approximately the same size.

8. The glass tubing shown on the right-hand side of the manometer in Figure 1 may be replaced by a second pipet, if this simplifies the equipment requirements.

9. Since the cost of purchasing as many as 30 mice may be prohibitive, the materials list indicates the requirements for one set-up. It is left for the instructor to decide on the number of set-ups per class. If desirable, the activity may be presented as a demonstration either by the instructor or by a student.

MATERIALS: (per set-up)

- 2 mice, approximately the same size
- mouse food
- 2 to 4 g soda lime, 4-8 mesh (MCB SX217)
- 2 Erlenmeyer flasks, 250-ml
- 2 stoppers, rubber, two-hole, #6
- beaker, 250-ml
- pipet, 10-ml
- glass tubing, 8 mm O.D., 30-cm length (an additional 10-ml pipet may be substituted)
- glass tubing, 6 mm O.D., 4 short lengths
- rubber tubing, 3/16" I.D., 2 60-cm lengths, 1 30-cm length, and 2 short lengths.
- water-bath container
- 2 ring stands
- 2 ring-stand clamps
- 2 screw clamps
- thermometer
- ice
- cheesecloth
- scissors
- string
- masking tape

ANTICIPATED RESULTS:

The rise in the level of the manometer fluid on the experimental side should be on the order of 1 to 2 ml at 20 °C, and 2 to 5 ml at 10 °C, after a 6-minute interval (i.e., about double the change at 10 °C as at 20 °C).

ANSWERS TO DISCUSSION QUESTIONS:

1. The manometer fluid level changes more when the mice are subjected to the lower temperature.

2. Since the pressure was reduced more on the experimental side at the lower temperature, one can infer that more carbon dioxide was absorbed at the lower temperature. Thus, at the lower temperature, more carbon dioxide must have been eliminated by the experimental mouse, which strongly suggests that the rate of respiration and oxygen consumption was increased.

3. The response supplies the additional oxygen needed for chemical reactions that compensate for the increased heat loss to the environment, i.e., that enable the mouse to maintain a constant internal temperature.

4. The difference in pressure on the two sides may be determined by measuring the height difference in the two columns and multiplying by the density of the manometer fluid. If this difference is measured in cm, the value obtained is the pressure difference in g/sq cm, since the density of water is 1 g/cu cm.

LESSON 18: (A) LUNG VOLUMES AND CAPACITIES

(B) MEASURING FORCED EXPIRATORY VOLUME

RATIONALE:

ST-18 is primarily devoted to the various measurements that may be made of the capacity of the lungs. One such measurement (FEV) is the subject of LA-18. This measure will be re-examined, in an even more significant context, in LA-38. In addition, the text discusses the breaking-point reflex, which will be returned to in ST-31 and LA-32.

OBJECTIVES:

The student will define the terms forced expiratory volume, residual volume, tidal volume, total lung capacity and vital capacity.

The student will describe the breaking-point reflex and list two factors which affect it.

The student will measure his or her forced expiratory volume and examine its relationship to several other body measurements.

SEQUENCE: ST-18; LA-18

SUGGESTIONS:

1. Have the students compare their maximum breath-holding time with the lungs fully inflated and fully deflated. Ask them to explain the differences they find.

2. Have the students hyperventilate for a time (e.g., ten rapid and deep breaths), and then determine the maximum breath-holding time. Ask for an explanation of the increase in breath-holding.

INFORMATION ON LABORATORY ACTIVITY 18:

TEACHING NOTES:

1. This activity enables the student to determine his vital capacity (forced expiratory volume). In addition, measurements are made on various parts of the body to see whether these measurements appear to be related to FEV.

2. Meter sticks should be placed in convenient places about the room for the height measurements. The sticks can be attached to the wall, one meter above the floor, using masking tape. A book placed perpendicular to the wall on the student's head will provide a reasonably accurate measurement.

3. The bathroom scale may need re-adjusting from time to time so that it reads "0" when no one is standing on it.

4. Three pieces of information on each student are needed by the mathematics instructor for Mathematics Lesson 22. These are sex, height and FEV (the largest of the three measurements). It is desirable to compile these data on one ditto master so that a classroom set can be made for use in the mathematics class. A useful way to organize the information is as follows.

MALES		FEMALES	
Height	FEV	Height	FEV

5. There are many ways in which the various measurements may be compared. One possibility is to have the students place all data on the board. Different groups of students could then compare FEV with different ones of the other measures, either for the total class or by each sex separately. The data may also be graphed, if time permits. Any graphs that are produced should be passed along to the mathematics instructor, following their discussion in the science class. It would be useful for all graphs to have FEV plotted on the vertical axis so that they might be readily compared [illegible] additional graphs to be introduced in Mathematics Lesson 22.

6. Although not specifically mentioned in the procedure, students may find interest in comparing FEV to the Fitness Index values calculated in LA-14 from the step test.

7. Approximately 1 gram of sodium nitrite ($NaNO_2$) should be added per liter of water in the spirometer apparatus to inhibit rust formation.

8. The measurement of chest circumference should be made with the chest completely expanded. In the case of the females in the class, chest circumference should not be confused with bust measurement.

MATERIALS:

This list presumes 10 groups of students. Two meter sticks may be taped to the wall for height measurements. The other eight meter sticks that are specified may be used by the eight groups that are not using a spirometer.

2 spirometers (more if possible)

plastic wrap or other suitable mouthpiece covering

10 meter sticks

8 tape measures (or lengths of string)

bathroom scale

PREPARATION OF MATERIALS:

As indicated in the student procedure, the spirometer consists of two cylindrical containers, one of these fitting completely inside of the other. The inner container must have a capacity of at least 2 gallons (approximately 8 liters). Three sources of such containers are as follows.

1. The inner container may be made with 4 two-pound coffee cans. The ends of three of the cans are removed, and the cans are stacked on top of each other forming a cylinder. The ends of the cans may be joined with solder to prevent the leakage of water. The outer container may be assembled in the same manner using 4 three-pound coffee cans.

2. It is possible to purchase large containers of the proper volume. The Freund Can Company markets the following cans.

Stock Number	Fluid Content	Size (inches)
5450	2 gallon	$7\frac{1}{2} \times 11\frac{3}{4}$
5475	$3\frac{3}{4}$ gallon	$9\frac{7}{8} \times 12\frac{5}{8}$

The address is 193 West 84th Street, Chicago, Illinois, 60620. Telephone: (312) 224-4230.

3. Heating duct material may be purchased in five-foot lengths in a variety of diameters. A piece 5" in diameter by 5' in length may be cut into two lengths to make two inner containers 30" long. This approach will still necessitate

soldering a base on one end and soldering the seam to insure that the container is watertight.

The tubing may be made from 3/4" plastic pipe, available in most hardware stores. "PVC" pipe is recommended, since it provides a strong bond with silicone rubber cement. Plastic elbows may be purchased to provide the bends in the tubing. A hole is drilled and reamed to the proper size near the bottom of the outside container. The pipe is inserted through the hole the edges of which are sealed with silicone rubber cement. Allow 24 hours for the cement to cure. The tubing is then assembled as shown in the student procedure. The joints of the elbow inside the large container should be sealed with silicone rubber cement to prevent water from leaking into the pipe.

A bent paper clip attached with silicone rubber cement to the top of the inner container serves as a hook for the string. Two pulleys may be suspended from a short dowel that is clamped to a ring stand. The weight hung from the string should not be heavy enough to lift the inner container by itself; it should be approximately the same weight as the inner container.

A meter stick taped to the side of the outer container serves as a scale. A piece of paper taped around the meter stick can be marked to correspond to the volume of air in the inner container. For example, in the coffee-can spirometer described above, 8 centimeters of vertical displacement correspond to almost exactly one liter of air.

It should be kept in mind when selecting materials that a tall and narrow spirometer will provide more precise measurements than a short and wide model.

ANSWERS TO DISCUSSION QUESTIONS:

1. FEV should be fairly well related to height and chest circumference. Age and the amount of physical activity should not show a significant correlation.

2. Depends upon student data.

3. In general, larger people should have larger lungs. Thus, it may be possible to demonstrate correlations associated with arm length and sex. Since obese persons do not have larger lungs than other people of the same height, correlations between weight and FEV may be more difficult to demonstrate.

4. To make a new scale, one would need to know the radius or diameter of the inner container.

BACKGROUND INFORMATION ON PULMONARY FUNCTION TESTING:

(This information is placed here because FEV is first measured in LA-18. The medical significance of the measurement is not taken up in the student materials until Lesson 38.)

Pulmonary function testing (PFT) similar to that done by the students in Laboratory Activities 18 and 38 is of great value in the diagnosis of early lung disease as well as in the evaluation of treatment. It should be stressed that PFT is a much more sensitive indicator of early disease than either the X-ray or physical exam. PFT is always part of muliphasic health testing.

Testing of this type is usually done in hospitals and clinics. In addition, physicians who specialize in medicine will often perform PFT in their own offices. The person who usually does the testing is a pulmonary function technician. A necessary requirement for this position is the ability to communicate well with people (so that the patient cooperates properly). Mathematical skills are needed because the final report is the result of considerable calculation.

The two commonest tests are the ones done in Laboratory Activities 18 and 38, FEV_1 and FEV_T. FEV_T is reported as total volume (4,560 ml for example) and as a per cent of predicted normal. (If, for example, the predicted was 5,150 based on age, height and sex, the per cent of predicted would be reported as $\frac{4560}{5150}$ x 100%, or 89%.) A reduction of FEV_T below about 80% of predicted usually indicates some lung impairment of a restrictive type. The commonest cause is obesity, where the restriction is due to the extra weight over the chest wall cause by fat. Almost any kind of chronic lung disease will also cause restriction if scarring has occured or if lung tissue has been destroyed.

The other common lung test is the FEV_1. This result is usually expressed as a per cent of FEV_T. FEV_1 gradually drops off with increasing age, typically being about 90% in young people and about 75% in the elderly. A reduction of FEV_1 below these values indicates some obstruction or narrowing in the pulmonary airway system. Common causes include asthma, emphysema and chronic bronchitis.

PFT is very commonly used in industry to detect possible early lung impairment due to exposure to mine dust (silicosis), asbestos fibers (asbestosis) and cotton linters (byssinosis). However, in spite of the frequency of air pollution and hazardous industrial exposure, the commonest cause of impaired lung function is cigarette smoking.

LESSON 19: (A) PRESSURES WITHIN THE LUNG AND PLEURAL SPACE

(B) PNEUMOTHORAX

(C) REVIEW

RATIONALE:

ST-19 completes the consideration of the mechanics of breathing with a discussion of the pressures in the lungs and pleural spaces throughout the breathing cycle. This information is used to explain how an injury can cause collapse of the lung. The text also includes a review of Lessons 13 through 19.

OBJECTIVES:

The student will explain why maintaining a negative pressure within the pleural space is essential to respiratory function.

The student will define pneumothorax and explain how this condition causes the collapse of the lung.

The student will list three types of pneumothorax and list the distinguishing characteristics of each.

The student will list two ways in which the body compensates for the impairment caused by a closed pneumothorax.

The student will explain why a tension pneumothorax is lethal if not treated immediately.

The student will describe the decompression procedure used to treat pneumothorax and state its purpose.

The student will define mediastinum.

SEQUENCE: ST-19; Review

SUGGESTIONS:

1. Have the students describe the causes and effects of the three types of pneumothorax using the bell-jar model of the respiratory system.

2. Go over Review Set 19 in class.

INFORMATION ON COLLAPSE OF THE LUNG:

Collapse of the lung occurs under conditions that may be broadly divided into three categories.

1. OBSTRUCTION OF A BRONCHUS OR BRONCHIOLE. In this case, the gas in the alveoli located beyond the obstruction is absorbed causing a reduction in pressure within the affected region. Under the condition of reduced pressure, the elastic

recoil of the lung causes the collapse of the affected region. If the affected region is large, and a large part of the lung is collapsed, the reduction in lung volume causes, in turn, a reduction of the pressure within the pleural space. The intrapleural pressure on the affected side therefore becomes lower than on the unaffected side, pulling the mediastinum (the dividing wall between the two pleural spaces) toward the affected side. Because of an increase in vascular resistance in the collapsed lung, blood is diverted to the other lung. If the other lung is normal, the condition may persist indefinitely without severe effects upon the oxygenation of the blood.

2. ABSENCE OR INACTIVATION OF SURFACTANT. Under normal conditions, the alveoli are coated with a thin film of fluid that acts to reduce surface tension. Without this surfactant, the forces exerted by surface tension would prohibit the expansion of the alveoli. The absence or inactivation of this fluid appears to be a major cause of the failure of the lungs to expand normally at birth.

2. INCREASE IN INTRAPLEURAL PRESSURE. Collapse of the lung may result from the entry into the pleural space of air (pneumothorax), tissue fluids (hydrothorax), or blood (hemothorax). A pneumothorax may stem from either a rupture in the lung or a hole in the chest wall.

a. Closed Pneumothorax. If a hole is opened into the pleural space which quickly seals (or is sealled) off, respiratory distress is not severe. Intrapleural pressure rises to atmospheric, and the lung collapses on the affected side. There is some movement of the mediastinum toward the normal side in response to the difference in the two intrapleural pressures. As in the case of bronchial obstruction, blood is diverted to the functioning lung. The condition is self-correcting in that within one to two weeks all of the air in the pleural space will be absorbed, and the collapsed lung will re-inflate.

b. Open Pneumothorax. If the hole to the exterior remains open, the resistance to air flow into the pleural space is less than the resistance to air flow into the intact lung. Although air leaves the intact lung during expiration, very little air re-enters the lung during inspiration. The result is that more air moves in and out of the pleural space with each breath. Progressive deflation of the intact lung reduces the intrapleural pressure on that side and causes a severe shift of the mediastinum toward the intact side. The condition is fatal if the hole is not closed.

c. Tension Pneumothorax. In some cases a flap of tissue over the hole may act as a flutter valve. During inspiration the flap opens and air enters the

pleural space, but during expiration the flap closes preventing the exit of air. In this situation, the pressure within the pleural space rises further above atmospheric with each succeeding breath. The effects are essentially the same as those of an open pneumothorax, except that the pressure differential between the two pleural spaces is greater and the shift in the position of the mediastinum is even more extreme. For this condition, closure of the hole is not sufficient to return the intact lung to adequate function. It is also necessary to decompress the affected pleural space by removing the air.

Explanatory Note. In the preceding material the absorption of trapped air ...ntioned both in connection with a closed pneumothorax and with an obstructed ...hus or bronchiole. In both cases the reasons for such absorption are essen-...lly the same.

The partial pressures of the components of the trapped air will be approximately the following.

O_2	149 mm Hg
N_2	564 mm Hg
H_2O	47 mm Hg
	760 mm Hg

The comparable values for the interstitial fluid are as follows.

O_2	40 mm Hg
CO_2	40 mm Hg
N_2	572 mm Hg
H_2O	47 mm Hg
	699 mm Hg

Initially there is rapid absorption of O_2 into the interstitial fluid and diffusion of CO_2 and small quantities of N_2 into the air cavity until a state similar to the following is reached.

O_2	90 mm Hg
CO_2	35 mm Hg
N_2	588 mm Hg
H_2O	47 mm Hg
	760 mm Hg

Note that the total pressure of the trapped air remains at or near atmospheric at all times. The reason for this is that the surrounding tissues are sufficiently elastic to reduce the volume of the cavity at a rate commensurate

with the rate of gas absorption. This also accounts for the rise in the P_{N_2} above that of the interstitial fluid.

A final equilibrium state is reached at values similar to the following.

O_2	43 mm Hg
CO_2	40 mm Hg
N_2	630 mm Hg
H_2O	47 mm Hg
	760 mm Hg

From this point on, oxygen and nitrogen are continually absorbed. The resulting reduction in volume causes the CO_2 and H_2O pressures to rise temporarily slightly above the values shown. Thus they too are absorbed. The process continues until all gas is absorbed and the cavity is totally collapsed.

KEY--REVIEW SET 19:

1. Increased force and/or decreased area will increase the pressure. Decreased force and/or increased area will decrease the pressure.

2. 12.36 g/sq cm

3. sphygmomanometer; mm Hg

4. The pain was caused by excessive pressure in the pulmonary blood vessels as a result of increased pulmonary circulation. Running another lap might have led to the development of pulmonary edema.

5. bronchi, bronchioles, alveoli, capillary walls

6. Aerobic capacity is the maximum rate at which a person can use oxygen. The greater the aerobic capacity, the greater the ability to endure strenuous exercise.

7. (see pp. 72-3 of text)

8. (see p. 74 of text)

9. Increasing the temperature increases the volume of a gas. Decreasing the temperature decreases the volume.

10. (see p. 79 of text)

11. (see (p. 82 of text)

12. (see p. 86 of text)

13. The respiratory center is a region of the brain that controls the rate and depth of breathing.

14. (see p. 86 of text)

15. (see pp. 87-8 of text)

16. (see pp. 88-9 of text)

17. (see pp. 93-5 of text)

LESSON 20: (A) ELECTROSTATICS AND CHARGE

(B) CURRENT AND VOLTAGE

(C) ARTIFICIAL RESPIRATION

RATIONALE:

This lesson begins a sequence on introductory chemistry. An understanding of basic chemical principles is essential not only to the study of bodily processes, but also to the performance of most of the clinical tests upon which modern health care relies. The primary focus of ST-20 and LA-20 is on electric charge. The concepts presented here are needed for the treatment of ionic solutions in following lessons. In addition, ST-20 discusses artificial respiration, a topic which is not only important in its own right but serves to reinforce the concepts of pressure and respiratory anatomy presented earlier.

OBJECTIVES:

The student will state, in terms of positive and negative charge, the conditions under which charged objects attract and repel one another.

The student will give examples of how positive and negative charges may be separated.

The student will define the words electron and current, and state what is actually moving when electricity flows through a wire.

The student will define the word voltage and explain its role in causing electricity to flow.

The student will explain the difference between a respiratory and a resuscitator.

SEQUENCE: ST-20-1; LA-20; ST-20-2,3,4

SUGGESTIONS:

1. Note that LA-20 assumes that the students have not read ST-20-2. Reading ST-20-1 prior to performing LA-20, however, may provide some motivation for investigating electrical properties.

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2. There are many activities which involve static electricity. Students may perform the experiment illustrated in the text, using ping-pong balls instead of pith balls. Or they may make the electroscope described in the teaching notes for LA-20. Testing the ability of various materials as insulators against static electric forces is another possibility; e.g., place a sheet of aluminum foil between two charged objects and see whether the objects still affect one another. The ability of materials to conduct charge may also be tested; e.g., roll the aluminum foil into a long cylinder, place it between (but not touching) two objects, charge them both up and touch one to one end of the cylinder and see whether the other object is affected.

3. Students may seek out information on lightning, such as voltage values, number of persons struck, and damage costs annually, and lightning rods.

4. Discuss the tank respirator in terms of how it operates through negative pressure. This provides a review of pressure. Its use with polio victims was once widespread. Students may wish to research polio, including the question of how it affects breathing.

5. Students may wish to research how long a person can live without breathing, and why this is so.

INFORMATION ON LABORATORY ACTIVITY 20:

TEACHING NOTES:

1. The purpose of this activity is to observe the effects of electric charge on objects under a number of different circumstances.

2. Anticipated time: two periods.

3. The activity is divided into three parts. Parts I and II are laboratory activities, while Part III is interpretation of results.

4. The activity could be organized so that the class is divided into six groups to correspond to the six stations in Part II. If the equipment for Part I is also avai' 'le at each station, the students could perform Part I and their respective station for Part II. Then rotation from station to station would enable all the students to complete all parts of the lab. Some of the stations might be duplicated to avoid bottlenecks.

5. The activities will not work or will not work well on humid days. If this problem arises, it is left to your discretion whether to postpone the activity, attempt to complete it, or explain what is "supposed" to happen.

6. Equipment is very important in getting like and unlike charges.

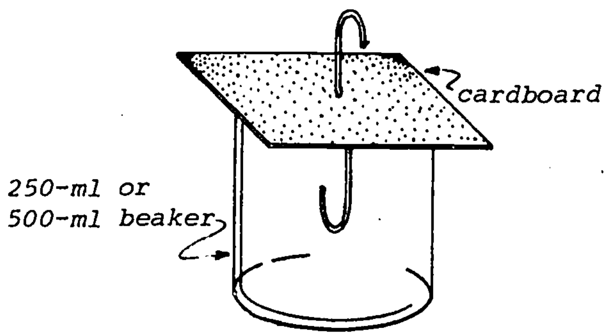
a. In Parts I and II, plastic ball point pens, plastic straws, plastic spoons, etc., can be substituted for the rulers. It is important that the objects be identical to obtain expected results.

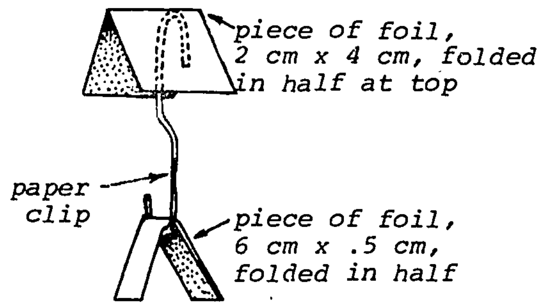
b. Glass rods or tubes can be substituted for the glass pipet.

c. The cloths should be of wool or flannel. Many stores sell squares of flannel which can be cut smaller and used.

7. Equipment substitutions for Part II:

a. A simple electroscope can be made using a beaker, a piece of cardboard, a paperclip and aluminum foil





b. If carpeting is not available, a piece of blanket or other "fuzzy, wooly" fabric will suffice. Some department and carpet stores sell sample pieces of carpeting or give away leftover strips.

c. If a water faucet is not readily available, an alternate set-up can be used. Punch a hole about 3 to 4 mm in diameter in the bottom of a plastic half-gallon or gallon jug. Fill the jug one-fourth to half full of water and place it on a ring which is on a ring stand. Place a container below to catch the water.

d. Paper confetti can be made by cutting paper into pieces about 0.5 cm square or by using the circles from a paper punch.

e. Plastic wrap can be used instead of the acetate sheet, but the results are not as dramatic.

f. The "pie pan" for the "dancing syringes" can be any container about 3 cm deep. Greeting card boxes with acetate lids are ideal. If the syringes do not dance, the container may be too deep. Plastic wrap is recommended for use since the wrap can be allowed to sag into the container and get close enough to the tissue paper pieces to create the effect.

MATERIALS: (for class set-up of six stations)

- 12 plastic rulers
- 12 pieces of wool or flannel cloth
- 6 rods 20 to 30 cm in length (any material)
- 6 glass pipets, 10-ml
- 6 ring stands
- 6 ring-stand clamps
- tape, cellophane or masking
- 6 pieces of string, 15 to 20 cm long
- electroscope
- piece of carpeting
- water faucet and sink or equivalent (see teaching notes)
- sheet of paper
- acetate sheet, about 15 x 20 cm
- 5 to 6 pieces of paper confetti
- scissors
- sheet of tissue paper, about 15 x 15 cm
- pie pan or other shallow container
- piece of plastic wrap, large enough to wrap pie pan

ANSWERS TO QUESTIONS IN PROCEDURE:

1. Excess charge goes to your body.
2. neg.
3. pos.
4. repel
5. attract
6. neg.
7. pos.
8. pos.
9. neg.
10. pos.
11. neg.
12. electrons
13. repelled
14. pos.
15. pos.
16. attracted
17. neg.

ANSWERS TO DISCUSSION QUESTIONS:

1. The leaves of the electroscope were charged with the same charge by induction. Since the leaves had the same charge, they repelled one another.

2. When the charged object is removed, the leaves no longer have an induced charge and fall together.

3. (See explanations below.)

EXPLANATION OF STATIONS:

1. The Electroscope: A charged object brought near the top of the electroscope induces the same charge in the leaves. Since the leaves have the same charge, they repel and move away from each other. When the charged object is removed, the induced charged leaves and the leaves of the electroscope move to their resting position.

2. How Are You Charged: When you rub your feet on carpeting, your body picks up electrons from the carpet and becomes negative.

3. Flowing Water: A charged object brought near a stream of water induces a like charge in the water near the object. The stream of water bends towards the charged object. Both a negatively and positively charged object cause this phenomenon.

4. Paper the Wall: When a piece of paper is rubbed it becomes negative. The negative charges repel the negative charges in the wall and induce a positive charge in the wall. These opposite charges attract, causing the paper to stick to the wall.

5. Popping Paper Confetti: When the acetate sheet is rubbed with the cloth, the acetate becomes negative and induces a positive charge on the table. The confetti, which starts out neutral, becomes negative by picking up excess negative charges from the acetate. The confetti is attracted to the positive table top. When the acetate sheet is picked up, the negatively charged acetate and negatively charged confetti repel and the chips pop away.

6. Dancing Syringes: When the acetate sheet is rubbed with the cloth, the acetate becomes negative and induces a positive charge on the tissue paper if brought close enough. Continued rubbing with the cloth moves the charge around. The tissue paper responds by moving from forces of attraction and repulsion.

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LESSON 21: (A) ATOMS, IONS AND ELEMENTS

(B) ELECTRON ORBITALS

RATIONALE:

The preceding lesson presented students with the effects of the accumulation and flow of electrons. ST-21 describes the structure of the atom, which is necessary to gain an understanding of how atoms and molecules interact in chemical reactions. Atoms will be referred to again and again in the curriculum to explain biochemical and physiological concepts. Since ionic interaction is especially important in the body and is also the basis of several laboratory activities in this sequence on chemistry, the electron orbital structures of atoms are also presented in this section. This forms the basis of understanding ions, as well as bonding, which is presented in the next lesson.

OBJECTIVES:

The student will explain why a knowledge of chemistry is important in understanding the body.

The student will give examples of how the use of chemistry has improved our health.

The student will describe the structure of an at in terms of protons, neutrons and electrons, and state the charge on each particle.

The student will state the conditions under which an atom's charge is neutral, positive and negative.

The student will de ne the word ion and state three techniques by which atoms may be made to become ions.

The student will define the words element and atomic number and name at least five elements that occur in the body.

The student will state how the order of elements in the periodic table is determined.

The student will define the term atomic weight.

The student will explain how an atom's electrons are grouped into shells, and group the electrons of several atoms into their shells.

SEQUENCE: LA-21; ST-21

SUGGESTIONS:

1. No written procedure for LA-21 has been provided. It is hoped that you will utilize the time in one of a number of ways relating to resuscitation and breathing. In advance of the period, a member of the Fire Department or Red Cross may be scheduled to talk about artificial respiration and related first aid. Or, an inhalation therapist from a local hospital might discuss this profession

and the way the human breathing apparatus may be manipulated by respirators in different diseases. A physician's assistant or nurse familiar with first aid or anesthesia delivery is another possibility.

There is also available a training mannikin called "Resus Annie," on which mouth-to-mouth resuscitation may be practiced. It is available from the Red Cross, but must be scheduled well in advance.

2. Students may research and present a talk on the technique of mouth-to-mouth resuscitation, without actually performing it. There will be a full presentation of this technique in the second year of the curriculum.

3. With respect to atoms, you may wish to present the fact that matter is mostly space between atoms. This was shown in the classic experiment by Rutherford, mentioned in the Student Text. Students may wish to research this experiment in more detail. It led to the idea of a nucleus surrounded by electrons, and measured the charge on the nucleus. The following books are helpful.

> Chemistry, An Experimental Science. prepared Chemical Education Materials Study, 1963 (or later editions), pp. 244-5.
>
> Baker, Bradbury, Eichinger, and Sigler. Chemistry and You. Lyons and Carnahan, 1966, pp. 30-2.

4. Students might research the names and uses of elements not mentioned in this section, or the elements in the air, in the sea, etc.

5. The names of synthetic elements, and their half lives, may be researched.

6. Students may draw pictures of the atoms in Problem Set 21 showing protons, neutrons and electrons in their proper orbitals.

7. The diameter of the electron shell of hydrogen is 100,000 times that of the nucleus. Make this clear by pretending a marble or a tennis ball is the nucleus, and calculate the diameter of the electron shell.

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KEY--PROBLEM SET 21:

	Atomic No.	Element	Symbol
A	6	carbon	C
B	6	carbon	C
C	7	nitrogen	N
D	8	oxygen	O
E	8	oxygen	O
F	10	neon	Ne
G	11	sodium	Na

1. The table is shown completed above.

2. The two carbons are isotopes.

3. Sodium is an ion. It has a positive charge.

4. Oxygen (E) is an ion. It has a negative charge.

5. The oxygen ion (E), neon and the sodium ion all have full outer shells, since each atom has ten electrons.

LESSON 22: (A) IONIC BONDS AND IONIC COMPOUNDS

(B) ELECTRON-DOT FORMULAS

(C) THE PERIODIC TABLE

RATIONALE:

In introducing atoms, the preceding lesson stressed how electrons are arranged in a series of shells. A further development of this idea, alluded to at the end of the preceding lesson, is now presented: atoms tend to gain or lose electrons so as to have a complete outer electron shell. This results in ion formation, which is important in the chemistry of the body fluids, nerve conduction, and other physiological properties. The ability to visualize ions by drawing their outer electron shells helps in understanding chemical and electrochemical events; electron-dot formulas are therefore presented. Finally, the concept of ionic solutions, the basis of several activities in this sequence on chemistry, is introduced. LA-22 provides tangible evidence of the existence of ions and their electrical properties.

OBJECTIVES:

The student will explain in what way the outer electron shells of the noble gas elements are similar, and relate this to their chemical stability.

The student will use electron-dot formulas to represent atoms.

The student will use electron-dot formulas to show how sodium, chlorine, and magnesium attain more stable electron configurations by becoming ions.

The student will describe the ionic bond that holds the sodium and chlorine atoms in sodium chloride together.

The student will define the word compound.

The student will explain the significance of different elements having the same electron-dot formulas, and relate this to the periodic table.

The student will explain what happens to the ions in an ionic compound when it is dissolved in water.

The student will explain the process of electroplating.

SEQUENCE: ST-22; LA-22

SUGGESTIONS:

1. Students might compile a list of compounds containing sodium, potassium, chloride, calcium, magnesium, bromide, iodide, lead, and other ions. Sources include food labels, household medicines, cleaners, chemicals, etc.

2. Students might investigate the qualities atoms have in their non-ionized state, e.g., sodium metal and CL_2 have very different properties than Na^+ and Cl^-.

3. Ambitious students might draw electron-dot formulas, or construct models on a table top, of large atoms. The shells have the following maximum numbers of electrons: first--2, second--8, third--8, fourth--18, fifth--18, sixth--32. This allows for atoms as large as no. 89, radon.

KEY--PROBLEM SET 22:

1. $\cdot\dot{\underset{\cdot}{C}}\cdot$ $\quad :\ddot{S}: \quad \ddot{Mg} \quad :\ddot{\underset{\cdot\cdot}{O}} \quad :\ddot{\underset{\cdot\cdot}{Cl}}\cdot \quad \ddot{Ca}$

$\cdot\ddot{P}: \quad :\ddot{\underset{\cdot\cdot}{Ar}}: \quad \dot{K}$

a. Ar; b. Cl; c. K; d. Mg and Ca; e. Mg and Ca, O and S.

2. $[K]^+ \quad [:\ddot{\underset{\cdot\cdot}{Br}}:]^- \quad [Ca]^{+2} \quad [:\ddot{\underset{\cdot\cdot}{O}}:]^{-2}$

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3. $CaCl_2$, CaF_2, $MgBr_2$ are correct.

$[:\ddot{\underset{\cdot\cdot}{Cl}}:]^- [Ca]^{+2} [:\ddot{\underset{\cdot\cdot}{Cl}}:]^-$ $[:\ddot{\underset{\cdot\cdot}{F}}:]^- [Ca]^{+2} [:\ddot{\underset{\cdot\cdot}{F}}:]^-$ $[:\ddot{\underset{\cdot\cdot}{Br}}:]^- [Mg]^{+2} [:\ddot{\underset{\cdot\cdot}{Br}}:]^-$

4. a. CaO; b. Li_2O; c. $AlCl_3$

5. $[Na]^+ [:\ddot{\underset{\cdot\cdot}{I}}:]^-$

6. $[K]^+ [:\ddot{\underset{\cdot\cdot}{Br}}:]^-$

7. $[Mg]^{+2} [:\ddot{\underset{\cdot\cdot}{O}}:]^{-2}$

8. Probably not, since helium has a stable electron configuration.

INFORMATION ON LABORATORY ACTIVITY 22:

TEACHING NOTES:

1. In this activity electroplating is used to demonstrate the movement of ions in solution in the presence of a source of electric current. Electroplating was chosen because it applies some of the principles the students have been studying and produces visible results. Hopefully, this will make the concept of ions somewhat less abstract.

2. The containers that are used to hold the $CuSO_4$ solution should measure about 10 cm deep, 18 cm long and 13 cm wide. These are approximate dimensions. The length is more important than the other dimensions because a distance of 10 ± 1 cm between the anode and the cathode is desirable to obtain good plating.

It is also important that the containers be made of plastic, not metal. The variety sold in supermarkets for storage of foods will do quite well. Students may be able to bring such containers from home.

3. After the students have completed the procedure, they may want to experiment by replacing the carbon rod at the cathode with other objects. They should be warned not to try the procedure on anything that is of value to them, since the results are not always predictable. A general idea as to which metals will plate on others can be obtained by referring to a table of half-cell reactions. For example, copper will plate on tin, lead, iron, nickel, etc. Some suggestions for objects to experiment with are nails and paperclips. Students may need to be told that plating coins falls under the heading of defacing American currency.

4. The grade of $CuSO_4$ used can be the least expensive available; reagent grade is not necessary.

MATERIALS: (for 10 set-ups)

- 55.5 ml conc. H_2SO_4
- 200 g $CuSO_4$
- 10 graduated cylinders, 100-ml
- 10 beakers, 250-ml
- 10 BIP's and programming wire
- 20 wires with alligator clip on one end
- 10 10KΩ resistors
- 20 carbon rods
- 10 glass stirring rods
- 10 glass-marking pencils
- 10 metric rulers
- 10 balances
- 10 plastic containers
- 10 spatulas or scoopulas
- steel wool
- tape
- soap

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PREPARATION OF REAGENTS:

1 M H_2SO_4: To 1,000 ml tap water add 66.7 ± 0.5 ml concentrated H_2SO_4. Dilute to 1,200 ± 10 ml.

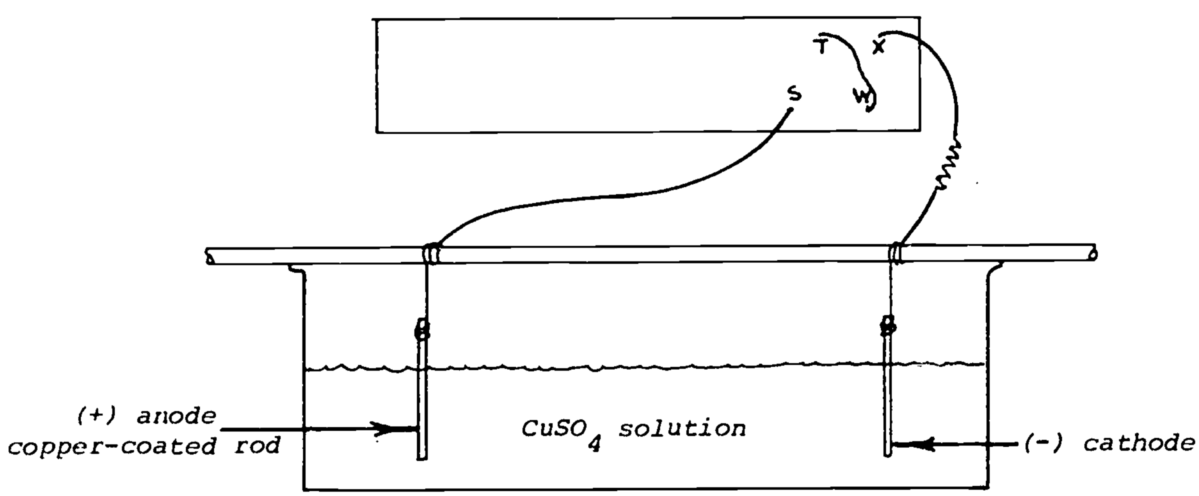
ANSWERS TO DISCUSSION QUESTIONS:

1. The carriers of electric charge in a liquid are ions. In this activity the carriers were copper (Cu^{+2}) and sulfate (SO_4^{-2}) ions.

2. The copper sulfate dissociates into Cu^{+2} and SO_4^{-2} in solution. The rod at the cathode becomes coated with copper because the cathode accumulates negative charge and this attracts the positively charged copper ions.

3. The copper atoms in solution have two fewer electrons than protons, which accounts for their charge of +2. The copper atoms deposited at the cathode have equal numbers of protons and electrons and are electrically neutral. In other words, the ion combines with two of the excess electrons to form the neutral atom.

4. The copper coating may be removed from the carbon rod by making the coated rod the anode. The accumulation of positive charges at the anode is the result of the flow of electrons from the anode toward the BIP. As copper atoms lose electrons, they become positive ions which go back into solution. They tend to migrate away from the anode because of the mutual repulsion of like charges. The set-up for performing this removal procedure is shown below.



LESSON 23: (A) COVALENT BONDING

(B) STRUCTURAL FORMULAS AND MOLECULAR FORMULAS

RATIONALE:

The preceding lesson presented ionic bonds and ionic compounds. Many compounds, however, are held together by covalent bonds. These include water, and most of the bonds in gases, proteins, fats, and many other substances. Covalent bonds are visualized with electron-dot formulas. It is also important to be able to use structural formulas and molecular formulas for compounds. These formulas are commonly used in laboratory activities and sections that deal with chemical reactions. They are also useful for preparing molar solutions, which students will be called upon to do in this unit.

OBJECTIVES:

The student will explain the difference between covalent and ionic bonds and give examples of molecules with covalent bonds.

The student will draw electron-dot formulas of several compounds with covalent bonds, including water, chlorine, hydrogen, and hydrogen chloride.

The student will express compounds using both structural formulas and molecular formulas.

The student will define the word molecule in terms of covalent bonds.

The student will construct three-dimensional models of compounds with covalent bonds.

SEQUENCE: ST-23; La-23

SUGGESTIONS:

1. Present, or have students research, the general shape of complex molecular structures such as glucose (a ring), albumin (a folded chain), DNA (a double helix), the vitamins niacin, A, B_1, B_2, C (all are or contain rings), or countless other compounds. The following books will be helpful, or any book on physiology.

Biological Sciences Curriculum Study. Biological Science: Molecules to Man. Blue Version, 1963.

Handbook of Chemistry and Physics. The Chemical Rubber Co., Cleveland, Ohio.

The Merck Index of Chemicals and Drugs. Merck & Co., Inc., Rathway, N.J.

Vander, et. al. Human Physiology: The Mechanisms of Body Function. McGraw-Hill Book Co., San Francisco, Calif.

2. Students may compile lists of all types of compounds from aerosol cans and food labels, and look up their formulas. Good dictionaries contain molecular formulas of the more common ones, and the above references may be `.elpful. There will be material on food additives in Unit II.

INFORMATION ON LABORATORY ACTIVITY 23:

TEACHING NOTES:

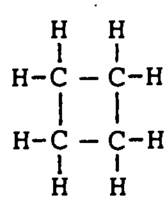
1. The purpose of the activity is to help the student to associate the molecular, structural and electron-dot representations of compounds and, at the same time, to see their three-dimensional structures as represented by ball-and-stick (or spring) models.

2. Anticipated time: one period.

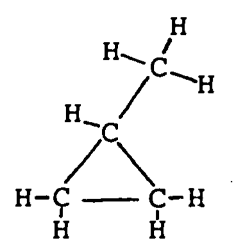
3. Note that no springs are necessary for this activity, since all of the bonds are single bonds.

4. Molecular model kits are more expensive than purchasing quantities of balls of specified color and number of holes.

5. If some students have time left over, you might challenge them by asking them to construct two different compounds with the formula C_4H_8.



(cyclobutane)



(methylcyclopropane)

MATERIALS: (for 15 set-ups)

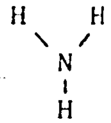
H--150	O--30	195 sticks or springs
C--60	N--15	
Cl--45	S--15	

ANTICIPATED RESULTS:

(Structural formulas only)

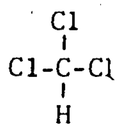
1. H-Cl

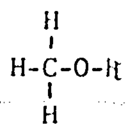
11i

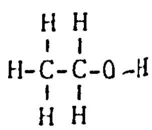
2. 

3. H-O-O-H

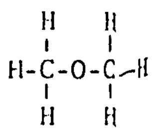
4. H-S-H

5. 

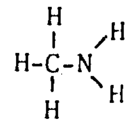
6. 

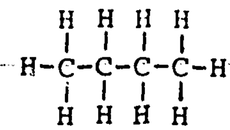
7. 

(ethyl alcohol)

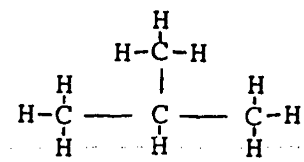


(methyl ether)

8. 

9. 

(butane)



(isobutane)

LESSON 24: (A) DOUBLE AND TRIPLE BONDS

(B) POLYATOMIC IONS

(C) DROWNING

RATIONALE:

In the preceding lesson the discussion of covalent bonding was limited to single bonds. In ST-24 the discussion is extended to include double and triple bonds, which are contained in many compounds of biological importance. The text also extends the discussion of ions to include polyatomic ions. The last portion of the text is devoted to drowning, a topic that will be discussed again when the students are familiar with diffusion and osmosis.

OBJECTIVES:

The student will explain the significance of the double bond and triple bond in the structural formulas for O_2 and N_2.

The student will draw electron-dot formulas for polyatomic ions.

The student will determine the charge on a polyatomic ion of unknown charge.

The student will relate the conductivity of a substance to its ability to form ions in solution.

The student will explain how a person can drown without water entering the lungs.

<u>SEQUENCE</u>: ST-24; LA-24

<u>SUGGESTIONS</u>:

1. The students may ask what the connection is between the chemistry they have been studying and drowning. There is no direct connection. The drowning information was placed here to provide a change of pace, as well as to reinforce some respiratory anatomy.

2. A class discussion might be held on why there are so many drownings in the 15 to 24 age category. The social science instructor may have some ideas on the subject. The drop in the death rate from ages 0-4 to 5-14 and the increase after age 74 are also worthy of consideration. (Where is an aged person most likely to drown?)

3. Polyatomic ions may be identified in household and auto chemicals and in food additives (e.g., nitrate in many salamis) by reading the labels. Students may compile lists and find their molecular formulas in the sources mentioned in Lesson 24. The commercial uses of these ions (e.g., nitrate for fertilizer) may also be researched.

4. Students may use models or drawings to explore the possibility of a quadruple covalent bond and predict possible compounds. Such bonds do not exist.

<u>KEY--PROBLEM SET 24</u>:

1. a. N_2O has two double bonds; HCN has one single bond and one triple bond; CH_2O has two single bonds and one double bond.

b. N=N=O   H-C≡N

```
  O
  ||
H-C-H
```

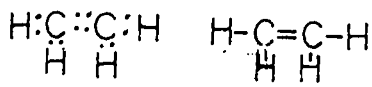
c. N_2O HCN CH_2O

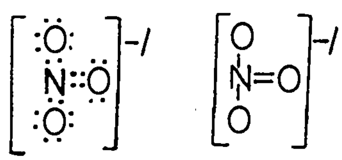
2. a. $\ddot{\underset{\cdot\cdot}{S}}::C::\ddot{\underset{\cdot\cdot}{S}}$ S=C=S

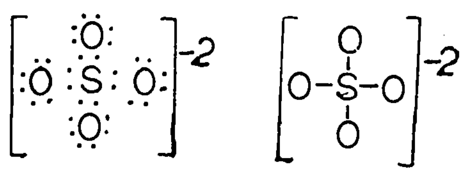
2. b. 

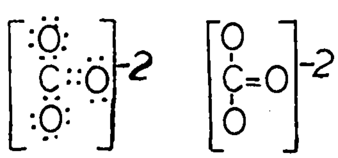
c. 

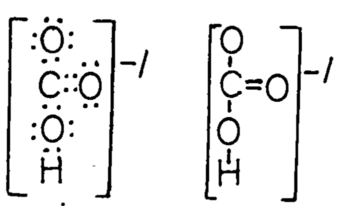
d. 

e. 

3. a. 

b. 

c. 

d. 

4. a. $NaHCO_3$

b. The formula must contain one Mg^{++} and two OH^- ions to balance charges. It is an ionic compound.

$$[H:\ddot{\underset{\cdot\cdot}{O}}:]^-[Mg]^{++}[:\ddot{\underset{\cdot\cdot}{O}}:H]^-$$

INFORMATION ON LABORATORY ACTIVITY 24:

<u>TEACHING NOTES</u>:

1. The purpose of this activity is to give the students an opportunity to compare the conductivity of different solvents, different solutes and different concentrations of the same solute.

2. Anticipated time: one period.

3. To minimize spillage, you might wish to rotate the students instead of the beakers. With 9 BIP's, there could be a single station set up for each of the 9 test liquids. This approach would also eliminate the chance of contaminating the solutions (some of which can be saved for use in LA-33).

4. Three solutions, .1 M $CuSO_4$, .01 M NaOH, and .1 M NaOH should be saved for use in LA-33. The "Preparation of Reagents" includes extra quantities which should be set aside for use later. (But see Information on LA-28.) The other solutions can also be saved, except the sugar solution which tends to mold quickly even if refrigerated.

5. It is important that the electrodes be dipped to the same depth each time or the results will vary. It is not critical that beakers be used as long as all the containers are the same so the electrodes will be dipped to nearly the same depth.

6. Since the students have not yet studied the concept of concentration, the concentrations of the solutions are given in grams of solute per liter of solution. The students should be able to compare the relative concentrations with this information. The molar concentrations are given in the "Preparation of Reagents" section.

7. Even in solutions that do not conduct enough current to light the light bulb such as .01 M NaOH, bubbles can be seen around the electrodes which should

indicate to the students that something is happening. These bubbles are not apparent in the sucrose, alcohol and tap water (rinse) solutions.

8. The students should be cautioned against leaving the electrodes in the solutions since some may adversely affect the electrodes.

9. A sample data table is not given. You could suggest a table which lists each of the solutions and has place for the students to record their observations.

MATERIALS: (for class set-up, 1 station for each of 9 solutions)

- 21.5 ml HCl, concentrated
- 2 g NaOH
- 24 g $CuSO_4$
- 1 g NaCl
- 20 g sucrose (table sugar)
- 250 ml denatured alcohol
- 18 beakers, 250-ml
- 9 BIP's and programming wires
- 9 screwdrivers
- 9 light bulbs, #40, 6.3 v, miniature lamp (attached to programming wire)
- 18 carbon electrodes (attached to programming wires)
- 9 stirring rods

PREPARATION OF REAGENTS:

250 ml .1 M HCl (4 grams/liter): To 21.5 ml concentrated HCl add enough tap water to make 250 ml. Store in capped bottle labeld "4 grams/liter (.1 M HCl)."

250 ml .01 M HCl (0.4 grams/liter): Add 25 ml of .1 M HCl (from above) to enough tap water to make 250 ml. Store in capped bottle labeled "0.4 grams/liter (.01 M HCl)."

500 ml .1 M NaOH (4 grams/liter): Dissolve 2 grams NaOH in enough water to make 500 ml solution. Store in capped bottle labeled "4 grams/liter (.1 M NaOH)." Use 250 ml for this activity and save remainder for LA-33.

250 ml .01 M NaOH (0.4 grams/liter): Dilute 25 ml of .1 M NaOH (from above) with tap water to make 250 ml of solution. Store in capped bottle labeled "0.4 grams/liter (.01 M NaOH)." Save for use in LA-33.

300 ml .5 M $CuSO_4$ (80 grams/liter): Dissolve 24 g $CuSO_4$ in enough tap water to make 300 ml solution. Store in capped bottle labeled "80 grams/liter (.5 M $CuSO_4$)."

250 ml .1 M $CuSO_4$ (16 grams/liter): Dilute 50 ml of .5 M $CuSO_4$ (from above) in enough tap water to make 250 ml solution. Store in capped bottle labeled "16 grams/liter (.1 M $CuSO_4$)." Save solution for use in LA-33.

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250 ml .07 M NaCl (4 grams/liter): Dissolve 1 g NaCl in enough tap water to make 250 ml solution. Store in a capped bottle labeled "4 grams/liter (.07 M NaCl)."

250 ml .23 M $C_{12}H_{22}O_{11}$ (sucrose) (80 grams/liter): Dissolve 20 grams sucrose (table sugar) in enough tap water to make 250 ml solution. Store in capped bottle in refrigerator labeled "80 grams/liter (.23 M $C_{12}H_{22}O_{11}$)."

PREPARATION OF MATERIALS:

Solder one end of a BIP programming wire to the tip of each light bulb.

ANTICIPATED RESULTS:

HCl (4 g/liter)	+++	bubbling at electrodes
HCl (.4 g/liter)	+	some bubbling
NaOH (4 g/liter)	++	some bubbling
NaOH (.4 g/liter)	0	slight bubbling
$CuSO_4$ (80 g/liter)	+++	bubbling
$CuSO_4$ (16 g/liter)	+	some bubbling
NaCl (4 g/liter)	++	bubbling
$C_{12}H_{22}O_{11}$ (80 g/liter)	0	--------
denatured alcohol	0	--------
tap water	0	--------

ANSWERS TO DISCUSSION QUESTIONS:

1. The stronger solutions of HCl and $CuSO_4$. On a "grams per liter" basis, HCl was the best conductor.

2. Sucrose, tap water and alcohol were the worst conductors. (Also the weak NaOH solution, if bubbling is not considered.)

3. It appears that the more solvent present in the solution, the greater the conductivity.

4. (see anticipated results)

5. One would expect all ionic compounds to be conductive to one extent or another. It appears that alcohol, water and sucrose may be covalently bonded, since they show no evidence of conductivity.

6. Sulfuric acid might be a good conductor because HCl is an acid and is a good conductor. Maple syrup and whiskey are probably not good conductors, since sucrose and alcohol are not.

LESSON 25: (A) CHEMICAL REACTIONS

(B) BALANCED EQUATIONS

RATIONALE:

Now that bonding and formulas for molecules have been presented in the preceding lessons, chemical reactions may be studied. Besides its evident value in physiology, a knowledge of chemical reactions is necessary for the activities on quantitative reactions and acid-base chemistry coming up in this unit, as well as in laboratory tests of biomedical significance in other units.

OBJECTIVES:

The student will define a chemical reaction and give two examples.

The student will state the two factors that must be considered in balancing a chemical equation, and show how to balance an equation.

The student will define a reversible reaction and give one example.

The student will give examples of the dissociation of ionic compounds in water and express them as chemical equations.

The student will determine the effect of various exercise programs on physical fitness as measured by the aerobic step test.

SEQUENCE: ST-25; LA-25 or the reverse

SUGGESTIONS:

1. The laboratory period for this lesson has been set aside for a repeat of the aerobic step test. (See LA-14 procedure.) If you have been unable to get the students to follow fitness programs, other alternatives exist. For example, have the class measure the fitness of the members of one of the school athletic teams who are currently in training. Measurements on members of the school staff would also be of interest.

2. Students may go back and identify chemical reactions in previous activities, and write the equations. These include LA-8 and LA-9 on oxygen and carbon dioxide; LA-22 on electroplating, where copper ions changed to copper metal ($Cu^{++} + 2e^{-} \rightarrow Cu$--students may deduce that this equation requires a source of electrons); and LA-24 on conductivity of solutions.

3. The reaction involved in burning a candle may be at least partially deduced. Test for water formation by holding a glass surface above the flame and looking for condensation. Test for CO_2 using some livewater in a bottle. Stand the candle in the bottle and cover the bottle. When the candle goes out, shake

the bottle and look for the cloudiness that signifies CO_2. Paraffin in candles is made up of different molecules. On is $C_{25}H_{52}$.

$$C_{25}H_{52} + 38\ O_2 \rightarrow 26\ H_2O + 25\ CO_2$$

4. Students may list all the reactions they can think of, without necessarily writing equations. These include ones resulting in acids (yogurt, vinegar), alcohol (beer, wine), gas-forming ones (baking soda, carbonated drinks), explosive ones (TNT, nitroglycerine, gunpowder, gasoline), heat-producing ones (oxidation of wood, paraffin, gasoline, butane, propane). Equations may be written for the oxidation of simpler ones to H_2O and CO_2, e.g., propane, C_3H_8 and butane, C_4H_{10}.

5. To show the importance of oxygen to a fire, wood chips may be heated in a test-tube with little oxygen by using a one-hole rubber stopper. This results in blackening and noxious odors.

The following books are useful for information on fire and oxygen.

Davis, Burnett, Gross, and Gardner. Science: Discovery and Progress. Holt, Rinehart, Inc., 1961, pp. 66-84.

Thurber and Kilburn. Exploring Physical Science. Allyn and Bacon, Inc., 1966, pp. 50-80.

6. Students may research the formulas for, and write equations for the oxidation of nutrients, assuming they are oxidized to H_2O and CO_2.

Glucose, fructose: $C_6H_{12}O_6$

Sucrose: $C_{12}H_{22}O_{11}$

Butterfat (one of the simplest fats): $C_{15}H_{29}O_6$

Ethyl alcohol: C_2H_6O

KEY--PROBLEM SET 25:

1. $6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$

2. $SiO_2 + 4\ HF \rightarrow SiF_4 + 2\ H_2O$
   Since HF reacts with glass, it can't be stored in glass bottles.

3. $3\ Cu^{+2} + 2\ Fe \rightarrow 3\ Cu + 2\ Fe^{+3}$

4. a. $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

b. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

c. $2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

d. $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

e. $C_2H_6O + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$

f. $3\ Ca^{+2} + 2\ PO_4^{-3} \rightarrow Ca_3(PO_4)_2$

5. a. $PdCl_2 + CO + H_2O \rightarrow Pd + CO_2 + 2\ HCl$

b. $3\ Cu + 2\ As^{+3} \rightarrow 3\ Cu^{+2} + 2\ As$

c. $3\ C_2H_6O + 2\ Cr_2O_7^{-2} + 16\ H^+ \rightarrow 3\ C_2H_4O_2 + 4\ Cr^{+3} + 11\ H_2O$

6. a. $S + O_2 \rightarrow SO_2$

b. $NaOH \rightarrow Na^+ + OH^-$

c. $2\ O_3 \rightleftarrows 3\ O_2$

LESSON 26: (A) GRAM MOLECULAR WEIGHTS

(B) QUANTITIES IN CHEMICAL REACTIONS

RATIONALE:

The quantitative treatment of chemical reactions is important to biomedicine. In medical laboratories, quantitative reactions are used to measure the amounts of substances in samples of blood and urine, for example, ST-26 and LA-26 introduce the use of quantities in chemical reactions. These concepts are important throughout the curriculum, and prepare the student for the study of concentration in the next several lessons.

OBJECTIVES:

The student will define the terms molecular weight and gram molecular weight and determine their values for specified compounds.

The student will define the word precipitate.

The student will use gram molecular weights to predict how much precipitate and other reaction products will form in a chemical reaction.

The student will perform a quantitative laboratory test and compare the calculated mass of the reaction product with the observed mass.

SEQUENCE: ST-26; LA-26

SUGGESTIONS:

1. Students may calculate how much CO_2 and water form when the body

oxidizes a chocolate bar to CO_2 and H_2O. Bowes and Church, Table of Food Values, to be used in Unit II, will be helpful in determining how much sugar it has. Assume all the sugar in the bar is sucrose, $C_{12}H_{22}O_{11}$. Other foods may also be used, such as bread, which has starch $(C_6H_{10}O_5)_n$, and butter (butterfat is $C_{15}H_{29}O_9$).

2. The amount of CO_2 produced by an automobile using up a full tank of gasoline (C_8H_{18}) may be calculated, assuming complete oxidation to CO_2 and H_2O.

KEY--PROBLEM SET 26:

1. 44.01 amu

2. a. 32.00 amu; b. 28.01 amu; c. 17.04 amu; d. 32.05 amu; e. 180.18 amu.

3. a. 46.08 amu; b. 60.06 amu; c. one; d. 60.06 g $C_2H_4O_2$/46.08 g C_2H_6O e. approximately 130.34 g

4. approximately 25.57 g

5. a. $C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{yeast}} 4\ C_2H_6O + 4\ CO_2$; b. four; c. approximately 26.92 g; d. approximately 33.65 ml

INFORMATION ON LABORATORY ACTIVITY 26:

TEACHING NOTES:

1. The purpose of this activity is to provide the students with an opportunity to verify the information that was presented in ST-26 on the relationship between the amounts of reactants and products in a balanced chemical equation. In addition, the activity introduces the technique of filtration.

2. Anticipated time: 2 periods.

3. Note that the mass of the sodium carbonate given in the procedure is for the anhydrous form. If you use a hydrated form, it will be necessary to change this figure accordingly.

4. The filtration process in the activity will require about 20 minutes. To minimize the time a larger size of filter paper (Whatman No. 1, 12.5 or 15.0 cm in diameter) is used. You may wish to give the students a demonstration of how to make a funnel out of the paper. Also, during the time in which the reaction mixture is being filtered, the students will have an opportunity to work on the calculations that appear at the end of the activity.

5. The drying process is carried out overnight in an oven kept at a temperature of about 130 °F. The oven should not be turned off before the weighing is carried out. The reason for this is that $BaCO_3$ absorbs water from the atmosphere. If the precipitate is left out of the oven for any period of time before the weighing the results will be less accurate.

6. Note: In the materials list for the activity in the Student Text (p. 110) Na_2CO_3 appears as $NaCO_3$. This error should be corrected.

MATERIALS: (for 15 set-ups)

- 25 g anhydrous sodium carbonate (Na_2CO_3)
- 50 g barium chloride ($BaCl_2 \cdot 2H_2O$)
- oven
- 45 beakers, 150-ml (or 250-ml)
- 15 graduated cylinders, 100-ml
- 8 Petri dishes, glass
- filter paper, 12.5- or 15-cm
- 15 stirring rods
- 15 gas burners
- 15 ring stands, with ring
- 15 balances
- 15 wire gauzes

ANSWERS TO CALCULATION QUESTIONS:

1. $BaCl_2 \cdot 2H_2O$--244.28 g

   Na_2CO_3--105.99 g

   $BaCO_3$--197.35 g

   NaCl--58.44 g

2. $\dfrac{197.35 \text{ g } BaCO_3}{244.28 \text{ g } BaCl_2\ 2H_2O}$

3. $\dfrac{116.88 \text{ g NaCl}}{105.99 \text{ g } Na_2CO_3}$

4. 1.97 g

5. 1.17 g

SAMPLE RESULTS:

Mass in grams of:

Reactants $\left\{ \begin{array}{l} BaCl_2 \cdot 2H_2O\text{: } \underline{2.44 \text{ g}} \\ Na_2CO_3\text{: } \underline{1.06 \text{ g}} \end{array} \right.$

filter paper: 1.69 g

beaker: 64.18 g

Petri dish: 29.74 g

beaker + NaCl: 65.24 g

Petri dish + filter paper + $BaCO_3$: 33.5 g

Products $\left\{ \begin{array}{l} NaCl\text{: } \underline{1.06 \text{ g}} \\ BaCO_3\text{: } \underline{2.13 \text{ g}} \end{array} \right.$

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ANSWERS TO DISCUSSION QUESTIONS:

1. Our initial results were 1.06 g NaCl and 2.13 g $BaCO_3$. As you can see, the figure for the NaCl is about 0.1 g short of that to be expected according to the calculations and the figure for $BaCO_3$ is about 0.16 g too high. This is probably due to the fact that a significant amount of solution is still left on the precipitate and filter when it is finally put into the oven. This solution probably contains a small portion of dissolved NaCl which adds to the weight of the $BaCO_3$ and also accounts for the lesser figure obtained for the NaCl product.

You may also notice that when the water of hydration is discounted, the weight of the products is greater than that of the reactants. This observation led us to believe that another reason for the increased weight of the $BaCO_3$ precipitate was that it was not completely dry.

Taking into account the observations mentioned above we performed two procedures in the laboratory. They are described below. You may want to see if your students can come up with them on their own, with a few helpful hints from you. Also, if you have the time, you might have the students perform the procedures to see if their results can be improved upon.

Procedure A. The first step was to dry the $BaCO_3$ precipitate further and reweigh it to see if in fact some of the extra mass was due to incomplete drying. Upon doing this, the second weighing gave a figure of 2.07 g, showing that approximately 0.06 g of the mass had been due to retained water.

Procedure B. The object of this procedure was to test the idea that some of the NaCl had been left behind on the filter paper, thus decreasing the product mass of the NaCl and increasing that of the $BaCO_3$. The $BaCO_3$ was placed in 50 ml of water and stirred for about 5 minutes to make sure that any NaCl that was present would dissolve. The mixture was then filtered once more and the precipitate was rinsed twice with water. The filtrate was then boiled down as before and both the filtrate and precipitate were placed in the oven to dry. When weighed the next day the $BaCO_3$ was found to weigh 1.96 g and the NaCl that was recovered weighed 0.09 g, giving a total NaCl product mass of 1.15 g. Note that these two product masses, 1.96 g for $BaCO_3$ and 1.15 g for NaCl, are almost exactly the masses predicted by the calculations.

2. The water of hydration has no effect on the calculations that predict the masses of the products. It does have an effect when the mass of the reactants is compared to the mass of the products, because the water molecules that comprised

part of the reactant mass evaporated in the drying. Therefore when answering Question 3, one has to subtract the amount of the reactant mass that was due to the water of hydration, i.e., instead of using 2.44 g for the reactant mass of $BaCl_2 \cdot 2H_2O$ one has to use 2.08 g.

3. As stated in the answer to Question 2, the mass of the reactants will not equal the mass of the products unless the water of hydration is taken into account. Also, as we discussed in Question 1, the products may actually weigh more than the reactants if the drying process is not complete.

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LESSON 27: (A) MOLES AS CHEMICAL QUANTITIES

(B) ACUTE ASTHMA

RATIONALE:

The last lesson introduced the use of molecular weights in calculating quantities in chemical reactions. Easier to use than molecular weights in calculations is the mole. This important unit will be used again and again in the curriculum. It is used in concentration (moles/liter) in the next activity, and with gases in later lessons in this unit.

OBJECTIVES:

The student will define a mole and state its equivalent mass.

The student will convert between units of mass and moles.

The student will use moles to calculate quantities in grams in chemical equations.

The student will state what happens to the bronchioles during an asthma attack.

SEQUENCE: Completion of LA-26; ST-27

SUGGESTIONS:

1. The treatment of asthma here is not directly related to the chemistry. It is provided as a break in the chemistry sequence.

2. Allergic asthma introduces the concept of substances that cause allergic reactions. You may make a list of such substances, such as hay fever pollen, poison oak, dust, animal fur, strawberries, penicillin.

3. To get a better "feel" for Avogadro's number, the students may calculate the size of a mole if each molecule were the size of a grain of sand. Assume there are 4,000 grains in a ml.

4. Almost all of the carbon atoms in plant molecules come from CO_2 in the air, not from carbon atoms in the soil. The following problem might be of interest. How many moles of CO_2 would it take to make a 5-ton tree, if the tree contains 1.5 tons of cellulose $(C_6H_{10}O_5)_n$, the major carbon molecule?

5. Ask the students how many moles of each reactant they weighed out in LA-26.

INFORMATION ON ASTHMA

The symptoms of asthma are caused by constriction and/or blockage of the air passageways in the bronchioles. The condition is frequently precipitated by allergic reactions to various substances (plant pollens, animal fur, dust, etc.). It can also arise from chemical or mechanical irritants such as smoke, air pollutants, etc. It often comes on during periods of respiratory infection. Some types of asthma are markedly influenced by emotional states.

A person with asthma may have a mild continuous form or may suffer sudden, severe attacks. These attacks may come at any time, and may last minutes, hours, or days. Symptoms of the mild attack are itching about the eyes and nasal passages, a tightness in the chest and labored breathing. A person having a severe asthma attack feels as if he is choking. He coughs a great deal and spits up a white mucus, he perspires, and he feels as if he cannot get enough air out of his lungs. His breathing is a labored wheezing one, that can be heard some distance away.

Since the bronchioles normally enlarge upon inspiration and narrow upon expiration, constriction or partial blockage of the bronchioles tends to interfere more with expiration than with inspiration. Asthma is not accompanied by fever unless the attack is associated with an infection.

Acute asthmatic attacks, especially those associated with allergic reactions, are caused by spasm of the muscular walls of the bronchioles which constrict the air passageways. In this case, injections of adrenalin (epinephrine) usually result in immediate relief. Even without treatment, such attacks are rarely fatal. The distress accompanying the attack causes the release into the bloodstream of the body's own supply of adrenalin, which dilates the bronchioles by relaxing the bronchiolar muscles.

If attacks are caused by a reaction to a specific substance, the substance can sometimes be identified by skin tests. The cause, however, is rarely a single substance.

When the cause is known, avoidance of the allergen will usually prevent further attacks. Desensitizing injections are helpful, but have proven successful in preventing attacks in only about half of all cases.

The milder, chronic form of asthma is caused by swelling in the walls of the bronchioles and subsequent secretion of thick mucus into the air passageways. Treatment in this case consists of administering drugs that reduce edema and

mucus production. One such drug, ephedrine, figured prominently in the withdrawal of a gold medal during the 1972 Olympic Games.

With a long-standing asthmatic condition, the chest may become enlarged or "barrel-shaped" because of chronic over-inflation of the lungs.

Hay fever is an allergic reaction similar to allergic asthma, except that the region of involvement is confined to the eyes and the nasal passages.

KEY--PROBLEM SET 27:

1. a. two, one, two; b. 12×10^{23}, 6×10^{23}, 12×10^{23};
c. 1 mole, 2 moles, 1 mole, 2 moles; d. $\frac{2 \text{ moles } O_2}{1 \text{ mole } CH_4}$, $\frac{1 \text{ mole } CO_2}{1 \text{ mole } CH_4}$, $\frac{2 \text{ moles } H_2O}{1 \text{ mole } CH_4}$
e. 1.34 moles, .62 mole, 1.34 moles.

2. a. 6 moles; b. $\frac{6 \text{ moles } O_2}{1 \text{ mole } C_6H_{12}O_6}$; c. 24 moles; d. 24 moles

3. .004 mole

4. a. 58.44 amu; b. 58.44 g; c. 58.44 g; d. 58.44; e. 35.06 g

5. a. 342.34 amu; b. 342.34 g; c. 342.34 g; d. .20 mole

6. a. 1.28 moles; b. 58.98 g

7. 6 moles

LESSON 28: (A) THE CONCENTRATION OF SOLUTIONS

(B) MOLARITY

RATIONALE:

The importance of familiarity with the notion of concentration of solutions in performing laboratory tests and in characterizing body fluids is evident. Its presentation here comes after the presentation of chemical quantities in the previous lesson, and enables the student to deal quantitatively with solutions in this activity and ones on pH that are coming up.

OBJECTIVES:

The student will define the word concentration.

The student will define the term molar concentration.

The student will convert between units of concentration in grams per liter and moles per liter.

SEQUENCE: ST-28; LA-28

SUGGESTIONS:

1. Answer "c" on p. 177 should read "3" moles, instead of "6."

2. Use the body masses of the elements magnesium, chlorine, sodium, potassium and calcium given in Section 21, p. 114, to calculate their concentration in body water. There are 41 liters of water in a 70-kg man. Compare these theoretical concentrations to the actual concentration of these ions in blood plasma.

ACTUAL CONCENTRATIONS

Mg^{++}	1-2 mg/100 ml
Cl^-	350-375 mg/100 ml
Na^+	310-340 mg/100 ml
K^+	14-20 mg/100 ml
Ca^{++}	9-11 mg/100 ml

Speculate on reasons for the difference. These include the fact that most body water is inside cells rather than in blood and cells are higher in K^+ and Mg^{++} and lower in the other ions than blood.

3. Students might research the question of why the sugar concentration of fluid administered to a patient is so critical.

4. Have the students calculate the molar concentrations of pure water and pure ethyl alcohol, assuming densities of 1000 g/liter and 790 g/liter, respectively.

$$\text{water:} \quad \frac{1000 \cancel{g}/\text{liter}}{18 \cancel{g}/\text{mole}} \simeq 55.5 \text{ moles/liter}$$

$$\text{ethyl alcohol:} \quad \frac{790 \cancel{g}/\text{liter}}{46 \cancel{g}/\text{mole}} \simeq 17.2 \text{ moles/liter}$$

KEY--PROBLEM SET 28:

1. Dissolve 32.46 g $Hg(NO_3)_2$ in one liter of solution.

2. Dissolve 140.26 g NaCl in .8 liter of solution.

3. Dissolve 540.54 g glucose in 10 liters of solution.

4. 0.73 mole

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INFORMATION ON LABORATORY ACTIVITY 28:

TEACHING NOTES:

1. This activity provides the students with a standard technique for the preparation of solutions of molar concentrations. These serves to reinforce the concept of molar concentration discussed in ST-28. In addition, the preparation of solutions by the students can reduce the time spent by the instructor in preparing for laboratory activities. The solutions prepared are to be used in future activities.

2. Anticipated time: one period.

3. The instructions provided are designed for solutions with a final volume of 100 ml or less. This figure has been chosen since, in most cases, the students only have access to 100-ml graduates. The procedure may be amended as necessary to provide for greater volumes.

4. To prepare solutions with a final volume greater than 100 ml, the graduate may be used to measure the additional amounts of water needed. This does not pose any problems when dilute solutions are prepared, and in such cases, the instructions in Procedure Steps 12 and 13 apply. When near-saturated solutions are diluted, however, considerable error may be introduced. (For example, when 100 ml of water are added to 100 ml of a saturated solution of NaCl, the final volume is less than 200 ml.) For this reason, if solutions near saturation must be diluted in order to obtain the desired final volume, it is necessary to use a graduated cylinder or volumetric flask of the appropriate size. (Note: the students have not yet been formally introduced to the concept of saturated solutions in this course.)

5. In certain cases the solution resulting from Step 5 may be at or near the saturation point. Material remaining undissolved after Procedure Step 5 may be dissolved either by gentle heating or in the rinse described in Step 7.

6. Glass-marking pencils may be substituted for labels. The students should be cautioned to avoid rubbing markings off of their bottles, however.

7. This activity may be implemented again later in the course as opportunities arise for student preparation of needed solutions.

MATERIALS: (for 15 set-ups)

15 balances
15 stirring rods
15 beakers (size depending upon volume of solution being prepared)

- 15 bottles (or flasks with stoppers)
- 15 graduated cylinders (size depending upon volume of solution being prepared)
- labels (15 are needed for each solution being prepared)
- 15 scoopulas
- 15 pipets, 10-ml (if desired for dilution of NaOH solution below)
- samples of chemicals needed to make the solutions; the following are suggested:
  - 100 g chromium potassium sulfate [$CrK(SO_4)_2 \cdot 12H_2O$]
  - 80 g sodium hydroxide (NaOH) pellets
  - 10 g sodium chloride (NaCl)

SUGGESTED SOLUTIONS:

1. 100 ml chromium potassium sulfate solution, .112 M, for use in LA-31. This may be prepared by dissolving 5.59 g of the solid in a total volume of 100 ml of water. The molecular weight of chromium potassium sulfate is 499.41 amu.

2. 100 ml sodium hydroxide solution, .100 M, for use in LA-33. This may best be prepared by dissolving 4.00 g sodium hydroxide pellets in a total volume of 100 ml of water, and then diluting the resulting solution by a factor of 10. (An alternative method would be to dissolve .40 g of the solid in a total volume of 100 ml. This produces slightly less accurate results, since the pellets cannot easily be weighed to ±.01 g. However, this method is acceptable, since the concentration needed in LA-33 is not critical.) The molecular weight of sodium hydroxide is 40.00 amu. The students should be instructed to avoid touching the sodium hydroxide pellets as they are quite caustic and can cause burns. The cap should be replaced on the reagent bottle immediately after use, since sodium hydroxide absorbs water from the atmosphere very rapidly.

3. 50 ml sodium chloride solution, .14 M, for use in LA-34. This may be prepared by dissolving .41 g of the solid in a total volume of 50 ml of water. The molecular weight of sodium chloride is 58.44.

ANSWERS TO DISCUSSION QUESTIONS:

1. The volumes given in Steps 5 and 7 would have to be smaller.

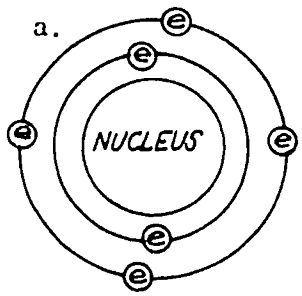
2. If the bottle is not tightly capped, some of the solvent may evaporate, thereby causing the concentration to change. In addition, the contents of the bottle are less likely to be spilled if the cap is on securely.

KEY--REVIEW SET 28:

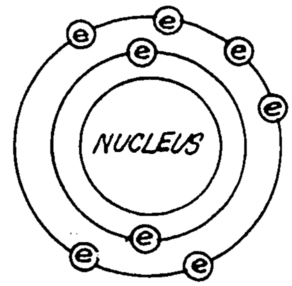
1. In walking across the rug, you became slightly charged electrically. Because there was a difference in charge between you and the doorknob, electrons passed from one object to the other.

2. a. positive; b. negative

3. a.



Carbon atom



Oxygen atom

b. carbon: 6 protons, 6 electrons, 6 neutrons
oxygen: 8 protons, 8 electrons, 8 neutrons

c. No. In ions, the total plus charges from protons and the total minus charges from electrons would not be the same.

4. a. K·, Mg:, $[:\ddot{\underset{..}{F}}:]^-$, $[:\ddot{\underset{..}{S}}:]^{--}$, $[K]^+[:\ddot{\underset{..}{F}}:]^-$, $[K]^+[:\ddot{\underset{..}{S}}:]^{--}[K]^+$, $[Mg]^{++}[:\ddot{\underset{..}{S}}:]^{--}$, $[:\ddot{\underset{..}{F}}:]^-[Mg]^{++}[:\ddot{\underset{..}{F}}:]^-$

b. The bonding between atoms in a salt is ionic. The cations, as exemplified by K^+ and Mg^{++}, tend to lose electrons to the anions (F^-, S^{--}).

5. a.

```
           ..
          :Br:
     ..    ..    ..
   : Br :  C  :  Br :          Br—C—Br          Ö::C::Ö          O=C=O
     ..    ..    ..
          :Br:
           ..
```

(Br above and below C in the structural formula.)

b. In covalent bonds, elements share electrons rather than give or take electrons.

6. a. $C_2H_6O + O_2 \rightarrow CO_2 + H_2O$

b. $C_2H_6O + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$

c. $C_2H_6O + 3\ O_2 \rightleftarrows 2\ CO_2 + 3\ H_2O$

d. C_2H_6O: 46.1 amu; 3 O_2: 96.0 amu; 2 CO_2: 88.0 amu; 54.1 amu

e. 8.8 g CO_2 and 5.4 g H_2O

f. 0.1 mole

g. 0.2 mole

7. Dissolve 342.34 g lactose in 2 liters of water.

LESSON 29: (A) ACIDS AND BASES

(B) NEUTRALIZATION

(C) TITRATION

RATIONALE:

Acis and bases are fundamental to chemistry. They are particularly relevant to respiration, because regulating CO_2 expiration is an important means by which the body controls the acidity of its fluids. In the clinical laboratory, it is important to be able to determine the concentration of a dissolved substance. Acid and base concentrations provide a straightforward opportunity for students to learn how to do this, with titration. Hence, the activity introduces students to the technique of titration.

OBJECTIVES:

The student will define the word acid, and write chemical equations for the dissociation of acids in solution.

The student will define the word base, and write equations for the dissociation of bases in solution.

The student will write chemical equations for the reaction that occurs when an acid and base are mixed.

The student will determine whether the mixing of an acid with a base results in a solution that is acidic, basic or neutral.

The student will calculate the molar concentration of an unknown acid or base from information on the volume of a known acid or base required to titrate it.

SEQUENCE: ST-29; LA-29

SUGGESTIONS:

1. Students may compile lists of acids from food labels, vitamins, household cleaners and write chemical equations for their dissociation. The book, Chemistry, An Experimental Science, cited in Lesson 20, may be helpful in looking up molecular formulas. So might a good dictionary.

2. $NaHCO_3$ (baking soda) is a weaker base than NaOH. When mixed with an acid a neutralization reaction occurs in which CO_2 gas forms. Students may use this as an indicator reaction: when bubbles stop forming, the solution is nearly neutral.

3. A homemade indicator may be made and tested by boiling purple cabbage pieces in a pan of water and straining off the water. Bases make the water green, acids red. The same can be done with beets and other pigmented fruits and

vegetables. Flower petals may be dropped into acids and bases to see whether they change color.

KEY--PROBLEM SET 29:

A. 1. basic; 2. acidic; 3. acidic; 4. neutral; 5. acidic

B. 1. a. 0.02 mole; b. 0.02 mole; c. 0.02 M; 2. 0.031 M

INFORMATION ON LABORATORY ACTIVITY 29:

TEACHING NOTES:

1. This activity is designed to introduce the student to the methods of measuring the concentrations of solutions. In this activity, the concentrations of various acidic solutions are measured titrimetrically--that is, it is a volumetric procedure accomplished with the buret. Besides introducing important new laboratory technique, the activity reinforces the concepts of the mole, concentration and acidity discussed in the Student Text. In addition, the students measure the concentrations of three acids that are commonly encountered in life science: hydrochloric acid (in gastic juice), acetic acid (vinegar) and ascorbic acid (Vitamin C).

2. Anticipated time: one period.

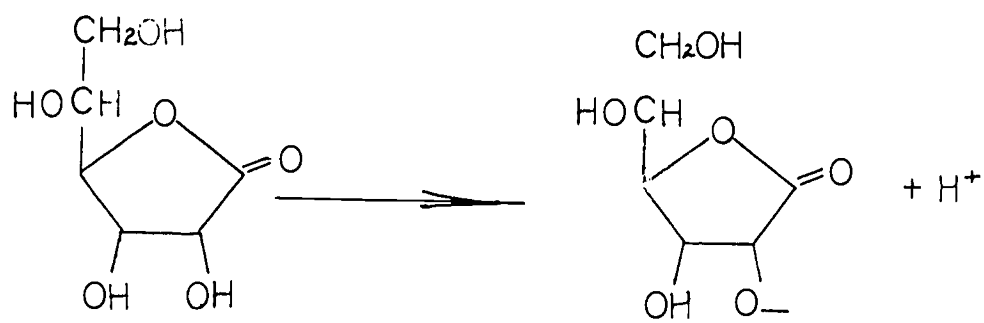
3. Note that this activity does not deal with the "strengths" of acids in any way. It deals only with total acid concentration. (Strong and weak acids--the pH of solutions--are dealt with in LA-30.)

4. Note that the procedure does not include information covering the actual operation of the buret. Since burets dispense liquids in various ways (stopcocks, pinch clamps, etc.) this instruction is left to you. The students should be cautioned that no bubbles should be allowed to remain in the tip of the buret. Ground glass stopcocks should be greased and checked to see that they are not clogged. (Note: Teflon lubricated stopcocks do not require this treatment.)

5. The hydrochloric acid solution may be safely mouth-pipetted. A dilute solution is used (about 0.1 M) which is approximately the same concentration as in the stomach (in the stomach, the pH ranges between 1 and 2).

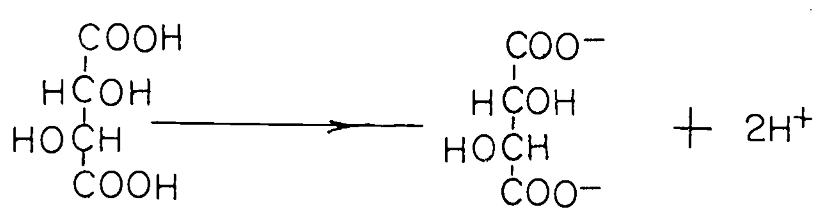
6. The students may notice that ascorbic acid is a diprotic acid, which therefore should release into solution two moles of hydrogen ions for every

mole of acid. The treatment of this question is related to the strength of the acid and the pH of the solution as the titration proceeds. As NaOH is added to the solution of a weak acid, the pH increases. Although the first proton of ascorbic acid is released at low pH, the second proton is not freed until the pH of the solution is approximately 12, which is past the endpoint of the titration. Since phenol red changes color between pH 6.6 and 8.0, it will detect only the dissociation of the first proton of ascorbic acid. The dissociation of ascorbic acid may be represented as



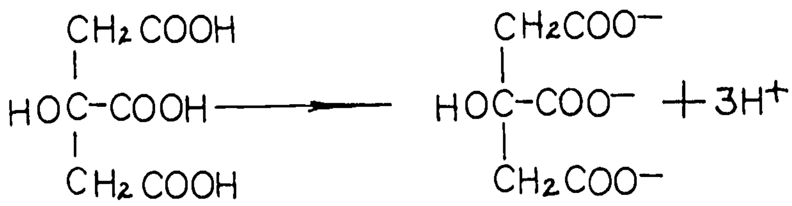
Ascorbic acid has a molecular weight of 176.12; 3 g dissolved in 100 ml of water produces a .170 M solution.

7. The activity may be augmented with other unknown acids. Tartaric acid is a diprotic acid which releases its two protons at relatively low pH. It is therefore recommended since it is non-toxic and readily available. Its dissociation may be represented as



The molecular weight of tartaric acid is 150.09; 3 g dissolved in 100 ml of water produces a .200 M solution. Citric acid is a triprotic acid that may

also be used. Its dissociation may be represented as:



Citric acid has a molecular weight of 192.12; 3 g dissolved in 100 ml of water produce a .156 M solution. (Note: if the hydrated form of citric acid is used, the molecular weight is 210.14 and the concentration is .142 M.) Both tartaric acid and citric acid are widely distributed in nature in fruits.

MATERIALS: (per 10 set-ups)

- 10 beakers, 250-ml
- 10 g sodium hydroxide (NaOH)
- 10 burets, 50-ml
- 10 ring stands
- 10 ring-stand clamps
- 20 beakers, 150-ml
- 5 ml hydrochloric acid (HCl), concentrated
- 10 beakers, 50-ml
- 10 pipets, 10-ml
- 20 flasks, 125-ml
- 10 medicine droppers
- 0.1 g phenol red (phenolsulfonephthalein), water soluble
- 250 ml vinegar, white
- 40 g ascorbic acid
- 10 balances
- 10 graduated cylinders, 10-ml

PREPARATION OF REAGENTS:

Sodium hydroxide, 0.1 M: Dissolve 10.0 ± .1 g sodium hydroxide (NaOH) in 2500 ml total volume. Standardize the solution against an ascorbic acid solution of known concentration. This is most simply accomplished by dissolving 1.76 ± .01 g ascorbic acid in 100 ml of water, total volume. Titrate the sodium hydroxide solution against 10.0 ml aliquots of the acid solution, adjusting the base with NaOH or H_2O until the concentration is such that 10.0 ± .1 ml are needed to reach the endpoint.

Phenol red indicator: Dissolve 0.1 g water-soluble phenol red in 250 ml water.

Hydrochloric acid: The final concentration of this solution should be between 0.10 and 0.15 M to ensure that the students use at least 10 ml of the base during the titration, and that the concentration is not too high for safe mouth pipetting. Such a solution may be prepared by mixing between 2.16 and 3.24 ml of concentrated

hydrochloric acid in 250-ml total volume water. The precise concentration is not critical. Let the students figure it out.

ANSWERS TO DISCUSSION QUESTIONS:

1. Dust or droplets of water will make the concentration of sodium hydroxide inaccurate unless they are rinsed out prior to beginning the titration.

2. The total hydrogen ion concentration calculation would be unaffected. The total acid concentration would be one-half the hydrogen ion concentration.

3. Sources of error include the imprecision of the buret readings, pipetting the unknown, going somewhat beyond the endpoint, etc.

LESSON 30: (A) pH

(B) THE DIFFERENCE BETWEEN WEAK AND STRONG ACIDS

RATIONALE:

pH is a convenient measure of acidity, routinely used in describing solutions. It is used in LA-30 and many future activities.

OBJECTIVES:

The student will define the term pH.

The student will define the strength of an acid or base in terms of how much it dissociates.

The student will explain what is meant by a neutral, acidic, and basic solution.

The student will explain why two acids with the same concentrations may have different strengths.

SEQUENCE: ST-30; LA-30

SUGGESTIONS:

1. The pH of foods may be tested before and after boiling or freezing.

2. Students may research why water is slightly dissociated at pH 7.

3. Students may research the pH of stomach acid and the advantages of this.

4. Students may list products which are advertised to affect acidity: antacids, skin creams, shampoos, soaps, test their pH, and speculate on their advantages.

INFORMATION ON LABORATORY ACTIVITY 30:

TEACHING NOTES:

1. The purpose of this activity is to demonstrate two methods for measurement of pH. It also provides reinforcement of the concept of pH and the relation of pH to concentration of an acid.

2. You may wish to review proper pipetting techniques. Acetic acid is a weak acid and may be pipetted safely by mouth at these concentrations. However, HCl, especially at the highest concentration used, should not be pipetted by mouth. The use of either a rubber bulb or a syringe in conjunction with a pipet (as in Laboratory Activity 3) is recommended.

A possible alternative to pipetting is the use of a medicine dropper. Twenty drops of a standard medicine dropper held in a vertical position should amount to about 1 ml. To be more rigorous, you could have the students calibrate a medicine dropper by determining the actual number of drops needed to add one ml to a buret or to a small graduated cylinder.

3. The activity is rather lengthy but may be either shortened to fit into one lab period or extended over two lab periods if desired. If you choose to break the lab into more than one period, the lab can be stopped after Parts I or II. The solutions used are stable although, if real urine is to be stored for a day or more (see Teaching Note 12), it should be kept in a refrigerator.

4. If you want to shorten the activity, there are many ways this can be done. A few possibilities follow: (1) You could omit one or more of the solutions shown in the table in Part I. (2) If you can make available several rolls of pH paper rather than just a few, the lab will move faster. Strips of pH paper may be precut and distributed around the classroom in small beakers. However, if you do this, the students will need access to the color charts that come on each container. Additional charts may be obtained at a small cost from: Micro Essential Laboratories, Inc., 4224 Avenue H, Brooklyn, N.Y. 11210. (3) The instructor or an assistant could make available HCl and acetic acid solutions at all four concentrations. (However, this time-saver would deprive the students of experience in making serial dilutions.) (4) The pH meter could be standardized before class or, as a demonstration, at the beginning of the class.

5. It is possible to extend the activity if desired by testing other substances such as vegetable or fruit juices, hair shampoos, coffees, blood sera. One drop of blood from a finger puncture (see Laboratory Activity 34) would

suffice for the pH paper test. In Part II, additional serial dilutions of the two acids could be made and tested. In Part III, the pH of additional solutions besides the urine could be determined. It would be interesting to repeat Part II using a pH meter in place of pH paper.

6. In general, the need for clean glassware merits stressing in this lab. In Part II, it would be a good idea for students to rinse their pipets with each solution to be tested before determining the pH. Any pipets used for HCl should be rinsed before the acetic acid dilutions.

7. One way to facilitate completion of the lab would be to arrange the various solutions to be tested in Part I at one station and have the pH meter and materials for Part III at a second station. Students would spend most of the lab period on Part II and could circulate to the two stations when they saw a vacancy.

8. The use of pH indicators was demonstrated in the titration in Lab Activity 29. But Hydrion paper involves several indicators and this is a more complicated situation. A demonstration of color change in a solution containing two different pH indicators might help the student to understand how Hydrion paper works. For example, you could take a basic solution and add a drop of two different pH indicators (e.g., phenolphthalein and bromothymol blue). The original solution should be purple. If you add acid drop by drop, the color should change to blue and eventually to yellow.

9. Part I could be done with solutions in beakers or in a rack of test tubes, or spot plates could be used. A convenient device for spot plating can be obtained from art supply stores--it is used for mixing paints.

10. Students may wonder why distilled water is not always at a pH of 7. The answer is that distilled water is usually slightly acidic because of absorption of CO_2 and formation of carbonic acid.

11. The activity calls for the use of urine in Parts I and III. It should be stressed to the students that urine, a body fluid usually taken for granted, is actually a valuable clinical tool. A low urine pH could indicate diabetes, among other things.

12. The urine called for in the directions could be provided by the instructor. Another option would be to make a simulated urine by adding a drop or two of yellow food coloring to a container of water and adjusting the pH to 5.0 - 6.8 with a drop or two of acid. Still another option would be to have the students

test their own urine. This would provide an opportunity to discuss the idea of normal concentration ranges in body fluids.

13. A few ml of saliva are needed for Part I. The saliva could be provided by the instructor or the students. The saliva should be in a beaker--it would not be good technique to have the students place the pH paper in their mouths.

14. It may be necessary to discuss the disposal of pH paper. Otherwise, some of the paper is likely to end up in the sinks.

15. In Part II, water is used for the dilutions. This water sould be at a pH close to 7. Distilled water may be used for this operation. If this is not convenient, tap water may be used instead. In either case, if the water is not in the range of pH 6.5 to 7.5, add a few drops of acid or base to a large volume of water until the pH is near 7.

16. It would be a good idea to review the pH probe cautions mentioned in the procedure with the class. The glass electrode is very easily broken and is expensive.

17. It may be necessary to start the students on the pH meter activity at the very beginning of the lab period. It is not necessary to complete Parts I and II before doing Part III. Part III will take about five to ten minutes and with only one set-up per class, this could become a bottleneck.

18. The pH 7 solution mentioned in the Student Text refers to a pH 7 buffer. The term "buffer" was not used since it might be confusing to the students at this point.

19. Baby food jars may be substituted for small beakers.

MATERIALS:

Part I:

See student list. (At least 5 ml of each solution will be needed per set-up.)

Parts II and III:

See student list.

PREPARATION OF REAGENTS:

10^{-1} M HCl:

Add 8.3 ml conc. HCl (12 M) to sufficient water to make 1 liter. Left-over HCl can be stored indefinitely and used in later activities.

10^{-1} M acetic acid solution:

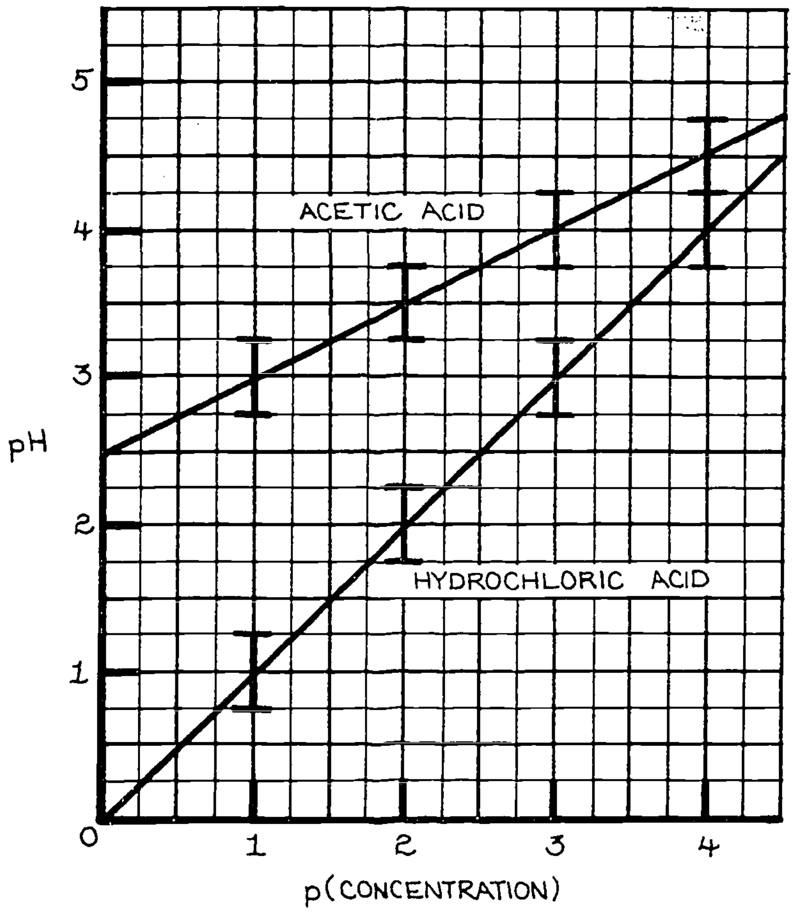
Add 5.7 ml glacial acetic acid to sufficient water to make 1 liter.

ANTICIPATED RESULTS:

Part I:

Urine: 5.0 - 6.8; Saliva: 5.6 - 7.6.

PART II:



HCl: pH = p(concentration)

acetic acid: pH = $\frac{1}{2}$ p(concentration) + $2\frac{1}{2}$

PART III:

Urine should be in the range of pH 5.0 to 6.8.

ANSWERS TO DISCUSSION QUESTIONS:

Part I:

1. Abnormal pH values may be an indication of disease.

2. Answers will vary. Deviations from expected values may be due to errors in interpretations of the colors of the Hydrion paper.

3. Acids--vinegar

Bases--household ammonia

All the other solutions are likely to be neutral or slightly acidic.

4. At best, to the nearest pH unit (±.5) with the 1-11 paper and to the nearest 0.5 unit (±.25) with the 1.0-5.5 paper.

5. Student differences may be due to different interpretations of the colors of the Hydrion paper.

Part II:

1. HCl. Lower pH at same concentration.

2. The one with the lower pH is the stronger acid (HCl). The lower pH means more hydrogen ions are released in solution--this suggests more complete dissociation.

3. The pipet may have picked up either almost pure water or almost pure 0.1 M acid. The error caused by a failure to mix the solutions could be very large.

4. Acetic acid is a weak acid. In addition, the concentration is low in salad dressing.

5. See "Anticipated Results," Part II.

Part III:

1. The BIP pH meter can be read to the nearest 0.1 pH unit; the pH paper, at best, can be read to the nearest 0.5 pH unit.

2. a. A situation in which a precise value is needed, such as measurement of the pH of blood.

b. A situation in which an approximate pH value is needed in a hurry, such as when one only wants to know whether a solution is acidic or basic.

LESSON 31: (A) pH OF THE BLOOD AND THE REGULATION OF BREATHING

(B) RESPIRATORY ALKALOSIS AND ACIDOSIS

RATIONALE:

In ST-29 the students read a case history in which Tom suffered from what is known as respiratory alkalosis. In that section and ST-30 the concepts of acid, base and pH were presented to give the students the background necessary to understand respiratory alkalosis. In this lesson we discuss how the hydrogen-ion concentration of the blood affects the respiratory center, as well as a few causes of hydrogen ion alteration in the body. Respiratory alkalosis and acidosis, their effect on the respiratory center and their treatment are covered. LA-31 serves as an introduction to colorimetry, a technique which will be used in many other activities.

OBJECTIVES:

The student will state the relationship between carbon dioxide and hydrogen-ion concentrations in the blood.

The student will explain the role of hydrogen-ion concentration in the blood in the regulation of breathing.

The student will state the relation between how long one can hold one's breath, hydrogen-ion concentration in the blood and the breaking point response of the respiratory center.

The student will define chemoreceptor.

The student will list three sites in the body that are concerned with monitoring hydrogen-ion concentration in the blood.

The student will define respiratory alkalosis and acidosis.

The student will list one cause of respiratory alkalosis.

The student will state the treatment for respiratory alkalosis.

The student will state two causes of respiratory acidosis.

SEQUENCE: ST-31; LA-31

SUGGESTIONS:

Discuss the students' ideas on possible treatments for respiratory acidosis. Respiratory acidosis is characterized by an elevation of blood carbon dioxide and a reduction in hydrogen-ion concentration, due to the inability of the respiratory system to eliminate carbon dioxide at the same rate as it is produced. As was pointed out in the text, treatment with oxygen may only serve to confuse matters by causing the respiratory center to decrease the respiration rate. What is

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needed is an increase in respiration to rid the body of the excess carbon dioxide. This is done by using a respirator which substitutes an increased breathing rate for that of the patient, thus increasing the elimination of carbon dioxide. These machines can also be set for different gas mixtures so that the problem of confusing the respiratory center with an excessive input of oxygen can be avoided.

INFORMATION ON LABORATORY ACTIVITY 31:

TEACHING NOTES:

1. The objective of this activity is to familiarize the students with the use of the BIP colorimeter and with the relationship between concentration, transmittance and absorbance.

2. The chromium potassium sulfate solution should not be mouth-pipetted.

3. If mortars and pestles are not available, the students could be supplied with powdered sodium potassium sulfate.

4. The light shields mentioned in the section on the colorimeter in the BIP Manual have not been mentioned in the procedure. If the test wells are located in strong light (e.g., direct sunlight), light shields may be necessary.

5. When the two graphs have been completed, discuss their implications. The graph of concentration vs. absorbance gives a rather smooth curve. However, it is rather difficult to estimate the concentration of an unknown from a curve. The function of the Absorbance-Transmittance Table is to convert the readings into a form that is linearly related to concentration. As indicated in Step 24 of the procedure, the region of best linearity for the BIP colorimeter is for absorbances between 0 and roughly .6 (this corresponds to transmittances between 100% and 25%). Discuss how the concentration of an unknown chromium potassium sulfate solution may be determined from the graph of concentration vs. absorbance.

6. This activity may be split by preparing the indicator solution (including the dilutions) on a separate day. In this case, the solutions should be tightly stoppered to prevent evaporation.

7. It might be very useful to extend this activity to include the determination of one or more unknown concentrations of chromium potassium sulfate. If this is done on a later day, it is important that the students use the same BIP and test well and re-standardize on tap water after a sufficient BIP warm-up period.

8. Anticipated time: two periods.

MATERIALS: (for 10 set-ups)

- 100 g chromium potassium sulfate [$CrK(SO_4)_2 \cdot 12H_2O$]
- 10 graduated cylinders, 100-ml
- 20 beakers, 150-ml (or larger)
- mortars and pestles (optional)
- 10 BIP's and colorimeter test wells
- programming wire
- 5 wire cutter-strippers
- 20 pipets, 10-ml
- 10 test tubes, 16 x 125 mm
- 10 test-tube racks
- 10 balances
- 10 screwdrivers
- Kimwipes or tissues
- parafilm

ANTICIPATED RESULTS:

Concentration (ml indicator per 10 ml solution)	Percentage Transmittance
10	11.5
9	14.0
8	19.0
7	24.0
6	30.5
5	37.0
4	47.5
3	59.0
2	68.0
1	89.5
0	100.0

ANSWERS TO DISCUSSION QUESTIONS:

1. As the concentration increases, percentage transmittance decreases and absorbance increases.

2. The blank is necessary in colorimetry because all readings are taken relative to a standard which consists of the solvent with no solute dissolved in it, i.e., a concentration of zero.

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3. The main components of the test well are a light source and a photocell. The function of the light source is just that--to provide a source of light. The photocell detects the percentage of light transmitted through the solution.

4. A dirty cuvet will increase the error of the readings, since foreign material will absorb some light. Wiping the cuvet also prevents solvents from damaging the test well.

5. If the solution is not homogenous, some parts of it will have more color than others. The part of the solution on which the measurement is made may not give a proper indication of the overall concentration.

6. The specific answers given will depend upon student results. This topic is discussed in Teaching Note 5.

INFORMATION ON THE CHEMICAL REGULATION OF BREATHING:

The chemical regulation of breathing has been the subject of rather violent controversy among respiratory physiologists over the years. Recent research, however, appears to have resolved this controversy. It now appears that the primary function of the regulation of breathing is to maintain a proper H^+ ion concentration in the brain. The regulation is accomplished by the respiratory center, which adjusts the rate of ventilation in response to nerve impulses from chemoreceptors.

Chemoreceptors of the Medulla Oblongata

Chemoreceptors in the vicinity of the respiratory center monitor the H^+ ion concentration of the brain extracellular fluid (i.e., cerebrospinal fluid). These receptors may act directly on the respiratory center or by means of nerve pathways to the respiratory center.

Carotid and Aortic Bodies

There is a carotid body near the carotid bifurcation on each side, and there are two or more aortic bodies near the arch of the aorta (Transparency I-S-35a shows three). Each of these bodies contains islands of chemoreceptor cells. The bodies make contact with the arterial blood by means of nerve fibers which extend into the blood vessels. The bodies make contact with the respiratory center

through major nerve trunks (carotid body via the glossopharyngeal nerve and aortic body via the vagus nerve).

The carotid and aortic bodies are sensitive to changes in plasma H^+ ion concentration. Their contribution to ventilatory response to changes in H^+ ion concentration, however, is quite small in relation to the response to the chemoreceptors in the medulla oblongata.

The carotid and aortic bodies also monitor the concentration of dissolved oxygen in the arterial blood. In fact, they are the <u>only</u> monitors of oxygen levels.

Breathing Response to Decreased H^+ Ion Concentration

The response to reduced H^+ ion concentration (alkalosis) is a decrease in ventilation or even a temporary cessation of ventilation. The resulting increase in CO_2 concentration increases the H^+ ion concentration until the latter returns to normal, at which point the ventilation rate returns to normal.

Breathing Response to Increased H^+ Ion Concentration

Hyperventilation is the response to increased H^+ ion concentration (acidosis). The resulting decrease in CO_2 concentration decreases the H^+ ion concentration until the latter returns to normal, at which point the ventilation rate returns to normal.

Breathing Response to Decreased O_2 Concentration

In experiments in which CO_2 (and thus H^+ ion) concentration is held constant, decreased O_2 concentration is a fairly strong stimulant of increased ventilation. In uncontrolled situations, however, the increased ventilation reduces the CO_2 and H^+ ion concentrations, which stimulates the even stronger response of decreased ventilation. Thus the two responses oppose one another.

In the case of rapid ascent to high altitudes, for example, the net effect of these two opposing responses is to limit ventilation to about 65 per cent greater than normal until acclimatization takes place. In acclimatized individuals, increased hyperventilation causes the concentration of CO_2 to remain at quite low levels without the expected depression of the respiratory center taking place. This is made possible by changes in kidney activity which return the H^+ ion concentration toward normal.

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LESSON 32: BREATH-HOLDING VS. CO_2 CONCENTRATION IN EXPIRED AIR

RATIONALE:

There is no student text for this lesson. The laboratory activity demonstrates the influence of breath-holding on the CO_2 content of the air, a principle which was discussed in ST-31.

OBJECTIVE:

The student will demonstrate that the longer one hold's his breath, the greater the CO_2 concentration of the exhaled air will be.

INFORMATION ON LABORATORY ACTIVITY 32:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to make a quantitative determination of the concentration of CO_2 in expired air, both under normal conditions and after various periods of breath-holding. The activity also introduces procedures for turbidimetry, including an explanation of the differences between this process and colorimetry.

2. The complete sequence of reactions in this procedure is as follows.

a. $Ba(OH)_2 \rightarrow Ba^{+2} + 2\ OH^-$

b. $CO_2 + H_2O \rightarrow H_2CO_3$

c. $H_2CO_3 \rightarrow H^+ + HCO_3^-$

d. $HCO_3^- \rightarrow H^+ + CO_3^{-2}$

e. $Ba^{+2} + 2\ OH^- + 2\ H^+ + CO_3^{-2} \rightarrow BaCO_3\downarrow + 2\ H_2O$

The students are familiar with reactions b and c and should have no difficulty with reaction a. The dissociation of bicarbonate to carbonate was not discussed in connection with the chemistry of respiration, because it occurs to only a slight extent under normal body conditions. The presence of excess hydroxide, however, facilitates the formation of carbonate. You may wish to defer discussion of reactions of this kind until equilibrium chemistry is introduced in Unit II.

3. The cautions concerning mouth contact with the $Ba(OH)_2$ solution may need reinforcement.

4. Starting with this activity, the materials list will not include such BIP accessories as programming wire, wire cutter-strippers and screwdriver.

5. Note that in Step 13 the blank is not inverted before it is placed in the test well. If any slight amount of $BaCO_3$ has formed in the blank (from CO_2 in the air), it is best left in the bottom of the cuvet.

6. Anticipated time: one period, if only one set of tests is made per BIP group. If each student prepares and tests his own breath samples, the time should be closer to two periods.

7. The students should be instructed to exhale in the same manner each time they exhale into the flask (Step 1). The exhalation should be done fairly rapidly and should evacuate the lungs as much as possible. Also stress the importance of shaking the flask virorously in Step 8.

MATERIALS: (for 10 set-ups--one set of breath samples each)

10 BIP's and colorimeter test wells
800 ml $Ba(OH)_2$ solution
10 Erlenmeyer flasks, 250-ml, with stoppers
10 Erlenmeyer flasks, 125-ml, with stoppers
10 graduated cylinders, 100-ml
10 graduated cylinders, 10-ml
60 cuvets, 16 x 125 mm, with stoppers
10 test-tube racks
10 glass-marking pencils
Kimwipes or other tissue
clock with second hand (visible to entire class)

Note: additional tests of breath samples will require an appropriate increase in the volume of $Ba(OH)_2$ solution prepared. Demands for additional glassware, etc., will depend upon whether additional samples are prepared simultaneously or in sequence.

PREPARATION OF REAGENT:

$Ba(OH)_2$ solution, saturated: Add 40 g $Ba(OH)_2 \cdot 8H_2O$ to 800 ml hot tap water. Place in hot water bath or over heat to dissolve. Filter and store in tightly capped containers. The solution should store well at room temperature if kept tightly capped. Some $BaCO_3$ may form on the surface, but it should not be enough to interfere with use in the activity. Another filtering is required only if the solution becomes cloudy.

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ANTICIPATED RESULTS:

The per cent CO_2 should range from about 5 for a normal breath to about 9 after 80 seconds of breath-holding.

ANSWERS TO DISCUSSION QUESTIONS:

1. The greatest concentration of CO_2 occurs after the longest breath-holding.

2. The CO_2 concentration might be further increased by holding the breath longer or by combining exercise with breath-holding.

3. The breath will contain a subnormal concentration of CO_2 following a period of hyperventilation.

4. Breath-holding causes a build up of CO_2 in the blood, as well as in the lungs.

5. At the breaking point, the respiratory center (primarily in response to the increased H^+ concentration in the cerebrospinal fluid) overrides voluntary control and forces a resumption of breathing.

LESSON 33: (A) DIFFUSION

(B) TRANSPORT OF OXYGEN AND CARBON DIOXIDE TO AND FROM THE CELLS OF THE BODY

RATIONALE:

In previous lessons we have stated that the function of the respiratory system is the exchange of oxygen and carbon dioxide. In this lesson we consider diffusion, the process by which this transfer takes place. In addition, the various barriers to diffusion of oxygen and carbon dioxide are discussed. LA-33 provides a first-hand observation of some of the examples of diffusion given in the Student Text.

OBJECTIVES:

The student will define the terms diffusion and permeable.

The studetn will list three factors that determine the rate of diffusion.

The student will define the terms erythrocyte, hemoglobin and plasma.

The student will state the function of the erythrocyte in the transport of oxygen and carbon dioxide.

The student will list, in order, the barriers across which oxygen diffuses on its way from the lung to the cells of the body, and the barriers that carbon dioxide diffuses across on its way from the cells of the body to the lungs.

The student will demonstrate the process of diffusion in the laboratory.

SEQUENCE: ST-33; LA-33

INFORMATION ON THE TRANSPORT OF O_2 AND CO_2 BY THE BLOOD:

Introduction

The transport of oxygen and carbon dioxide is one of the vital functions of the blood. Blood has a great capacity to carry both oxygen and carbon dioxide. The primary means of transporting these gases is through reversible chemical reactions which take place in the red blood cell (erythrocyte) and the blood plasma. The reactions involve the hemoglobin molecule, which is also responsible for the red color of the blood.

The Transport of Oxygen

Most of the oxygen in the blood is carried in the erythrocytes in combination with the red-pigment molecule, hemoglobin. The oxygen-carrying molecule is necessary because of the low solubility of oxygen in water. Hemoglobin is a protein made up of 4 subunits. Each of these four subunits contains one atom of iron which will bind reversibly one oxygen molecule. When oxygen combines with the iron of the hemoglobin molecule the compound is called oxyhemoglobin. The chemical reaction is as follows.

$$Hb + O_2 \rightleftarrows HbO_2$$

The above reaction represents the oxygenation of one subunit of hemoglobin. Since there are four subunits the complete oxygenation reaction is

$$Hb_4 + 4O_2 \rightleftarrows Hb_4O_8 \ .$$

The oxygenation of hemoglobin is a rapid reaction requiring less than 0.01 seconds. The affinity for oxygen increases as each subunit is filled.

The oxygen saturation of arterial blood hemoglobin is normally about 97 per cent. The saturation of hemoglobin depends on the partial pressure of oxygen in the plasma. When the oxygen tension is high most or all of the hemoglobin combines with oxygen; when the oxygen tension is low, only a small amount of hemoglobin combines with oxygen. These facts explain the dissociation of oxyhemoglobin at the tissue level. Oxygen is given up to the tissues from the arterial blood. The oxygen that is directly available to the tissues is that in solution in the plasma. As it is taken up by the tissue cells, the partial

pressure of the oxygen in the plasma falls, causing the oxyhemoglobin to dissociate into O_2 and Hb. The result is the release of oxygen from the erythrocytes into the plasma from where it is taken up by tissue cells.

The amount of oxygen given off by the blood to a particular tissue depends not only on the oxygen tension of that tissue but also on the partial pressure of carbon dioxide, the pH and the temperature of the blood.

The steps involved in oxygen transport may be summarized as follows.

1. Oxygen in the lungs diffuses through the alveoli into the blood plasma.

2. Most of the oxygen enters the erythrocytes and combines with hemoglobin, forming oxyhemoglobin. The rest remains in the blood plasma.

3. At the tissue or organ capillaries, oxygen in the blood plasma is taken up by the cells, thus reducing its concentration in the plasma.

4. The oxygen attached to the hemoglobin molecule is released and enters the plasma restoring the oxygen concentration level of the plasma. This oxygen is also taken up by the cell.

The Transport of Carbon Dioxide

Most of the carbon dioxide that diffuses into blood enters the erythrocytes where it reacts with water to form carbonic acid. The presence of the enzyme (a biological catalyst) carbonic anhydrase causes this reaction to take place rapidly. The carbonic acid dissociates to H^+, which is retained in the erythrocyte in combination with hemoglobin, and HCO_3^-, which is released into the plasma. The movement of the bicarbonate ion into the plasma occurs because of the low concentration of this ion in the plasma.

When the blood reaches the pulmonary capillaries the H^+ is released from the hemoglobin and replaced by oxygen which has diffused into the blood from the alveoli. The H^+ combines with the HCO_3^- and forms carbonic acid which is broken down by an enzyme into H_2O and CO_2. (The rapidity of this reaction prevents excess hydrogen ions from accumulating in the blood and lowering its pH.) The carbon dioxide diffuses into the alveoli and is exhaled from the body.

The steps involved in carbon dioxide transport may be summarized as follows.

1. Carbon dioxide, produced in the tissues and cells, diffuses into the blood with the great majority of CO_2 entering the erythrocytes.

2. About eight per cent of the CO_2 remains dissolved in the plasma and the erythrocytes.

3. About 25 per cent of the CO_2 reacts directly with hemoglobin to form $HbCO_2$.

4. About 67 per cent of the CO_2 combines with H_2O to form H_2CO_3. This reaction is catalyzed by the enzyme carbonic anhydrase. The carbonic acid dissociates into H^+ and HCO_3^- ions.

5. The H^+ ions are taken up by hemoglobin molecules (which aids in the release of oxygen), while the HCO_3^- ions are released into the plasma.

6. At the pulmonary capillaries, oxygen molecules (arriving from the alveoli) combine with the hemoglobin releasing the H^+ ions.

7. The H^+ ions combine with HCO_3^- ions forming carbonic acid which breaks down to CO_2 and H_2O.

8. CO_2 diffuses into the alveoli and is exhaled from the lungs.

INFORMATION ON LABORATORY ACTIVITY 33:

TEACHING NOTES:

1. The purpose of this activity is to give the students an opportunity to observe diffusion.

2. Anticipated time: one period.

3. The concentrations of the solutions have been kept as low as possible. The students are instructed to pipet the solutions. It is probably best to have them use one of the alternatives to mouth-pipetting.

4. An alternative method to the dialysis membrane bags is to either open the bag so you have a sheet or use sheets of cellophane. Put a rubberband around the lip of a test tube to form a larger lip. Stretch the membrane over the mouth of the test tube and secure with another rubber band. The solutions are added to the test tube which is then inverted into a beaker of solution.

5. The pH paper is best cut into 1-cm pieces before class to avoid waste. Forceps are used to handle the small pieces of paper. The students should be warned against throwing the paper in the sink.

6. The students should be cautioned about working with NaOH.

7. The students are instructed to determine how to dilute .1 M $CuSO_4$ to

make .01 M $CuSO_4$. To save time, this dilution could be done for them before class.

8. The egg albumin and glutamic acid solutions are supposed to be made before class. They could be prepared by some students at the beginning of the lab.

9. The precise measurement of the solutions which are put into the dialysis bags is not critical. If you feel the students could estimate these amounts, tell them so.

10. Glutamic acid was the amino acid chosen because of cost and solubility in water. Aspartic acid can be used if glutamic is not available.

11. One problem to look for is leaking of the dialysis tube. Leaking usually occurs because the knot in the end is not secure. Students should not fill the beakers with solution to a level above the string which secures the bag to the funnel.

12. The glutamic acid diffusion activity has a logical flaw in it. Glutamic acid can dissociate into glutamate$^-$ and H^+ ions. It is theoretically possible that H^+ ions diffused through the membrane while the glutamate$^-$ ions did not in the test as described. In other words, the pH test does not prove that glutamic acid actually passed through the membrane. (In reality, it is known that glutamic acid will pass through a dialysis membrane.)

The flaw was initially an oversight on our part. It was picked up in time to correct, but we decided not to correct it because the flaw has teaching value. We suggest that you use it to emphasize the care needed for clear thinking in research and to review the concept of dissociation of acids. With a few clues, and reference to Discussion Question 6, the students should be able to recognize the problem and to suggest the need for a more definitive test for glutamic acid.

If there is sufficient interest, it can be shown by the ninhydrin test that glutamic acid has indeed crossed the membrane. Ninhydrin (triketohydrindane hydrate) tests for amino acids and gives a purple color. To do this test, superimpose one drop of test solution and one drop of ninhydrin solution (0.2% in ethanol) on a clean piece of filter paper. The reaction will proceed at room temperature and give a pink to purple color after several hours. It can be made to react in a few minutes by placing the paper in an oven at 100 to 110 °C. Be careful not to get any finger prints on the wet ninhydrin since sweat contains

amino acids and will result in a false positive test. Also do not get any ninhydrin on the skin--it results in a stain which will remain for several hours.

MATERIALS: (for 15 set-ups)

- .1 M $CuSO_4$ solution saved from LA-24
- .1 M NaOH solution saved from LA-24
- .01 NaOH solution saved from LA-24
- 2.4 g glutamic acid
- 6 g dehydrated egg albumin (or 2-3 fresh eggs)
- 15 50-ml beakers
- 60 150-ml or 250-ml beakers
- 30 pieces dialysis membrane, approximately 10 cm long
- 30 lengths of string, 15 to 20 cm long
- 1 balance--optional
- 1 scoopula--optional
- 15 graduated cylinders, 100-ml
- 15 pipets, 10-ml
- 30 funnels
- 1-2 rolls pH paper and color scale (1-11)
- 15 forceps
- 30 or more test tubes, 16 x 125 mm
- 15 glass-marking pencils
- 15 toothpicks
- 1 (or more) bottles food coloring
- 15 medicine droppers

PREPARATION OF REAGENTS:

Egg Albumin Solution: Mix 6 g dehydrated albumin in 300 ml tap water. Stir to break up lumps of albumin. Store in refrigerator in capped container. Can be stored up to 10 days or until contaminants grow in solution. OR Dilute 30 ml fresh egg white to 300 ml solution with tap water.

Glutamic Acid: Dissolve 2.4 g glutamic acid in 200 ml tap water. Store in capped bottle in refrigerator.

ANTICIPATED RESULTS:

Part I: After 20 to 30 minutes the solution will be the same color throughout.

Part II: Mix 1 ml .1 M $CuSO_4$ with 9 ml water.

Part IV: The solution in the bag will turn violet indicating the presence of protein inside the bag. The solution outside the bag will remain clear and colorless.

The pH of the solution outside the bag will change from about 8 to about 5 or 6.

ANSWERS TO QUESTIONS:

1. The random movement of the molecules of water and of the food coloring. The movement of the molecules of food coloring was from a region of high concentration to a low concentration of food coloring. Gravity has some effect on the movement of the molecules.

2. The evidence of movement in the "protein" set-up was the color change observed in the tube from off-white to violet. The evidence of movement in the "amino acid" set-up was the change in pH of the water in the beaker. In the "protein" set-up the movement was of $CuSO_4$ into the tube. In the "amino acid" set-up the movement was of glutamic acid out of the tube and into the water.

3. The substances moved through the membranes because of differences in concentrations inside and ouside the tube.

4. Protein molecules are too large to pass through the membrane.

5. The concentrations of the glutamic acid both inside and outside the membrane would be the same if the set-up stood for a long time.

6. a. Yes, if the hydrogen ions alone moved through the membrane, the pH would become lower.

b. No, only that the pH changed.

c. (See Teaching Note 12.)

LESSON 34: (A) OSMOSIS

(B) THE IMPORTANCE OF ISOTONIC SOLUTIONS IN INTRAVENOUS THERAPY

RATIONALE:

In Lesson 33 we considered the process of diffusion and the transfer of gases in the lungs. Osmosis is essentially the diffusion of water, a key process in the maintenance of the human body. In this lesson we consider this process, its functions and its relationship to drowning.

LA-34 gives the student an opportunity to discover the importance of concentration of body fluid components when treating a patient with intravenous solutions.

OBJECTIVES:

The student will define osmosis and semipermeable.

The student will explain why water collects around injured cells, causing inflammation.

The student will explain how osmosis may result in death in both freshwater and seawater drownings.

The student will state the importance of administering a saline solution of a specific concentration rather than distilled water to patients.

SEQUENCE: ST-34; LA-34

SUGGESTION:

A suggested teacher demonstration of osmosis follows the Information on LA-34.

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INFORMATION ON LABORATORY ACTIVITY 34:

TEACHING NOTES:

1. The purpose of this activity is, first, for the students to observe what happens on the visible and microscopic levels when blood is mixed with water containing various concentrations of salt. Second, the students are asked to provide an explanation for their observations by relating them to the principle of osmosis.

2. This is the first time that students will puncture themselves with a lancet. They will be called upon to perform this procedure at several times in the Biomedical Program. You may wish to stress the safety factors involved, such as opening a lancet package at the correct end, holding the lancet at the correct end so as not to contaminate it, disposing of the lancet immediately after use, and wiping the fingertip with alcohol before. You may wish to point out that good aseptic techniques are essential to proper medical care and that these techniques should become habitual, so that each student will be able to use them almost instinctively if someday faced with an emergency situation and forced to act very quickly.

3. Note that the type of water (tap or distilled) to be used is not specified in the procedure. Tap water in some areas has a lot of dissolved minerals, which might alter results. If the tap water is suspect in this way, you may test it first by drawing a drop of blood with the lancet and using a capillary tube to transfer some of it to 5 ml of tap water and some to 5 ml of 1 per cent (1 gm/100 ml) sodium chloride in tap water. The plain tap water mixture should become clear and the salt water should remain cloudy. If necessary, use distilled water instead of tap water for the activity. 750 ml of distilled water would be needed in this case for 15 setups.

4. The procedure may be interrupted after Step 2 of Part I. In this case, the stock salt solution and the seven test solutions must be protected against evaporation.

5. Pipetting from a 1-ml pipet is used throughout this activity. Information on pipetting techniques was presented in Teacher Notes for Unit I, Laboratory Activity 3.

6. Blood will be tested in solutions of .14, .12, .10, .08, .06, .04 and .02 M sodium chloride. Some of the red blood cells will lyse (absorb water and burst) at .06 M and all will lyse at .04 and .02 M. To shorten the procedure, the .14 M may be eliminated and only tests on .10 M or less performed.

The concentration of physiological (normal) saline, which is transfused into people's blood, is 0.15 M, and not 0.06 M, the concentration at which some red blood cells lyse. The reason for this difference is discussed below, in "Answers to Discussion Questions," Number 6.

7. The activity calls for students to prepare 50 ml of 0.14 M sodium chloride. It is good reinforcement for the students to make the solutions themselves. It reinforces the concept of molarity and the laboratory techniques involving concentrations.

Provide help as needed in the determination of the mass of NaCl needed for the preparation of the stock salt solution in Step 1. You may wish to have the calculations handed in as part of the lab write-up. Each student or group should probably be required to check their results before preparing the solution. The calculations may be done as follows.

$$\begin{aligned} \text{GAW Na} &\approx 22.99 \text{ g} \\ \text{GAW Cl} &\approx \underline{35.45} \text{ g} \\ \text{GMW NaCl} &\approx 58.44 \text{ g} \end{aligned}$$

$$\frac{.14\,\cancel{M}}{\cancel{\text{liter}}} \times \frac{58.44 \text{ g}}{\cancel{M}} \times \frac{\cancel{\text{liter}}}{1000 \text{ ml}} \times 50 \text{ ml} = \frac{\cancel{50}(.14)(58.44)}{\cancel{1000}_{20}}$$

$$= \frac{\overset{.007}{\cancel{(.14)}}(58.44)}{\cancel{20}}$$

$$\approx .41 \text{ g NaCl}$$

8. The students are called upon to make several different dilutions of sodium chloride. Figure 1 in the Laboratory Activity shows the amounts of tap water and sodium chloride stock solution to be mixed together in order to make these dilutions. The numbers were arrived at as follows. Since a .12 M solution has six-sevenths the NaCl that a .14 M solution has, for the same volume, we can make a solution that is six-sevenths stock salt solution and one-seventh water, etc. Six-sevenths ≈ .86.

9. A capillary pipet is used to transfer blood from the fingertip to the watch glass. The reason blood enters the very thin capillary tube is because of attraction between the water molecules in blood and the glass inside the capillary tube. This phenomenon is called capillary action. A physics text will provide further material on this subject.

10. When blood cells lyse too easily they are said to be too fragile. While red blood cells in the test tube can be made to lyse in water with low salt

content, this rarely occurs in the body because the salt concentration of plasma is very stable. The clinical importance of the test tube test is that if red blood cells lyse too easily in the test tube, whatever cell defect is causing it to happen is probably also causing them to be destroyed in some other way by the body. The defect may be in the cell membrane or in the shape of the cell, and it occurs in a certain inherited anemia called spherocytosis, in which the red blood cells are spherical rather than biconcave in shape.

MATERIALS: (for 15 setups)

- 15 test-tube racks
- 105 test tubes, 16 x 125 mm
- 15 g NaCl (sodium chloride)
- 30 beakers, 150-ml
- 15 stirring rods
- 30 pipets, 1-ml
- 15 capillary tubes, 1.2 x 75 mm
- 15 alcohol cotton wipe packets
- 15 lancets
- 15 glass-marking pencils
- 15 metric rulers
- 15 balances
- 15 graduated cylinders, 50-ml
- 15 watch glasses
- 15 medicine droppers

ANTICIPATED RESULTS:

PART I:

When blood cells lyse they burst and release their hemoglobin and become barely visible membrane remnants. This scatters light much less than a solution of intact red blood cells. Therefore, a solution of lysed red blood cells appears clear (transparent).

Blood cells will lyse in the .04 M and .02 M solutions. These solutions turn clear. The .06 per cent solution may show partial lysis--it may be less cloudy than the higher concentrations. The .14 M through .08 M solutions will show no lysis--they will remain cloudy.

PART II:

Cloudy solutions will show red blood cells in the microscope. Clear solutions will not.

ANSWERS TO DISCUSSION QUESTIONS:

1. See "Anticipated Results, Part I."
2. See "Anticipated Results, Part II."

3. The microscopic observations suggest that the red blood cells in the clear solutions were destroyed.

4. Red blood cells placed in water with too low a salt concentration absorb water by osmosis. When the amount of water absorbed exceeds a certain volume, red blood cells burst.

5. More water flowed in when they were placed in a low salt concentration.

6. If the liquid is too dilute, the red blood cells will burst. (If it is too salty, water will leave them and they will shrink.) A salt concentration of .04 M or .02 M would be very dangerous.

The reason that normal saline, used clinically, has more than twice the salt concentration (.15 M) as that at which red blood cells lyse (.06 M) is as follows. At concentrations under .15 M, water will diffuse into the red blood cells, but unless we get below .06 M or so, hemolysis will not occur. In other words, between .15 M and .06 M, the membranes may stretch without bursting. Above .15 M, water will diffuse out of the cell, making the cells shrink in volume. (This was not done in the laboratory activity because the procedure was long enough, and because the phenomenon would be difficult to demonstrate without high magnification and better microscope technique than the students have at this point.)

INFORMATION ON OSMOSIS DEMONSTRATION:

In the laboratory activity, students will put blood into salt solutions of different concentrations, observe what happens, and try to explain the observations. The following optional demonstration of osmosis, performed by the instructor, will help to provide a better understanding of what happens to blood in the activity. If you don't wish to perform the demonstration, you may explain osmosis in some other way.

The demonstration utilizes dialysis membrane bags, which, like red blood cells, can be made to fill with water due to osmosis.

MATERIALS:

ring stand and clamps
dialysis tubing, 1 in flat width
2 beakers, 250-ml
string or wire
16 fluid ounces (1 pint) of molasses or corn syrup

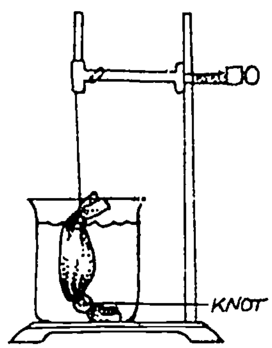
PROCEDURE:

At the beginning of the period, while the students are working, you can set up a demonstration of osmosis. The steps in the next paragraph below may be done before class, even the day before, and the bags set aside.

Cut two 15-cm pieces of dialysis tubing. Hold the cut edge of each under running water for about 30 seconds to get the two sides of the tubing separated. Then tie one end of each tube into a simple tight knot.

Over a sink, fill each tube about a third full of molasses or corn syrup and tie off the open end of each tube. Squeeze gently to check for leaks. These bags may be set aside in a dry place if necessary.

Tie a string or wire around one end of each bag and suspend each from a ringstand clamp into a 250-ml beaker. See diagram below. Fill one beaker with molasses (or corn syrup if that is used) and the other with tap water. Suspend the knot at the top end of the bags above the liquid in the beaker, to reduce the chance of leakage.



Describe the demonstration to the class. In an hour or more, the bag surrounded by water will have swollen up and become sausage-shaped. Explain why this happens. The key point is the phenomenon observed in the previous activity: diffusion. More water diffuses into the bag than out of the bag because of the high sugar concentration inside. See the Student Text for more details. The bag of molasses is similar to red blood cells in that both absorb water under certain conditions. Relate the bag to the laboratory activity after the students have made their observations.

ALTERNATIVE OR ADDITIONAL DEMONSTRATION OF OSMOSIS

The advantage of the following demonstration is that it shows osmosis within ten minutes and may be done instead of, or along with, the above demonstration. However, the above one provides a closer analogy to the red blood cell because it utilizes a closed bag.

MATERIALS:

Same as above, plus:

food coloring (if corn syrup is used)

2 1-ml pipets

PROCEDURE:

If corn syrup instead of molasses is used for this procedure, color it by adding 4 or 5 drops of food coloring to 350 ml of corn syrup. Prepare dialysis bags as described except fill the bags almost completely with molasses or corn syrup. Then, insert a 1-ml pipet about 2 cm into each bag and tie each bag to the pipet with a string. Rinse any sugar off the bags and place each in a 250-ml beaker. Support the glass tubing with a ring-stand clamp. Fill one beaker with enough water to cover the bag (but not the string tie) and the other beaker with molasses or corn syrup.

Osmosis will occur so fast that liquid will flow out the top of the pipet in a half-hour. To avoid this, you may want to use a 10-ml instead of a 1-ml pipet, but the movement of the liquid up the pipet will be less dramatic.

Describe the demonstration, stressing that the only difference between the bag set-ups is that one beaker is filled with molasses (or corn syrup) and the other with water. In fifteen minutes there will be a clear difference between the level of the fluid in the two pipets. Discuss the results, explaining why the difference occurs. You can point out that the bags of molasses are similar to red blood cells in that they both absorb water under certain conditions. Relate this to the laboratory activity after the students have made their observations.

LESSON 35: (A) AVOGADRO'S PRINCIPLE

(B) ELECTROLYSIS OF WATER

RATIONALE:

The function of the respiratory system is to provide the body with oxygen for chemical reactions and eliminate the carbon dioxide which is a by-product of these reactions. The metabolic processes will be discussed in more depth in Unit II (Nutrition). One of the most important reactions from which our bodies derive energy is the oxidation of glucose. But how many liters of oxygen must a person breathe to oxidize a given amount of glucose? Questions of this sort are of importance when planning respiratory therapy for a patient, because his oxygen requirements must be taken into account. To answer such questions, it

is necessary to consider Avogadro's Principle, which explains the relationship between moles of a gas and the volume they occupy. This is the topic of Lesson 35.

OBJECTIVES:

The student will state Avogadro's Principle and use it to solve problems.

The student will electrolyze water into hydrogen and oxygen gases and will test for and identify each gas.

SEQUENCE: ST-35; LA-35

KEY--PROBLEM SET 35:

1. a. 3.5 liters of O_2 react with 7 liters of SO_2.

   b. 3.5 liters

2. a. 18 liters

   b. 53.8 g

3. a. 32 g

   b. .50 moles

   c. same as b

   d. 11.2 liters

   e. 22.4 liters

4. 2.24 liters

5. a. 14.78 liter/hr

   b. 16.14 liter/hr

   c. 387.29 liter

INFORMATION ON LABORATORY ACTIVITY 35:

TEACHING NOTES:

1. In this activity, water is electrolyzed, dissociating it into its component elements, hydrogen and oxygen. The principles of the activity parallel the study of the gas laws in the Student Text, and review the phenomenon of solution conductivity. In addition, some of the simple chemistry of hydrogen gas is shown.

2. Anticipated time: one period.

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3. The electrolysis is carried out with electrodes made from iron nails in an electrolysis solution of 0.1 M sodium hydroxide. The electrolyte provides enough conductivity so that current flows freely through the solution. The overall reaction may be represented as follows:

$$2\,OH^- \longrightarrow O_2 + 2\,H^+ + 4e^- \quad \text{at the anode (S)}$$

$$4\,H^+ + 4e^- \longrightarrow 2\,H_2 \quad \text{at the cathode (X)}$$

$$2\,H^+ + 2\,OH^- \rightarrow 2\,H_2 + O_2$$

which is equivalent to the reaction, $2\,H_2O \rightarrow O_2 + H_2$.

4. During electrolysis, an external voltage source is applied to a solution, which brings about a chemical change. The opposite occurs in electrochemical cells (batteries, for example), where a spontaneous chemical reaction occurs that provides electrical power. Electrolysis is of great importance in industry since it can be used to separate many of the active elements from their compounds.

$$2\,NaCl\text{ (fused)} \rightarrow 2\,Na + Cl_2$$

Another typical reaction is the electrolysis of a solution of sodium chloride. The products include sodium hydroxide and chlorine gas.

$$2\,NaCl + 2\,H_2O \rightarrow 2\,NaOH + Cl_2 + H_2$$

5. If mossy zinc is not available, approximately 5 g of zinc of a different grade is suitable.

6. Tell students to ignore the ring stand and clamp listed on p. 156 of the lab manual.

MATERIALS: (for 10 set-ups)

10 beakers, 250-ml
12 g sodium hydroxide (NaOH)
20 electrodes
10 BIP's
40 to 60 test tubes, 16 x 125 mm
40 to 60 stoppers, cork, #4
10 test-tube racks
clock with second hand
10 glass-marking pencils

75 g zinc metal
30 ml hydrochloric acid, concentrated
10 gas-generating set-ups from LA-8
- 10 test tubes, 25 x 200 mm
- 10 rubber stoppers, one-hole, #4
- 50 cm glass tubing, 6 mm O.D.
- 750 cm rubber tubing, 3/16" I.D.
- 10 ring stands
- 10 ring-stand clamps

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PREPARATION OF REAGENTS:

Hydrochloric acid, 1 M: To approximately 200 ml of water, add 30 ml of concentrated hydrochloric acid. Dilute to a final volume of 350 ml.

Sodium hydroxide, 0.1 M: Dissolve 12 g of sodium hydroxide pellets in 3000 ml of water, total volume.

PREPARATION OF MATERIALS:

Electrodes may be prepared by soldering a length of BIP programming wire to the head of an iron nail, 1-1/2 to 2" long. The nail must not be galvanized. The soldered connection should be coated with a layer of silicone rubber cement to prevent corrosion of the connection point. Note that the cement requires 24 hours to cure.

ANSWERS TO DISCUSSION QUESTIONS:

1. Oxygen causes a glowing splint to burst into flame while hydrogen gas extinguishes the splint. A burning splint causes the hydrogen to burn rapidly with a distinct "pop."

2. $2\ H_2O \rightarrow 2\ H_2 + O_2$

3. The reverse of the above reaction.

4. $Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$

5. The anode is attached to S. Since the anode is positively charged, it attracts electrons, thus supporting the reaction $2\ OH^- \rightarrow O_2 + 4\ e^- + 2\ H^+$. At the negatively charged cathode, electrons combine with hydrogen ions as in the reaction $2\ H^+ + 2\ e^- \rightarrow H_2$.

LESSON 36: (A) THE UNIVERSAL GAS LAW

(B) OXIMETRY

RATIONALE:

Earlier the students were introduced to Boyle's Law, Charles' Law and Avogadro's Principle, each of which deals with the properties of gases under certain conditions. In this lessson all this information is combined and the Universal Gas Law is derived. This law is important in that it relates the volume, temperature, pressure and number of moles of a gas to one another. An understanding of this law is also required to calculate partial pressures of gaseous mixtures, which, in turn, are of great physiological importance, as will be shown in Lesson 37.

In LA-36 the students use an oximeter to determine the relationship between the amount of oxygen in the blood and the length of time they hold their breath.

OBJECTIVES:

The student will state the Universal Gas Law and demonstrate its usefulness in the solution of problems.

The student will explain how an oximeter may be used to determine the amount of oxygen in circulating blood.

The student will demonstrate that the amount of oxygen in the blood decreases as breath-holding time increases.

SEQUENCE: ST-36; LA-36; or the reverse

KEY--PROBLEM SET 36:

1. 800.86 liters
2. 0.003 moles O_2
3. 0.524 moles air

INFORMATION ON LABORATORY ACTIVITY 36:

TEACHING NOTES:

1. This activity is designed to acquaint the students with some of the properties of hemoglobin, the respiratory protein in all vertebrates. Using a device called an oximeter, the degree to which the hemoglobin in the blood is oxygenated may be monitored. Oximeters are used clinically in measuring the rate of blood circulation and to detect abnormally low levels of hemoglobin oxygenation (a condition known as cyanosis).

2. Anticipated time: one period.

3. If breath-holding does not produce marked results, it may be possible to demonstrate a reduction in hemoglobin oxygenation by impairing the arterial circulation to the thumb. This is accomplished by applying firm pressure to the ulnar and radial arteries which provide the thumb with oxygenated blood.

4. ACE bandages, 2" wide, may be purchased from drug stores in six-foot lengths. These may be cut in half to make two three-foot lengths. ACE bandages are used later in the course for taking electrocardiograms and electroencephalograms with the BIP.

5. The oximeters should be made at least one day before the activity, since the silicone rubber cement used in the assembly requires 24 hours for a complete cure.

MATERIALS: (per 10 set-ups)

10 BIP's

10 oximeters

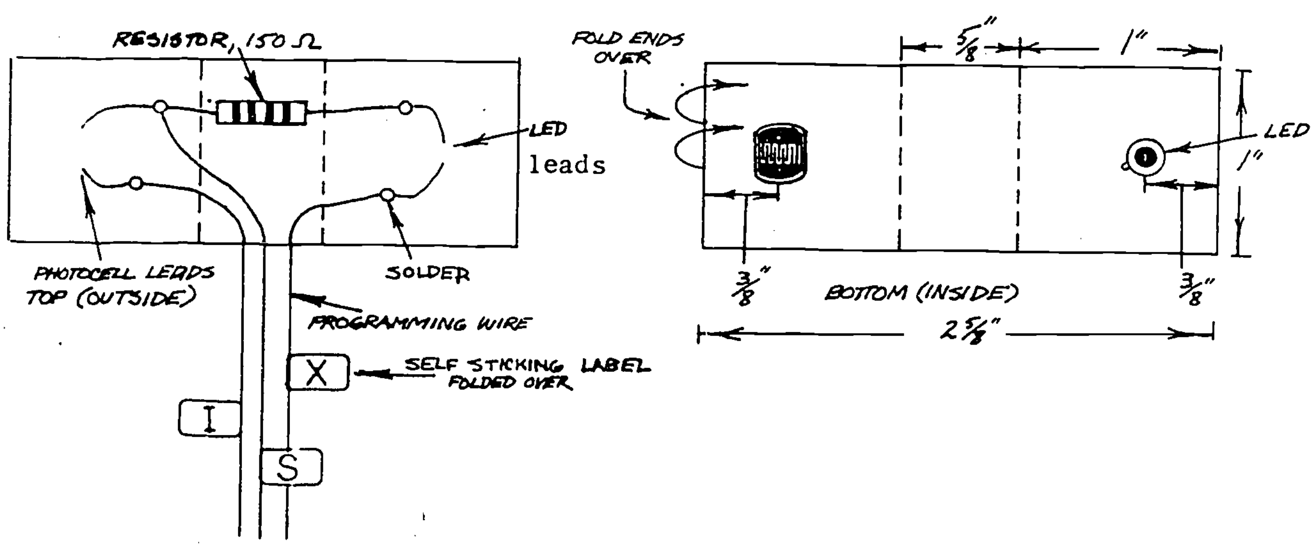
10 ACE bandages, 3 ft x 2 in

PREPARATION OF MATERIALS:

An oximeter may be prepared using some of the extra supplies provided with the BIP. The materials necessary for one oximeter are

photocell, Vactec #721
light-emitting diode (LED)
150Ω resistor, 1/4 watt
thin cardboard, 1" x 2-5/8"
programming wire, 3 2-ft lengths
silicone rubber cement
soldering iron, solder, wire cutters
labels, self-sticking

A full-sized diagram of the oximeter opened up is provided below, showing both a view from the top and from the bottom.



A pin may be used to make holes for the photocell and LED leads.

Examine the case of the LED. One of the leads of the LED is marked with a small metal tab on the case. The lead next to the tab must be connected to the resistor lead. After making sure that the orientation of the LED is correct, insert the leads through the pinholes and attach them to the resistor and a length of programming wire. Insert the photocell and connect its leads as shown in the diagram (the orientation of the photocell is not important). Solder the connections and snip off any loose ends. The exposed wires may be held in place by sticking them to the cardboard with small amounts of silicone rubber cement. This ensures that no bare wires come into contact. The silicone rubber should be allowed to cure overnight. (If silicone rubber cement is used, and the leads to the photocell and LED are not cut too short, the device may be disassembled easily; this permits the components to be used in other activities.)

After the cement has cured, the oximeter is folded into a rectangular shape where indicated by the dotted lines. The ends of the programming wire that are to be plugged into the BIP should be labeled as indicated in the diagram. This may be accomplished by writing the appropriate letter on a self-sticking label, which is then folded over the wire so that the label sticks to itself.

ANTICIPATED RESULTS:

After holding the breath for as long as is reasonably possible, the BIP reading should decrease approximately 4 to 10 units on the mA dial. Shorter periods of breath-holding produce less marked results.

The circulation time from the lungs to the thumb may be measured as follows.

1. The subject breathes normally. With the oximeter in place as before, the BIP is nulled and a reading is taken and recorded.

2. The subject holds his or her breath until the reading on the mA dial drops 4 to 6 units. (This change may be monitored by continually adjusting the mA dial to the null point.) This second reading is recorded.

3. When the subject resumes breathing, the time is noted and the dial is quickly set midway between the first and second readings. For example, if the first reading is 40 and the second reading is 32, the midpoint setting would be 36.

4. When oxygenated blood reaches the thumb, the BIP reading begins to increase, and passes the midpoint setting. At this point, the state of the diode

lights changes; that is, one shuts off and the other goes on. The time should again be noted. The circulation time from lung to thumb is the interval between the resumption of breathing and the change in the state of the diode lights. In healthy people, this circulation time should range between 20 and 30 seconds.

LESSON 37: (A) OXYGEN AND CARBON DIOXIDE TRANSPORT AND PARTIAL PRESSURE

(B) DECOMPRESSION SICKNESS

(C) REVIEW

RATIONALE:

In Lesson 31 the diffusion of oxygen and carbon dioxide into and out of the body's cells was discussed. The amount of oxygen or carbon dioxide that the hemoglobin can carry to and from cells is determined by the partial pressures of these two gases both in the air we breathe and in the body fluids. Partial pressures also help to explain such diseases as decompression sickness and high-altitude sickness.

OBJECTIVES:

The student will state the Law of Partial Pressure.

The student will state the relationship between the partial pressure of a gas and its solubility.

The student will define decompression sickness and state its cause and treatment.

The student will explain the relationship between partial pressures of oxygen and carbon dioxide in the body and the transport of these gases by hemoglobin to and from body cells.

The student will explain how altitude affects the partial pressure of oxygen in the atmosphere and how this, in turn, contributes to altitude sickness.

SEQUENCE: ST-37; REVIEW

SUGGESTIONS:

If any of the students have done scuba diving you might ask them to share their experiences with the class. What does it feel like as you descend deeper and deeper? How do you gauge how fast to come back to the surface?

KEY--PROBLEM SET 37:

1. 0.053 atm

2. 0.126 atm

3. $P_{N_2} = 0.663$ atm

$P_{O_2} = 0.169$ atm

$P_{H_2O} = 0.009$ atm

$P_{argon} = 0.007$ atm

4. 0.028 atm

5. 2.31 atm

KEY--REVIEW SET 37:

1. This was an unfair question because the Student Text does not provide a basis for the students to answer it. Sorry. As a matter of fact, deep sea divers do carry pure oxygen in their tanks. But inhaling too much oxygen for too long a period can cause damage to the central nervous system and even death. This may be related to the fact that blood flow to the brain decreases significantly when a person breathes pure oxygen.

2. The symptoms of respiratory alkalosis include dizziness, numbness, weakness, and twitching. If treatment is not given the person may become unconscious. Treatment involves decreasing the amount of CO_2 lost through the lungs. There are various ways to do this such as holding the breath or expiring into a bag filled with CO_2-rich air.

3. Characteristics of acids: Acids produce hydrogen ions in solution; they have a sour taste, they may dissolve metals and burn skin and body tissue.

4. Characteristics of bases: Bases produce hydroxide ions in solution; their solutions feel slippery; they taste bitter; they tend to be poisonous; they may cause severe burns.

5. A salt is an ionic substance that can be formed when an acid and a base neutralize one another.

6. The water in the pot was basic. A substance that changes color with a change in pH is an indicator.

7. pH tells you the hydrogen ion concentration in moles per liter: this tells whether the solution is basic or acidic.

8. If the amount of CO_2 in the bloodstream becomes excessive, the breathing rate increases. If there is too much O_2, the breathing rate decreases. If there is too little O_2, the breathing rate increases.

9. The chemoreceptors that affect breathing include those of the respiratory center and the aortic and carotid bodies. The function of these

chemoreceptors is to monitor the hydrogen ion concentration in the blood and to send out signals that adjust the breathing rate accordingly. The aortic and carotid bodies also monitor the amount of oxygen dissolved in the blood. When the concentration of oxygen drops below a certain value these chemoreceptors send signals to the respiratory center to increase the breathing rate.

10. The blood pH of a person who is hyperventilating is going to be high. Another term for this condition is respiratory alkalosis.

11. Diffusion is the movement of a substance from a region of high concentration to a region of low concentration. Osmosis is also a form of diffusion but its definition is more restricted: it is the diffusion of water across a semipermeable membrane from a region of high concentration to one of low concentration. The interchange of gases in the lungs occurs via diffusion. The movement of waterinto and out of cells is an example of osmosis.

12. No. Hemoglobin may also transport carbon dioxide, carbon monoxide or nitrogen dioxide.

13. In fresh-water drownings, water diffuses from the lungs into the blood stream, increasing the blood volume, and upsetting the chemical balance. This leads to heart failure. In salt-water drownings, water diffuses from the blood into the lungs, causing pulmonary edema. However, in this case the cause of death is also likely to be due to the imbalance in the blood chemistry, leading to heart failure, rather than suffocation.

14. Avogadro's Principle states that equal volumes of gases at the same temperature and pressure contain the same number of molecules.

15. The volume of 1 mole of gas at 273° Kelvin and a pressure of 1 atm is 22.4 liters.

16. The volume of a gas is proportional to its absolute temperature at a constant pressure. $V = kT$, where k is the proportionality constant.

17. The volume of a gas is proportional to the reciprocal of the pressure at a constant temperature. $V = k_1(\frac{1}{P})$, where k_1 is the proportionality constant.

18. The volume of a gas is directly proportional to the number of moles and the temperature, and inversely proportional to the pressure. $V = \frac{RnT}{P}$, where R is the universal gas constant.

19. In a mixture of gases, each gas exerts the pressure that it would exert if it alone occupied the space and the total pressure exerted by the mixture of gases is equal to the sum of the partial pressures of the individual gases.

20. A sudden lowering of the partial pressure of nitrogen gas within the blood causes nitrogen bubbles to form in the blood.

21. If you ascended to a high altitude quickly in an unpressurized plane, the pressure drop would cause lowering of the partial pressures of the gases in your body. The result would be similar to what happens in decompression sickness.

LESSON 38: (A) SURFACE AREA AND RESPIRATION

(B) BRONCHITIS

RATIONALE:

In this lesson the surface area to volume ratio is related to the size of an object. This ratio is discussed in relation to the feasibility of respiration through the skin. The larger the animla the lower this ratio is and the less feasible skin respiration becomes. How this difficulty is overcome in various animals, including man, is the topic of the first part of this lesson. The second portion is concerned with the nature of chronic bronchitis, a respiratory disorder that reduces the surface area in the lungs available for gas diffusion.

The the case history, one of the tests administered to determine whether Tom has a respiratory impairment is FEV_1. In LA-38 the students will perform this test upon themselves.

OBJECTIVES:

The student will state the effect of size on the ratio of surface area to volume.

The student will explain why large animals cannot use their outer surface as a respiratory organ.

The student will explain how the structure of the human respiratory system maximizes the surface area available for gas exchange.

The student will define the terms acute, chronic and bronchitis.

The student will list the criteria for classifying a particular case of bronchitis as chronic.

The student will state the main symptom of bronchitis.

The student will define cilia and explain their function in the respiratory tract.

The student will list the effects that bronchitis has on the respiratory system.

The student will explain how smoking maypredispose a person to respiratory infections such as bronchitis.

The student will state the treatment for bronchitis.

The student will determine the volume of air he/she can exhale in 1 second (FEV_1) and express it as a percentage of FEV_T.

The student will explain how the FEV_1 test is used to assess respiratory impairment.

SEQUENCE: ST-38; LA-38

SUGGESTIONS:

1. Another example that can be used to illustrate the effect of a change in size on the surface area to volume ratio involves a bar of soap. The bar has a particular volume and surface area. If we now slice the bar in half, what has happend to the volume and the total surface area? Note that the total volume has not changed. All the original surfaces are left, but now there are also two new surfaces, so the total surface area has increased. This model based on a bar of soap is another way of illustrating why a small cubeast has an advantage in respiration relative to a larger cubeast.

2. In the Student Text the hypertrophy of mucus cells in the respiratory system is discussed as one of the symptoms of bronchitis. If you can obtain microscope slides of these cells, the students could look at them when bronchitis was discussed in class. You may wish to check with a hospital laboratory well in advance of this activity to find out if they can provide pathological specimens.

3. If you have been able to obtain any pamphlets or other materials on bronchitis, you might refer to them now.

INFORMATION ON CHRONIC BRONCHITIS

Introduction

Bronchitis is an inflammation of the lining of the bronchial tubes. It results in labored breathing and the production of heavy mucus or phlegm which is usually coughed up. It is a disease particularly common among people in their middle years. In terms of disability as well as dollars, it is among the most costly of all public health problems in the United States today.

Characteristics of Bronchitis

Chronic bronchitis is characterized by a chronic productive cough on most days for at least three successive months of the year over a two-year period. Chronic bronchitis is diagnosed only after other possible causes of the cough, such as tuberculosis, have been excluded.

The term "productive" means sputum is coughed up.

Sputum is a mixture of:

1. The plasma which normally escapes from circulation into the alveolar space.

2. Mucus secreted by specialized cells lining the bronchi.

3. Any foreign bodies trapped by this mixture.

4. Pus, bacteria, etc., resulting from infection or severe irritation.

The cough associated with bronchitis is a reflex, stimulated to expel sputum from the bronchial passages.

The sequence of events leading to bronchitis begins with changes in the tissues lining the bronchial passageways. In normal individuals the lungs are kept clear and clean. The bronchi and bronchioles are lined with mucus-secreting cells and ciliated cells. The bronchial mucus and any foreign matter it may have collected are swept upward along the bronchial passages by ciliary action. The mucus is propelled toward the trachea and larynx and swallowed without conscious effort.

Microscopic examination of lung tissue from bronchitis victims shows hypertrophy (abnormal increase in size) and hyperplasia (abnormal increase in number) of the specialized mucus-secreting cells lining the bronchial passages. This results in an abnormally high rate of mucus production.

Bronchitis victims also have diminished and impaired ciliary action. It is ciliary action which would normally clear the bronchial passages of excess mucus.

Hypersecretion of mucus and impaired ciliary action leads to mucus accumulation in the breathing passages.

Development of Bronchitis

Chronic bronchitis is usually accompanied by chronic bronchial infection. Bacteria and viruses are normally swept out of the breathing passages with the

bronchial mucus. When mucus accumulates (because of excess mucus production and decreased ciliary action), bacterial and viral proliferation can continue unhindered in the bronchial passages. The bacterial inflammation changes the normally clear mucus to a yellowish color, because of pus content.

Inflammation can cause extensive damage to the breathing passages. Severe inflammation can totally obliterate small air passages. Less severe inflammation may heal, leaving no trace.

Inflammation also destroys ciliary cells. Ciliated cells destroyed by inflammation are replaced by non-ciliated cells, further predisposing the bronchi to inflammation and damage.

The accumulation of mucus in the breathing passages can obstruct breathing to such an extent that dyspnea is encountered. Dyspnea is a feeling of suffocation or shortness of breath.

Mucus may also accumulate in the alveoli rendering them useless for gas exchange and compounding the problem of breathlessness.

<u>Treatment of Bronchitis</u>

Treatment of bronchitis relies on antibiotic drugs to speed recovery from bacterial infection, but these drugs do not cure bronchitis. As long as the cleansing action of the lungs is impaired (by hypersecretion of mucus and impaired ciliary action), the lungs are vulnerable to infection and damage.

It has been conclusively shown that cigarette smoke and certain components of air pollution cause excess mucus production and inhibit ciliary action.

With lung diseases such as bronchitis it is difficult to separate the initial causes of the disease from the effects which follow.

Treatment of bronchitis relies on prompt and definitive care for acute respiratory infection and other episodes such as asthma, and the removal of irritating factors such as cigarette smoking.

INFORMATION ON LABORATORY ACTIVITY 38:

TEACHING NOTES:

1. The purpose of this activity is to measure the amount of air that can be exhaled from the lungs in one second (FEV_1). When expressed as a percentage of the total vital capacity (FEV_T), FEV_1 serves as one of the best indicators of pulmonary function.

2. It is doubtful that any values for the timed exhalation percentage will be less than 75%. In the event that low values are obtained, it should be emphasized that improper procedure may be responsible for inaccurate results. Clinically, low values may indicate some type of airway obstruction or a reduction in lung elasticity. If a student's percentage is very low, or a student is concerned about his results, recommend a visit to the family doctor.

3. Since young people rarely show impaired lung function, it is recommended that the test also be performed on adults (teachers, etc.), and, if possible, on long-term smokers. (It is thought that smoking over long periods of time leads to loss of lung elasticity.)

4. This activity may be augmented by having the students attempt to breathe through a straw. This demonstrates how it feels to have an obstructive lung problem such as is associated with emphysema, chronic bronchitis or asthma. Have the students breathe through the straws while sitting quietly. After a few minutes, have them perform light exercise (such as running in place) while continuing to breathe exclusively through the straw.

The students should record their feelings and sensations resulting from the exercise. The sensation of suffocation is a result of insufficient oxygen intake, and is very similar to what a person with a respiratory limitation would feel if he attempted to climb a flight of stairs or perform some similar activity that most of us can accomplish with ease.

5. Note that no sample data sheet is provided for this activity. It is assumed that the students can record and report their own data.

MATERIALS:

source of timed, one-second signals
2 spirometers (more if possible)
plastic wrap or other suitable mouthpiece covering

PREPARATION OF MATERIALS:

See LA-14 for information on producing timed signals.

See LA-18 for information on making a spirometer.

ANSWERS TO DISCUSSION QUESTIONS:

1. FEV_T can vary considerably from person to person depending upon body dimensions. If FEV_1 were not expressed as a percentage of FEV_T, it could be possible for a person in poor health with large lungs to score higher than a healthy individual with small lungs.

2. The answers will depend on the class data accumulated. However, on the average, the non-smokers' timed exhalation values should be higher than the smokers' values. The conclusion the students can make is that smoking somehow affects amount of air one can exhale in one second. This implies that a breathing problem exists; however, in individual cases, low results may be caused by experimental or calculation errors.

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LESSON 39: AIR POLLUTION

RATIONALE:

In some of the previous les..ons cigarette smoke has been mentioned as a harmful agent, which may lead to respiratory damage. Since cigarette smoke is harmful to the body it may be considered as a pollutant. In this and in the next four lessons, air pollution, its origin, nature and effects on health will be considered.

In LA-39 the student will measure the amount of NO_2 emitted in a known volume of exhaust from a car engine.

OBJECTIVES:

The student will define pollutant.

The student will list at least three major sources of air pollution.

The student will list the three major air pollutants.

The student will list two ways in which the atmosphere acts to cleanse the air of pollutants.

The student will define photochemical.

The student will list two pollutants which participate in a photochemical reaction in the atmosphere as well as the two pollutants that result from this reaction.

The student will give two definitions of smog.

The student will determine the concentration of NO_2 gas in the exhaust of a car.

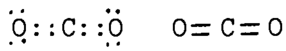
SEQUENCE: ST-39; LA-39

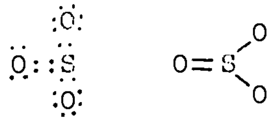
SUGGESTIONS:

1. The students might discuss some of the results of the research that they have been doing on the pollution problem in their community.

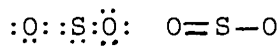
2. If the school is in an urban area the students might want to test different locations for the amount of particulate pollution. A rough estimte of this can be obtained by preparing a set of Petri dishes and putting scotch tape around them, sticky side out. These dishes can then be set in different locales where the particulate matter in the air will eventually settle on the tape and stick. Industrial areas should show a higher amount of particulate matter. Also, it might be interesting to look at the tapes under a microscope to study the nature of the particles that they have "collected."

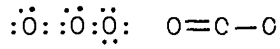
KEY--PROBLEM SET 39:

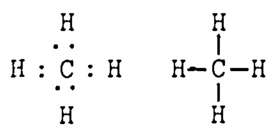
1. a. CO_2 

   b. SO_3 

   c. CO 

   d. SO_2 

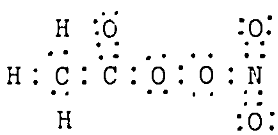
   e. O_3 

   f. CH_4 

2. $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

   $2\ C_8H_{18} + 17\ O_2 \rightarrow 16\ CO + 18\ H_2O$

   More O_2 is needed to oxidize to CO_2. CO is formed if too little O_2 is available.

3. a. 

   (Note that nitrogen violates the "8 electron" rule and actually completes the formation with 10.)

   b. $C_2H_3O_5N$

   c. 121 amu

   d. 48.4 g

INFORMATION ON MAJOR TYPES AND SOURCES OF AIR POLLUTANTS

GASES

A. Carbon Monoxide (CO)

An odorless, invisible gas which is an important component of automobile exhaust. It is one of the most common air pollutants, and one of the most harmful to man. It is seldom found in lethal concentrations in the atmosphere, but is often found in concentrations sufficient to affect judgment, coordination and reaction time. These effects occur at 30 ppm (parts per million) or higher. (The unit "ppm" will be taken up in detail in Mathematics Lesson 46.)

Carbon monoxide is produced by the combustion of hydrocarbons in the presence of a limited oxygen supply. Ty[illegible] concentrations in traffic range from 1 ppm to 100 ppm or more under circ[illegible] of extremely heavy traffic and poor ventilation, such as in tunnels.

Current federal safety standards are set at 8.5 ppm for eight hours and 12.5 ppm for one [illegible].

B. Sulfu[illegible]

The particular pollutants in this category are SO_2 (sulfur dioxide), H_2SO_4 (sulfuric acid), SO_3 (sulfur trioxide) and sulfate salts. They result from the heating and burning of "fossil fuels" such as coal and oil. Sulfur dioxide is recognized as the most important one in terms of current atmospheric concentrations and consequent injurious effects on the human respiratory system. It is usually found in combination with other matter. Sulfuric acid, the next most important, is highly corrosive and is frequently an end-product of atmospheric reactions involving SO_2.

Concentrations of SO_2 in city atmospheres range from 0.01 to 3.0 ppm. The higher level occurs only during air pollution disasters. New York and London are among the cities with the highest SO_2 concentrations.

Air quality standards have been established for SO_2 at 0.5 ppm for one hour and 0.04 ppm for 24 hours.

C. Hydrogen Sulfide (H_2S)

A colorless gas with a strong odor often described as "rotten eggs." It can be smelled at very low concentrations. The gas is produced largely by oil refineries, as a by-product in refining crude oil. It can also be detected near sewage treatment plants and mud flats. Air quality standards for concentrations of H_2S vary from state to state. California's standard is 0.03 ppm for 1 hour.

D. Oxides of Nitrogen (NO_x)

Of the various oxides of nitrogen, NO (nitric oxide) and NO_2 (nitrogen dioxide) are the important air pollutants. Nitric oxide is a colorless, odorless gas. It is a primary product of high-temperature combustion (greater than 1093° C). The concentration of this gas, together with carbon monoxide (also a primary combustion product), peaks in the early morning hours, and declines thereafter as sunlight energizes reactions with atmospheric gases. Nitric oxide is relatively harmless in itself.

Nitrogen dioxide is a reddish-brown gas with a pungent odor. It forms as a product of the photochemical reaction between nitric oxide and oxygen, in the vicinity of the source of the nitric oxide (which in most cases is the exhaust gas of automobiles). An air quality standard of 0.25 ppm for one hour has been established for NO_2.

E. Fluorides

Fluorides occur in both gaseous and particulate form. They are released into the air from steel mills, aluminum reduction plants, phosphate fertilizer plants, ceramic and brick kilns, metal processing plants and oil refineries.

F. Organic Compounds

This is a large and diversified class of air pollutants. They are created from the combustion of organic materials. The largest source of these compounds is gasoline combustion in automobiles. They are also released into the atmosphere when paints, inks, solvents and gasoline evaporate.

The concern over organic compounds results from their ability to react with other gases in the atmosphere (oxides of nitrogen), using the energy of ultraviolet radiation from the sun, to form other pollutants collectively called photochemical smog.

G. Photochemical Reaction Products

These pollutants are not themselves emitted, but are formed in the atmosphere by chemical reactions between other pollutants (principally NO_x and organic gases). They are secondary pollutants, the most significant of which are ozone (O_3) and peroxyacyl nitrate, or PAN.

Typical ozone concentrations in cities range from 0.01 ppm, or less, to over 0.26 ppm. The maximum is reached about midday, following production of nitrogen oxides by morning traffic and the action of sunlight. The concentration of PAN is minor compared with that of ozone (it ranges from nearly zero to a maximum of 0.06 ppm).

The air quality standard for photochemical reaction products has been set at 0.10 ppm.

PARTICULATE MATTER

This category includes matter falling within the size category of 0.0002 microns to 500 microns. Suspended solids such as dust and smoke, and liquid droplets, are examples of particulate matter. Some of this matter is of natural origin

(dusts, pollens, etc.); however, in heavily industrialized areas the man-made variety of particulate matter is far more prevalent. The latter type of particulate matter is created by burning or applying heat to materials, chemical and photochemical reactions or pulverizing operations.

The concentration of particulate matter in the air varies from one hundred particles per cubic centimeter in "clean" air to 10,000 particles per cubic centimeter in heavily polluted air. Seasonal maxima occur in mid-winter.

Three air quality standards have been established for particulate matter. A limit of 100 micrograms of particulate matter per cubic meter of air has been established for a 24-hour period, and at the same time no more than an average va of 60 micrograms per cubic meter may be attained over a year's time. In additio a third standard states that visibility must not be less than ten miles when relative humidity is less than 70 percent.

POISONOUS PARTICULATES

A. Lead (Pb)

A metallic element occurring naturally in soil, rocks, water, and food. It occurs in small quantities in the air and results from smelting operations and auto exhaust. As an air pollutant, lead is present in the form of particles so small that as much as 50 per cent of what is inhaled may be retained in the body. Lead is a cumulative poison in the sense that continued exposure leads to greater and greater concentrations within the body.

B. Asbestos, arsenic, beryllium, cadmium, mercury, etc. The list of pollutants that are considered serious problems may continue to expand.

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INFORMATION ON LABORATORY ACTIVITY 39:

TEACHING NOTES:

1. The objective of this activity is to measure concentrations of nitrogen dioxide present in the exhaust gases of automobiles. The exhaust gases are mixed with a chemical solution that reacts with NO_2. The amount of red color produced is measured using the BIP colorimeter. The activity introduces the students to a procedure that is commonly performed by air-pollution analysts.

2. The activity may be implemented in a variety of ways. Comparative tests can be run on old cars vs new cars. The exhaust gases can be tested before and after a car is tuned up, or before and after a NOx device is installed. (The NOx device is an emission control device that is supposed to lower emissions of NO_2 by at least 47%.) The volume of exhaust produced per minute may also be measured, from which the number of grams of NO_2 emitted per minute may be calculated.

3. The procedure may also be modified, depending upon the equipment available. Different bottle sizes are acceptable, provided that certain adjustments are made in the calculations or in the volume of the absorbing reagent. The procedure may be followed as written using a different size bottle if the volume of the absorbing reagent is adjusted to 1/200 of the volume of the bottle. For example, a 2-liter bottle would need 10 ml of absorbing reagent.

If it is not practical to follow this rule, it is possible to adjust the absorbance of the solution mathematically by using the following formula when making the calculations.

$$\text{measured absorbance } (A_1) \cdot 200 \cdot \left(\frac{\text{volume of absorbing reagent}}{\text{volume of bottle}}\right)$$

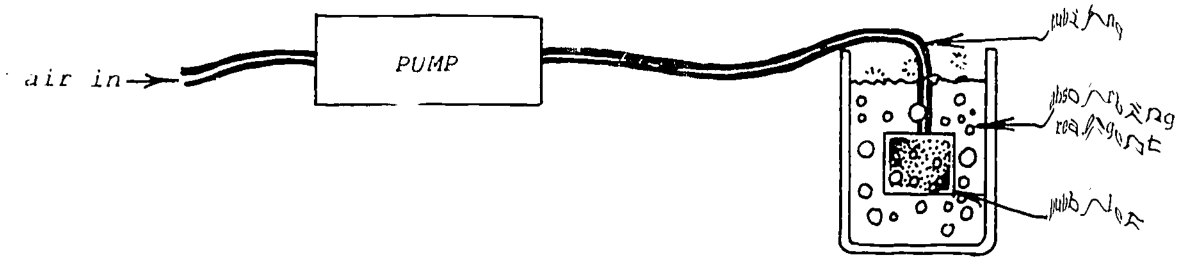
$$= \text{corrected absorbance } (A_2)$$

For example, if 10 ml of absorbing reagent are shaken in a bottle containing 1.0 liter of gas, the measured absorbance would be multiplied by 2 in order to obtain the corrected absorbance.

$$(A_1)(200)\left(\frac{.1 \text{ liter}}{1.0 \text{ liter}}\right) = (A_1)(A_2) = A_2$$

(Note: These calculations have been chosen to correlate with the proportions of chemicals specified for the preparation of the standard graph. In the procedure, 1 ppm is set equal to the amount of color produced by 10^{-6} liter of NO_2 gas in 5.0 ml of solution. All measurements must be made relative to this standard.)

4. The technique described in Part II will not measure NO_2 levels below 0.5 ppm accurately. However, it is possible to measure low concentrations using an aquarium pump connected to a fritted bubbler. (Pet stores sell an acceptable bubbler--normally called an air stone.) A diagram of the apparatus is shown:



The volume of air that is pumped per minute is measured (usually by timing how long it takes to displace a known amount of water in an inverted container). Air is then bubbled through a known volume of absorbing reagent until the amount of color produced is equivalent to an absorbance of at least 0.05. If, for example, 50 liters of air must be bubbled through 20 ml of reagent in order to produce an absorbance equivalent to 1 ppm, then the concentration of NO_2 is given by:

$$(1\text{ppm})(200)\left(\frac{.02 \text{ liter}}{50 \text{ liters}}\right) = 0.08 \text{ ppm}$$

With this technique, the atmospheric levels of NO_2 may be monitored daily for as long as desired.

5. The same type of water should be used to prepare the reagents as is used by the students to make dilutions. The water may be tap water, even if the local water supply contains a significant nitrite concentration since all measurements are made relative to the absorbing reagent solution. (If the local tap water has a high nitrite concentration, it may be necessary to explain to the students why the absorbing reagent is pink to start with.) The one exception to the above would be a case in which the tap water was subject to significant variation in nitrite content from day to day. In that case, distilled water should be used throughout.

6. The absorbing reagent should not be pipetted by mouth. Mouth pipetting of the $NaNO_2$ solution, however, should be encouraged in order to provide additional experience in the technique.

7. The procedure, as written, implies that samples of exhaust gas are to be collected on the school grounds following completion of the study survey. In

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fact, gas samples may be collected prior to school, the preceding evening, etc., provided that the collection bag is well sealed.

A second possibility is to complete Part I on one day and Part II on the following day, in which case the exhaust samples could be collected in between the two class sessions. If the tests on the unknowns are to be conducted on the following day, it is important that the blank be tightly stoppered and saved, that the colorimeter be re-standardized with this blank prior to testing the unknowns, and that the same BIP and test well be used.

Note that it is possible to postpone Steps 8 and 9 of Part I until after Part II, Steps 1 through 8.

8. A good optional activity would be to collect a gas sample at a busy intersection during a time of heavy travel, if local weather conditions happen to provide a relatively stagnant day.

9. Anticipated time: two periods.

MATERIALS: (for 10 set-ups)

The quantities of chemicals specified are sufficient for 150 tests.

0.1 g N-(1-naphthyl)-ethylenediamine dihydrochloride (Sigma N 9125)

17.5 g sulfanilic acid, anhydrous (or 19.25 g of the hydrated form; $NH_2 \cdot C_6H_4SO_3H \cdot H_2O$) (Sigma S 4127)

400 ml acetic acid, glacial (CH_3COOH)

0.5 g sodium nitrite ($NaNO_2$)

70 to 150 test tubes, 16 x 125 mm

70 to 150 stoppers for test tubes (cork stopper #4)

20 pipets, 10-ml

10 pipets, 1-ml

20 beakers, 50-ml

10 glass-marking pencils

10 BIP colorimeters

10 test-tube racks

10 bottles, 1 gallon, with cap

plastic bags, approximately 22 x 24 in (4 to 5 gallon capacity), with ties (as many as desired)

10 short lengths tubing (10-15 cm), glass, rubber or plastic, 12-20 mm in diameter

10 graduated cylinders, 100-ml

rubber bands

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PREPARATION OF REAGENTS:

N-(1-naphthyl)-ethylenediamine dihydrochloride stock solution: Dissolve 0.10 ± .01 g of the reagent in 100 ± 1 ml of water. The solution is stable for several months if kept refrigerated in a stoppered, brown bottle.

Absorbing reagent: To 490 ± 5 ml of glacial acetic acid, add approximately 1.0 liter of water. Dissolve 17.5 + .5 g of anhydrous sulfanilic acid (or 19.5 g of the hydrated form) in this mixture. Gentle heating is permissible to speed up the preparation. To the cooled mixture, add 70 ml of the stock solution of N-(1-naphthyl)-ethylenediamine dihydrochloride. Dilute the preparation to 3.5 liters. The solution is stable for several months if kept refrigerated in a stoppered, brown bottle. The absorbing reagent should be warmed to room temperature before use.

Sodium nitrite solution, .0005%: Dissolve 0.5 ± .01 g sodium nitrite in a total volume of 250 ± 5 ml of water. Dilute 1.0 ± .01 ml of the solution to 400 ± 5 ml. This solution is stable for only a few days, even if refrigerated.

ANTICIPATED RESULTS:

PPM NO_2	Absorbance
0.0	.000
0.5	.095
1.0	.200
1.5	.290
2.0	.380

ANSWERS TO DISCUSSION QUESTIONS:

1. Depends upon individual results.

2. In order to come as close as possible to bringing all the NO_2 in the bottle into contact with the absorbing reagent.

3. The relation between concentration and absorbance tends to become increasingly non-linear for absorbance values beyong .60.

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LESSON 40: (A) MOVEMENT OF THE AIR

(B) INVERSIONS

RATIONALE:

In the previous lesson we exemplified the natural cleansing action of the atmosphere. In this lesson we add another example, convection air currents. Thermal inversions occur when these convection currents are not operating. The significance of thermal inversions is also discussed.

In La-40, the effects of temperature on the vertical movement of air are investigated. A laboratory thermal inversion is created.

OBJECTIVES:

The student will define the terms stratosphere and troposphere.

The student will state the relationship between air temperature and altitude in the daytime.

The student will explain why cold air is denser than warm air.

The student will describe a convection current and state its cause.

The student will explain how a convection current serves to cleanse the atmosphere of pollutants.

The student will describe a thermal inversion, and list at least two types of environments that contribute to the existence of this phenomenon.

The student will explain how thermal inversions act to increase the pollution in the atmosphere.

The student will demonstrate the effect of temperature on air movement by creating convection currents and by creating a thermal inversion in the laboratory.

The student will demonstrate the effect of convection currents and a thermal inversion on the dispersion of smoke from a cigarette.

SEQUENCE: ST-40; LA-40

SUGGESTIONS:

1. If your community sometimes has smog alerts, the students could find out what conditions must be met before a smog alert is called. The conditions also tend to vary with location; comparing these differences might also be of interest.

2. One demonstration you might do to show that hot air rises is to close up the classroom (all the windows and doors). Then after about 15 or 20 minutes use a thermometer to measure the air temperature at different heights within the room.

3. In the Student Text, one heating system that takes advantage of convection currents was discussed. You may wish to discuss the efficiency of other heating systems with the class. For example, many new homes are designed with heating vents in the ceiling. How well do you think this arrangement would heat the rooms of a house?

INFORMATION ON LABORATORY ACTIVITY 40:

TEACHING NOTES:

1. The purpose of this activity is to investigate the influence of temperature on air movement and smog conditions. The two phenomena exhibited are vertical mixing of air and termal inversions.

2. Anticipated time: one period.

3. Acetate sheet is available from local plastics dealers. If it comes in a roll, it will be desirable to cut the sheets to the proper size before class.

4. A number of variations are possible with this equipment. The columns may be stacked one on top of another to give an 8-foot cylinder. Or, the column may be covered with a piece of cardboard at the beginning of the procedure. The results can be contrasted with those obtained using an uncovered column.

5. The BIP thermistor may be used to monitor the temperature of the water, thus reducing the number of thermometers needed. The demand for thermometers could be further reduced by reducing the number of set-ups to seven or eight.

MATERIALS: (for 10 set-ups)

- 10 acetate sheets, clear, 60 x 150 cm, .01 inch thick
- 10 rubber bulbs, pressure (Cenco #18065)
- 4.5 meters Tygon tubing, 5/16" I.D.
- [illegible] pans (or sinks) to hold cylinder 20 cm in diameter
- 5 lbs ice
- 30 thermometers, 0-100 °C
- 20 cigarettes, filter-tip
- 10 meters string
- 20 paperclips
- 20 beakers, 250-ml
- 10 lengths glass tubing
- masking tape or 30-40 large rubber bands
- 10 gas burners
- matches
- 10 small cans (for ash trays)

ANSWERS TO QUESTIONS ON PROCEDURE:

(1) Air is rising within the cylinder.

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(2) The air at the bottom is warmer than the air above it. The warmer air is less dense than the air above it. It therefore rises and is replaced by cooler air, which in turn is heated by the water bath.

(3) The smoke remains in the lower portion of the column.

(4) The air at the bottom is colder and more dense than the air above it. Therefore it cannot rise.

ANSWERS TO DISCUSSION QUESTIONS:

5. The activity does indeed reproduce conditions found in the environment.

6. Alterations in the diameter and length of the column should have no significant effect on the results.

7. 80 liters.

8. 30 g/liter; 15 g/liter.

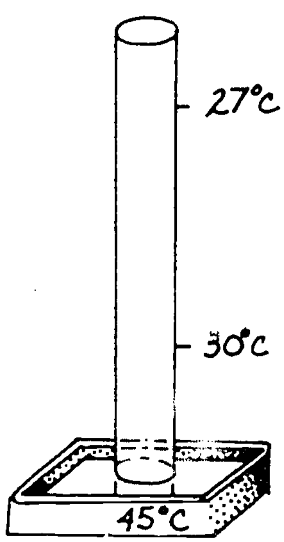
9. Temperature profile B is not an example of an inversion, because the air at all altitudes has cooler air above it.

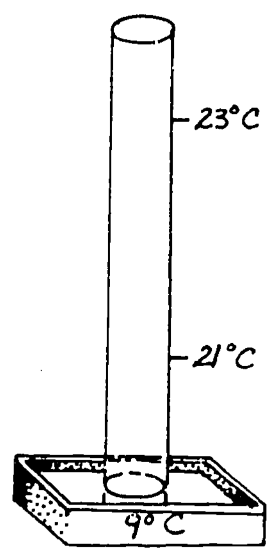
10. Any situation in which air has warmer air above it.

11. Polluted air will rise whenever its temperature is greater than that of the air above it.

12. Same as #4 above.

ANTICIPATED RESULTS:





LESSON 41: EMPHYSEMA

RATIONALE:

In Lesson 38 we studied chronic bronchitis. In the years after Tom developed bronchitis his condition worsened due to failure to stop smoking and to continuous respiratory infections. In this lesson we see the results, emphysema. The nature of emphysema and the respiratory impairment it causes are discussed in some detail.

OBJECTIVES:

The student will describe the causes, symptoms and treatment of emphysema.

The student will describe the effects of emphysema on the respiratory system and how they are related to the symptoms that the patient manifests.

The student will state the direct cause of destruction of alveolar tissue.

The student will explain why the pulmonary circulation is decreased in emphysema.

The student will explain how emphysema may lead to heart failure.

The student will list the clinical tests used to diagnose emphysema.

SUGGESTIONS:

1. There is a free film on emphysema available from the Tuberculosis and Health Association. If you can obtain it you will need a 16-mm film projector and screen to show it.

2. There is also a booklet entitled Living with Asthma, Chronic Bronchitis and Emphysema--A Guide to Self-Care that may be obtained from Riker Laboratories, Inc., Northridge, California. The booklet lists a series of exercises and techniques utilized to maintain clean, open airways in people with respiratory diseases. You may wish to have the students try some of these exercises.

3. It may be possible to obtain on loan an X-ray of both a normal and an emphysemic individual for a classroom demonstration. If you are interested in doing this, check with your community hospital well in advance. Assuming X-rays (or slides of X-rays) become available, there are a number of things that you may point out to your students. First of all, you can point out that X-rays are in "negative" form much like a film negative. The dark regions are where more of the X-rays reach the film. The light regions are where fewer X-rays have penetrated. Therefore, the bones will appear as light regions because they block some of the X-rays they contact. Lung tissue will be mostly dark because the lung is mostly air and air does not block X-rays.

It would be reasonable to study the normal tissue first. It should be easy to locate the shadows of the heart and ribs. The stringy shadows near the heart should be the pulmonary blood vessels. The diaphragm shadows are easily identified as the dome-shaped areas near the bottom of the X-ray picture.

Some features of the emphysemic lung follow:

a. The shape of the chest is more rectangular than the normal chest.

b. The diaphragms are lower and flatter.

c. The lungs are clearer.

The differences between the two X-rays are due to emphysema. Over-inflation of the lungs due to obstruction leads to all three of the above symptoms. The decreased clarity of the emphysemic lung X-ray is also explained by the destruction of lung tissue.

4. A class visitation with an X-ray technologist would be of interest, especially if the above suggestion is entertained. The specialist could explain how X-rays are taken typically and also explain some of the special techniques occasionally used. He or she could answer questions about educational training needed for this profession. Perhaps the X-ray technician could show some interesting X-rays related to the respiratory system--pneumothorax, emphysema, lung cancer are a few examples.

5. There are no scheduled lab activities for Lessons 41 through 43. You may wish to repeat one or more of the earlier activities in which the students ran into problems. You also could schedule a lab practical exam in which the students have to demonstrate a degree of skill in common lab techniques.

INFORMATION ON EMPHYSEMA

Incidence of Emphysema

Emphysema is one of the most widespread chronic diseases of the lungs. Many more people suffer from it in the United States than from lung cancer and tuberculosis combined. This is because of the long duration of emphysema, 30 to 40 years, as compared to the one- to two-year average duration of lung cancer. A recent national health survey estimated 923,000 diagnosed sufferers; there are many more who are as yet undiagnosed. Most of the diagnosed sufferers are older men. Nevertheless, women and younger people suffer from the disease too. Emphysema involves damage to the bronchioles and the alveoli of the lungs. It usually occurs together

with bronchitis. In fact, most emphysema victims have a case history of chronic bronchitis. It has also been discovered that some people are more susceptible to bronchitis and emphysema than others. These people may be genetically predisposed to emphysema. The incidence of emphysema is increasing rapidly throughout the United States. Researchers cannot explain why the rate of increase is so rapid. It is a most important disease to study and understand.

How Emphysema Starts

The initial cause of emphysema is probably the same as the initial causes of bronchitis: prolonged irritation or repeated injury to the bronchial passages. The bronchial tubes can be irritated by the inhalation of tobacco smoke, dusts and powders, air pollutants, etc. The bronchial tubes may also be injured by bacterial and viral infections. A smoker is many more times likely to suffer from the disease than a non-smoker.

Characteristics of Emphysema

Emphysema victims usually experience shortness of breath and chronic cough. As emphysema progresses, the victim becomes more easily fatigued; and he may develop a "barrel-chest" because of trapped air. In the later stages of the disease the victim may feel extremely fatigued, even at rest. Emphysema can cause total incapacitation.

Development of Emphysema

Emphysema is characterized by an abnormal increase in size, and eventual destruction, of the bronchioles and alveoli of the lung. The alveoli over-distend because of trapped inspired air that cannot escape during expiration. Obstruction of the air passageways by mucus is a contributing factor. This occurs when inflammation destroys the cartilage, muscle, and connective tissue that maintain the soundness of the air passages.

Inspiration is a more powerful force than expiration. Upon inspiration, all parts of the lung dilate. Elastic tissue and connective tissue hold the air passageways open during the general stretching of the inspiratory movement. During expiration the elastic recoil of the lung tends to collapse the bronchioles. It is only the structural soundness of the bronchial passages that holds them open. If infection has destroyed cartilage, muscle, and elastic tissue, the bronchial passages may collapse completely upon exhalation.

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In this case, air is inhaled and only incompletely exhaled. This results in hyperinflation of the alveoli. Eventually the hyperinflation becomes so acute that the alveolar walls are torn. When this occurs, large air spaces replace the many smaller air spaces which normally provide a large surface area for gas exchange. In this manner, the total surface area for gas exchange is decreased.

Chronic hyperinflation of the lungs is accompanied by permanent changes in the chest wall. It is this feature which gives the "barrel-chested" appearance to sufferers from advanced emphysema.

Emphysema can lead to enlargement of the right ventricle of the heart (cor pulmonale) and eventual heart failure. The pulmonary circulatory system is a low-pressure system, and the right ventricle of the heart is designed to pump large volumes of blood against the low outflow pressures of the pulmonary system. For reasons not entirely understood, emphysema can cause increased resistance to blood flow through the lungs. Increased resistance to blood flow causes pulmonary hypertension (increased blood pressure in the pulmonary system). The right ventricle responds to this increased pressure load by enlarging. Heart failure may be the eventual result.

Ventilation/perfusion imbalance is another problem associated with emphysema. Because of the difficulty emphysema victims have with expiration, many areas of the lung may be poorly ventilated, but have normal blood perfusion. Cardiac work to pump blood to poorly ventilated or non-ventilated lung tissue is wasted, because the blood returns unoxygenated to arterial circulation.

Treatment of Emphysema

The tissue damage causing the symptoms of emphysema is irreversible. The goal of treatment is to keep the disease from progressing further through the maintenance of clean and open airways. It consists of urging smokers to cease their habit, a variety of exercises and control of lung infections with appropriate medication.

LESSON 42: AIR POLLUTION AND HEALTH

RATIONALE:

In this section we return again to the question of how air pollution affects our health. A number of the major pollutants and their effects on the physiology

of the human body are considered. The difficulties which scientists encounter in trying to assess the effects of the various pollutants are also discussed. The question of how air pollution can be decreased and who is going to pay for it is put to the students.

OBJECTIVES:

The student will list three problems that scientists have encountered in their attempts to determine the effects of air pollution on our health.

The student will list some of the effects each of the following pollutants have on the human body: CO, sulfur oxides, NO_2, O_3, particulate matter.

The student will state the general relationship between the number of cigarettes a person smokes and his life expectancy.

The student will discuss the problems inherent in trying to cut down on the air pollution produced by man.

SUGGESTIONS:

If you have the time you may wish to introduce the topic of experimental controls and their function in research.

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INFORMATION ON THE HEALTH EFFECTS OF AIR POLLUTANTS

Carbon Monoxide

The major health effect of carbon monoxide is the impairment of oxygen transport by the blood. This is accomplished both by filling oxygen-bond sites on the hemoglobin molecule and by interfering with the release of oxygen already carried by the hemoglobin molecule. The resulting effect is hypoxia.

The symptoms of CO poisoning depend on the proportion of hemoglobin which is combined with CO. This is a function of the concentration of carbon monoxide in the inhaled air and the ventilation rate. At concentrations greater than 1000 ppm carbon monoxide kills quickly. Chronic exposure to CO experienced by people living near industries which emit it, or who work in association with it, is found to produce elevated red blood cell counts, chronic headaches, susceptibility to fatigue, and poor appetite. Impairment of sensitivity to light is also noted. These effects were noticed at carbomonoxyhemoglobin levels of less than three per cent. The table on the next page shows the effects of carbon monoxide at various concentrations.

Fifty ppm is recommended as the upper limit for workers exposed for an eight-hour period. However, exposure to 30 ppm for eight hours, or 120 ppm for one hour may be a health risk, since such exposures inactivate approximately five per cent of the body's hemoglobin. Levels of CO inside automobiles in city traffic have been found to range from 7 to 77 ppm, with the 30 ppm level exceeded in 10 per cent of the samples. Concentrations over 100 ppm often occur in garages and tunnels and directly behind vehicles.

Evidence has indicated that carbon monoxide, in concentrations present in the atmosphere of Los Angeles, is associated with increased mortality. It is predicted that eleven more deaths will occur in Los Angeles County on a day of average CO concentration of 20.2 ppm (the maximum daily average observed) than on a day of 7.3 ppm CO (the lowest daily average observed).

Sulfur Oxides

Sulfur oxides are respiratory irritants. They affect the sense of smell, and cause constriction of respiratory passageways. In addition, higher dosages (over 5.0 ppm) cause runny nose (rhinorrhea) and watery eyes (lachrymation), as well as high-pitched musical "rales" or whistling in the bronchial passageways.

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HEALTH EFFECTS OF CARBON MONOXIDE (CO)

Prepared by D. M. Snodderly, Jr.,
New York Scientists' Committee for Public Information

Concentration of CO in air	% Carbomonoxyhemoglobin in blood	Symptoms
Up to 300-400 ppm	30 - 40% and above	Severe headache, dim vision, nausea, collapse.[1]
100 ppm	Up to 20% depending on exposure and activity of subject	Headache at 20%. Impaired performance on simple psychological tests and arithmetic above 10% CO in blood.[1]
	20% in dogs exposed for only 5.75 hours per day for 11 weeks	Brain and heart damage found at autopsy.[2]
50 ppm and below	2 - 4% and above Maximum of about 8% (calculated from [5])	Ability to detect a flashing light against dim background worsens with increasing amounts of CO. 4% was lowest point shown, but authors state that even the CO from a single cigarette could be shown to cause rise in visual threshold.[3] It is, therefore, obvious that smoking and exposure to CO from auto exhaust interact. Subjects presented with two tones and asked to judge which is longer. Judgment impaired at this level of CO in the air; lower levels of CO not studied.[4] Results interpreted as impairment of ability to judge time.[5] Not known whether this may influence people's ability to drive safely. Another author[1] concluded that 1 - 2% CO in the blood should cause a detectable number of errors on psychological tests if a sufficiently large-scale experiment were done.
15 ppm	Up to 2.4% (calculated from [5])	New York's air quality goal. Even this amount of CO could cause some of the effects on vision and loss of judgment of time that are mentioned above.

1. J.H. Schulte, "Effects of Mild Carbon Monoxide Intoxication," Archives of Environmental Health, 7, 1963, pages 524-30.
2. F.H. Lewey and D.L. Drabkin, "Experimental Chronic Carbon Monoxide Poisoning of Dogs," American Journal of Medical Science, 208, 1944, pages 502-11.
3. R.A. McFarland, F.J.W. Roughton, M.H. Halperin and J.I. Niven, "Effects of Carbon Monoxide and Altitude on Visual Threshold," Journal of Aviation Medicine, 15, 1944, pages 381-94.
4. R.R. Beard and G. Wertheim, "Behavioral Impairment Associated with Small Doses of Carbon Monoxide," American Journal of Public Health, 57, 1967, pages 2012-22.
5. J.R. Goldsmith and S.A. Landau, "Carbon Monoxide and Human Health," Science, 162, 1969, pages 1352-59.

Most individuals show a response to sulfur dioxide at concentrations of 0.5 ppm. The response is increased airway resistance. British studies suggest that excess mortality is detectable in large populations if the concentration of SO_2 rises to about 0.25 ppm in the presence of smoke in heavy concentrations. Emergency clinic visits in New York City increased when SO_2 was less than 0.25 ppm in the presence of smoke. Illness rates followed a similar pattern in Chicago.

Tests involving inhalation of sulfuric acid droplets show that for equivalent amounts of sulfur, the acid is considerably more irritating than sulfur dioxide. Exposures of 7.0 ppm and up produce intense coughing and wheezing.

Hydrogen Sulfide

This gas has a strong and offensive odor which is often described as "rotten eggs." The odor can be detected at very low concentrations (0.034 ppm). In the concentrations usually found in the air, the gas is more of a local nuisance than a health hazard. However, at high concentrations it is extremely toxic. For example, in 1950 an accidental release of hydrogen sulfide gas occurred at an oil refinery located in Paza Rica, Mexico. An air inversion happened to accompany it. Within twenty minutes, people became ill. Three hundred twenty illnesses and 22 deaths in a population of 22,000 were attributed to this incident.

Nitrogen Oxides

Nitric oxide has not been shown to be toxic to humans in any concentration found in the atmosphere. However, when oxidized to form nitrogen dioxide it becomes very harmful. Animal experiments show that NO_2 at high concentrations will combine with hemoglobin to form methemoglobin. This reduces the oxygen-carrying capacity of the blood. Other animal experiments indicate that repeated exposure to NO_2 produces changes in lung tissue similar to emphysema.

Experiments with humans show that NO_2 odor is detected at 0.2 to 0.4 ppm. Exposures of 4 to 5 ppm for ten-minute periods at two-week intervals caused an increased resistance to air flow into and out of the lungs within 30 minutes after exposure.

In most epidemiological studies, the occurrence of SO_2 and oxidants with NO_x makes identification of effects of a specific NO_x compound impossible. However, a unique situation at Chattanooga, Tennessee, made an epidemiological study of the effects of NO_2 practical. Here, a TNT plant emitted pollutants high in

NO_2 and low in particulates. The study disclosed that the families living in the high NO_2 area had a relative respiratory illness rate 18.8 per cent greater than a control group in another part of the city. Exposure to intermediate and high NO_2 levels resulted in especially high rates of acute bronchitis in infants exposed for three years and school children exposed for two to three years. It is of interest that in the population range of 50,000 to 500,000, 54 per cent of United States cities have NO_2 levels in excess of those which were found to contribute to disease in the study.

Photochemical Oxidants

Experiments with animals indicate that photochemical oxidants, including ozone, alter pulmonary function and cause pathological changes in lung tissue. In humans, eye irritation is the most obvious response to these pollutants, although ozone alone does not have this effect.

Experiments in which humans were given prolonged exposure to ozone produced the following results. No effects were observed up to 0.2 ppm. At 0.3 ppm nasal and throat irritation began. After eight weeks of intermittent exposure of three hours per day, six days per week, to 0.5 ppm, a 20 per cent decrease in forced expiration volume occurred.

Short-term exposures produced the following results. Exposures to concentrations ranging from 0.5 ppm to 1.0 ppm for two hours resulted in increased airway resistance, as well as lowered total and timed vital capacity readings. Two-hour exposures of 1.0 to 3.0 ppm caused extreme fatigue and loss of coordination in some people. Pulmonary edema and possibly acute bronchitis resulted at concentrations of 9.0 ppm ozone. Exposures greater than about 0.3 ppm are higher than is experienced in usual Los Angeles traffic.

No conclusive studies have been made with PAN in regard to its effect on humans. Epidemiological studies involving all photochemical oxidants in the ambient air, together with NO_x, show no convincing relationship between short-term variations in photochemical oxidants and daily mortality or hospital admissions. One study involving 137 asthmatic patients concluded that they suffered more attacks when the oxidant level was above 0.13 ppm. In another study, patients in Los Angeles suffering chronically from emphysema were removed from hospital rooms open to the ambient atmosphere and placed in rooms with filtered air. An improvement in respiratory functions was noted. Other similar tests

did not show the same results. Such tests are difficult to control because of variation in smoking habits, age of patients, and variations in illness (some patients being too ill to respond to changes in the pollutant level).

Another report showed that the performance of Los Angeles high school track athletes was impaired when oxidant levels reached concentrations of 0.1 ppm. Experimental subjects suffered from coughing, choking, and severe fatigue following two-hour exposures to ozone concentrations of 1.0 ppm. Industrial workers exposed to ozone in concentrations ranging from 0.3 ppm to 0.8 ppm experienced severe headaches, fatigue, throat irritation, and chest pains.

Particulate Matter

Particulates, once deposited in the respiratory tract, can be cleared by the body in the following ways. Particles in the nasopharyngeal area may be eliminated by absorption into the blood stream or by being trapped in mucus and swallowed. Particles from the tracheobronchial area are eliminated by the same routes. Particles reaching the pulmonary compartment of the lungs may be absorbed by white blood cells and thus enter the blood or lumph, or coughed up and swallowed. Mucus and particles thus enter the gastrointestinal tract from all three parts of the respiratory system. They may pass through the tract and be eliminated, or may enter the blood stream through the lining of the stomach or intestine.

Those particles which are not eliminated affect the body in various ways.

1. Mechanical effects

a. Slowing of ciliary beat, making particle elimination slower.

b. Retardation of mucus flow.

c. The loading of alveolar white blood cells, preventing them from trapping other materials such as bacteria.

d. Penetration of the alveolar membrane to the lymph or blood stream.

2. Toxic effects

a. The particle may be intrinsically toxic (e.g., copper).

b. The particle may interfere with the clearance mechanisms of the respiratory tract, and thus its own toxicity or the toxicity of other substances may have time to take effect.

c. The particle may act as a carrier of an absorbed toxic substance, leading to an intensification of the effect of the absorbed material, both by increasing its time of residence and its concentration. In this way, carcinogens may be retained in the lungs or transported to the gastrointestinal tract as mucus is swallowed. A number of substances known to be carcinogenic (by animal experiments) are present in atmospheric pollutants in increasing amounts.

Epidemiological studies of particulates are the same as those relating to SO_2, in most cases, because particulates and sulfur oxides occur in the same kinds of polluted atmospheres (the "gray cities") and it has not been possible to differentiate adequately the effects of the two kinds of pollutants.

Respiratory Conditions Resulting From Specific Particulates

While a wide variety of toxic substances may enter the body through the respiratory system, only in certain cases are the lungs themselves the primary site of damage. The following four conditions are probably the most important ones in this category in this country.

1. Asbestosis--This disease results from the inhalation of minute fibers of asbestos, a substance widely used in insulation, roofing materials, household tile and brake linings. The condition is associated with a number of lung diseases, including cancer and pulmonary fibrosis.

2. Berylliosis--A disease similar in its symptoms to acute pneumonia. It causes small nodules or granular tumors to form in lung tissue. The condition results from inhalation of fumes or dust of beryllium salts, which are used in the manufacture of alloys and rocket fuels.

3. Byssinosis--Fibrosis and hardening of lung tissue, resulting from inhalation of high concentrations of cotton or linen dusts. Wheezing and dyspnea are most prominent in this disease.

4. Silicosis--A pulmonary disease resulting from the inhalation of silica dust. The disease is characterized by shortness of breath and increased susceptibility to tuberculosis.

LESSON 43: TOM'S DEATH

RATIONALE:

This lesson concludes the unit on respiration with a last look at emphysema, its relationship to smoking and its importance as a cause of death in this country.

OBJECTIVES:

The student will explain how emphysema contributes to deaths from pneumonia.

The student will state the relationship between smoking and the progress of emphysema once it is diagnosed.

KEY--REVIEW SET 43:

1. The ratio decreases.

2. A chronic condition is one that continues over a long period of time while an acute one is of short duration.

3. The symptoms of bronchitis include a cough in which sputum is coughed up, labored breathing, and at times fever due to infection. Treatment consists of antibiotics to get rid of infection and the cessation of smoking if the patient is a smoker. The best preventive measure that can be taken to avoid chronic bronchitis is to avoid substances that irritate the lining of the lungs, such as cigarette smoke.

4. The major sources of air pollution are transportation, generation of electricity, industry, space heating and refuse disposal.

5. (See pp. 252-3 of text.)

6. A thermal inversion occurs when the air near the earth's surface is cooler than the air above it.

7. (See pp. 243-5 of text.)

8. Inversions create pollution problems by trapping pollution near the earth and prohibiting the circulation of air currents which naturally cleanse the air.

9. (See pp. 250-1 of text.)

10. Cigarette smoking can be considered a major air pollution problem because it is injurious to the health and contributes to the early death of as many as 300,000 Americans each year.