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ABSTRACT

A group of scientists and science educators of Washington State University has developed and pilot tested an integrated physical science program designed for preservice elementary school teachers. This document includes the syllabus and class materials for the Chemistry block of the physical science courses developed by the group. Included are diagrams, lecture notes, laboratory exercises and evaluation materials to be used with the course. Topics include: (1) laboratory burners; (2) glassworking; (3) balances; (4) measuring length; (5) density; (6) heat; (7) physical and chemical changes of iron in air; (8) generation and properties of oxygen; (9) generation and properties of carbon dioxide; (10) simple acid/base chemistry; (11) experiments with iron; and (12) preparation of natural indicators. A section on biochemistry is included. Appendices contain information on proper techniques and lists of supplies. (CW)

FINAL REPORT

Submitted to the National Science Foundation

A MODEL TO IMPROVE PRESERVICE ELEMENTARY SCIENCE TEACHER DEVELOPMENT

Julie H. Lutz, Principal Investigator
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NSF Grant No. TEI-8470609
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June 15, 1988

CHEMISTRY LECTURES AND LABORATORIES

A MODEL TO IMPROVE PRESERVICE ELEMENTARY SCIENCE TEACHER DEVELOPMENT

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Volume III

ASTRONOMY 301. A COURSE IN THE PHYSICAL SCIENCES.

PART 2. CHEMISTRY AND GEOLOGY (4 credits)

SECTION 1. CHEMISTRY

DESCRIPTION. The CHEMISTRY section constitutes the first half of the semester (8 weeks). It is followed by the section on GEOLOGY (8 weeks). Although the two half-semesters are separate, only one grade is awarded for the semester. This is a grade that is an average of the two 8-week sequences. Each section consists of 3 lectures each week and one 3-hour laboratory section.

CHEMISTRY

The CHEMISTRY section consists of three (3) parts.

GENERAL AND INORGANIC CHEMISTRY. (4 Weeks)

ORGANIC CHEMISTRY. (2 weeks)

BIOCHEMISTRY. (2-weeks)

LABORATORY. (1 credit; 3 clock hours)

Each section has laboratory experiments designed to complement the lectures. The laboratory experiments were designed for the course and are experimental in nature. An attempt was made to relate the experiences in the laboratory to the kinds of experiences these prospective teachers would encounter in the school system.

EXAMINATIONS

EXAM 1. General and Inorganic chemistry.
EXAM 2. Organic and Biochemistry.

HOMEWORK. Homework was assigned, collected and graded.

MATERIALS

TEXT: Bettelheim and March, INTRODUCTION TO GENERAL, ORGANIC AND BIOCHEMISTRY. CBS College Publishing.

LAB MANUAL: Designed by the lecturers in the course.

LECTURE OUTLINE: GENERAL AND INORGANIC CHEMISTRY (12 Lectures)

LECTURE 1: The Scientific Method. Exponential Notation. Measurements. Use of English and Metric Units. Conversion of units. Common Metric Prefixes. Some useful conversions to memorize: 1 lb = 453.6 g, 1 in. = 2.54 cm. useful techniques for converting from one set of units to another. Density. Specific Gravity. Heat. (Note. Because heat was covered in the section on physics, this topic is not emphasized). Memorize 1 cal = 4.184J

Assignment: Read Chapter 1 (Bettelheim and March).
Do: Problems 1.23, 1.24, 1.25, 1.26, 1.31, 1.33, 1.35, 1.38, 1.44, 1.56, 1.73, 1.79.

LECTURES 2 & 3: Elements, Compounds and Mixtures. Physical and Chemical Change. The Basic Laws of Chemistry: Law of Conservation of Mass (atoms); Law of Constant Composition. The Theory of the Atom. Relationships of Atomic Properties to the Periodic Table. The electrical nature of matter. The atomistic nature of electricity. Coulomb's Law. The concept of ions. The Electroneutrality Principle.

Assignment: Sections 2.1, 2.2, 2.3, 2.4.
Do: Problems 2.4, 2.5, 2.9, 2.10, 2.12, 2.16,

LECTURES 4 & 5: Atomic Weights and the Atomic Weight Scale. The relative weights of molecules. Isotopes. Atomic and Molecular Weights as averages. The Periodic Table. The structure of the Table. Some Group Properties. Names and positions of some common elements in the Table. Metals, Nonmetals. The Transition Elements. The shell structure of the atom. Relation of atomic structure to the position of the element on the Table. How to obtain the shell structure from the Table.

Assignment: Sections 2.5, 2.6, 2.7, 2.8.
Do: Problems 2.23, 2.24, 2.26, 2.28, 2.35, 2.36, 2.48, 2.51.

LECTURES 6 & 7: The Rule of Eight. Tendency for shell completion. Relationship of shell structure to the Periodic Table. Ionic bonds and the Electroneutrality Principle. Prediction of chemical formulas from charge neutrality. Covalent Bonds. Completion of octets by sharing. Lewis Octet Diagrams. The single, double, triple covalent bond. Inorganic and organic examples. The coordinate-covalent bond. Analysis of the type of bonding in familiar compounds.

Assignment: All Sections <u>except</u> 3.6.
Do: Problems 3.1, 3.2, 3.3, 3.4, 3.8, 3.9, 3.17, 3.18, 3.19, 3.20, 3.25, 3.26, 3.34, 3.35, 3.43, 3.49.

LECTURES 8 & 9: Formula Weight and the Mole Concept. The meaning of a chemical equation on the atomic scale, on the macroscopic scale. Balancing equations. Why equations are balanced. Converting an atom/molecule equation to a macroscopic equation through multiplication by N. Conversion to weight measurements. Types of Problems: mole/mole; mole/weight; weight/mole; weight/weight. Simple reactions in aqueous solutions. Percentage yield.

Assignment: Chapter 4. All sections <u>except 4.8. and 4.9.</u>
Do: 4.1, 4.6, 4.8, 4.9, 4.14, 4.15, 4.16, 4.17d, 4.22, 4.26, 4.27, 4.29, 4.33, 4.44.

LECTURE 10. Heat of Reaction. Endothermic and Exothermic Reactions. δH and its sign. Molarity. Making up molar solutions. Dilution exercises. Percent composition by weight.

Assignment: Chapter 4, Section 4.9. Chapter 6, Sections 1-7 inc.
Do: 4.52, 4.53, 4.54, 4.65, 6.18, 6.19, 6.33, 6.34, 6.41.

LECTURES 11 & 12: Acids and Bases. The Arrhenius Definition. The Bronsted/Lowry concept of acids and bases. Acidic solutions, basic solutions. The water auto-ionization reaction and its consequences. Concept of a strong acid/base, a weak acid/base; Reactions of acids and bases. pH, its definition and uses. Concept of a buffer. The uses of buffers. The human body as a buffered system.

Assignment: Chapter 8: Sections 1-10 inc.
Do: 8.15, 8.17a, 8.22, 8.23, 8.25, 8.26, 8.28, 8.30, 8.32, 8.73.

LABORATORY EXERCISE

ARRANGING TWENTY-ONE ELEMENTS

Time About one hour to perform, plus one hour for discussion

Materials 21 cards containing information about 21 elements

Introduction

For many years chemists have tried different arrangements of the elements in an attempt to find some logical order among them. In this exercise you'll try to find your own arrangement of the elements. You will make up a small deck of cards by cutting out the cards printed on the next page of this manual. There are 21 cards, representing 21 elements. Each card carries certain information, and your job is to find some logical way of arranging these 21 cards. Each card indicates the atomic weight, the ionization potential, and the formula for the hydride, oxide, and fluoride of the element it depicts. In your attempt to find order, look for trends among these properties. There is no "correct" way to arrange the cards, but some arrangements are better than others. After you have finished your initial arrangement, you may want to make changes until you find the best possible order. Set the cards on the table or lab area and line them up any way you choose. If you wish, use the questions that follow as guides for your arrangement.

As you become more at home in the world of chemistry, you will learn the different ways in which chemists themselves have arranged the elements. When you compare your arrangements with theirs, you will be able to note similarities and differences.

Some Questions to Ponder and Answer

1. Is there any pattern to be found in the atomic weights?

2. Do the ionization potentials form a pattern?

3. Does a pattern exist in the hydride formulas?

4. Is there any pattern to be found in the oxide formulas?

5. Do the fluoride formulas form a pattern?

Atomic Weight: 1 No. of H in hydride: 1 No. of F in fluoride: 1 No. of O in oxide: 0.5 Ionization pot.: 314	Atomic Weight: 4 Hydride unknown Fluoride unknown Oxide unknown Ionization pot.: 567	Atomic Weight: 7 No. of H in hydride: 1 No. of F in fluoride: 1 No. of O in oxide: 0.5 Ionization pot.: 124
Atomic Weight: 9 No. of H in hydride: 2 No. of F in fluoride: 2 No. of O in oxide: 1 Ionization pot.: 215	Atomic Weight: 10 No. of H in hydride: 3 No. of F in fluoride: 3 No. of O in oxide: 1.5 Ionization pot.: 190	Atomic Weight: 12 No. of H in hydride: 4 No. of F in fluoride: 4 No. of O in oxide: 2 Ionization pot.: 260
Atomic Weight: 14 No. of H in hydride: 3 No. of F in fluoride: 3 No. of O in oxide: 2.5 Ionization pot.: 335	Atomic Weight: 16 No. of H in hydride: 2 No. of F in fluoride: 2 No. of O in oxide: 1 Ionization pot.: 314	Atomic Weight: 19 No. of H in hydride: 1 No. of F in fluoride: 1 No. of O in oxide: 0.5 Ionization pot.: 402
Atomic Weight: 20 Hydride unknown Fluoride unknown Oxide unknown Ionization pot.: 497	Atomic Weight: 23 No. of H in hydride: 1 No. of F in fluoride: 1 No. of O in oxide: 0.5 Ionization pot.: 119	Atomic Weight: 24 No. of H in hydride: 2 No. of F in fluoride: 2 No. of O in oxide: 1 Ionization pot.: 176
Atomic Weight: 45 Hydride unknown No. of F in fluoride: 3 No. of O in oxide: 1.5 Ionization pot.: 151	Atomic Weight: 40 No. of H in hydride: 2 No. of F in fluoride: 2 No. of O in oxide: 1 Ionization pot.: 141	Atomic Weight: 39 No. of H in hydride: 1 No. of F in fluoride: 1 No. of O in oxide: 0.5 Ionization pot.: 100
Atomic Weight: 40 Hydride unknown Fluoride unknown Oxide unknown Ionization pot.: 363	Atomic Weight: 36 No. of H in hydride: 1 No. of F in fluoride: 1 No. of O in oxide: 0.5 Ionization pot.: 300	Atomic Weight: 32 No. of H in hydride: 2 No. of F in fluoride: 2 No. of O in oxide: 3 Ionization pot.: 239
Atomic Weight: 31 No. of H in hydride: 3 No. of F in fluoride: 3 No. of O in oxide: 2.5 Ionization pot.: 254	Atomic Weight: 28 No. of H in hydride: 4 No. of F in fluoride: 4 No. of O in oxide: 2 Ionization pot.: 188	Atomic Weight: 27 No. of H in hydride: 3 No. of F in fluoride: 3 No. of O in oxide: 1.5 Ionization pot.: 138

EXPERIMENT A
USE OF THE LABORATORY BURNER

Many laboratory procedures involve the use of heat that is supplied by a gas flame. This experiment illustrates the use of the laboratory burner.

There are two principal types of burners used in the laboratory. The Bunsen type (Fig. 1) and the Fisher type (Fig. 2).

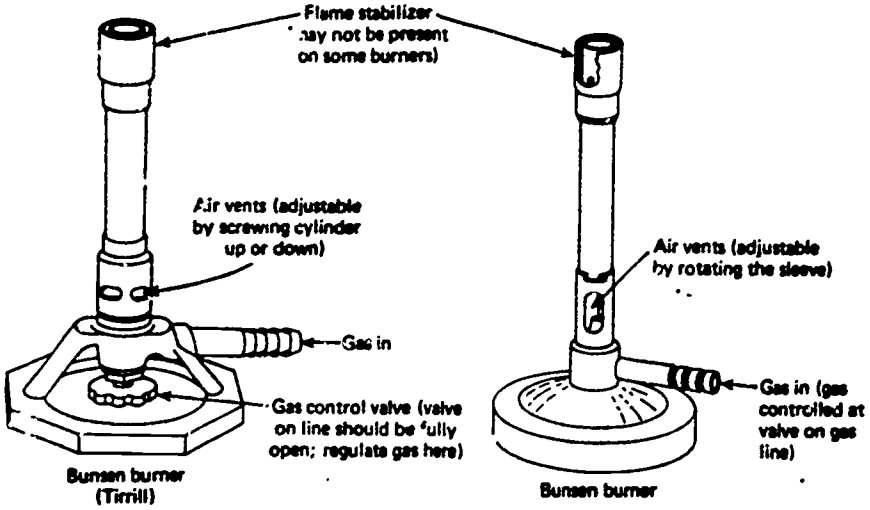


Figure 1. Bunsen Burner and Modified Bunsen Burner (Tirrill Type)

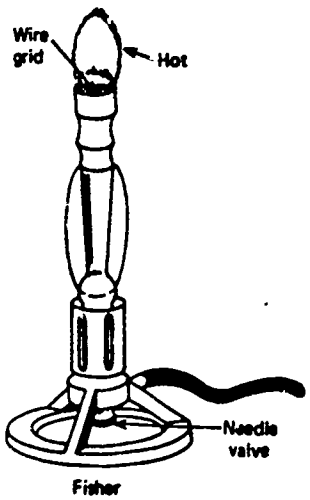


Figure 2. Fisher Burner

All laboratory burners have two adjustments: (1) an adjustment that controls the amount of gas entering the burner funnel, and (2) an adjustment that controls the amount of air being mixed with the gas for combustion. The following instructions and questions will help you discover how the burner works.

1. Close the air vent completely by rotating the sleeve at the bottom of the burner or by screwing the burner barrel down tightly to seal off the barrel. Turn the gas on so that it enters the barrel as slowly as possible and light the burner.

What is observed? _____

_____

_____

_____

2. Increase the amount of gas flowing into the burner by adjusting either the burner or the valve on the gas line. What happens? _____

_____

_____

_____

3. Using tongs, hold a porcelain evaporating dish in the flame. What happens to the bottom of the dish? _____

_____

_____

4. With the burner lit, begin to open the air vent and record what happens as the vent is opened wider and wider. _____

_____

_____

_____

5. Refer to Figure 3 and adjust the flame correctly to give the highest possible temperature. Lower a wire screen supported by a ring into the flame. At which part of the flame does the wire screen appear the hottest? _____

_____

_____

_____

6. It is very difficult to heat liquids in a test tube over an open flame. Practice this technique by filling a large test tube about half full of water and heating the

test tube and water gently. Always start heating at the top part of the liquid and work toward the bottom of the test tube. Always agitate the liquid constantly to mix the hot and cold parts of the liquid and to break up any large gas bubbles that may form. *Be extremely careful not to point the test tube at anyone in your vicinity.* (See Fig. 4.)

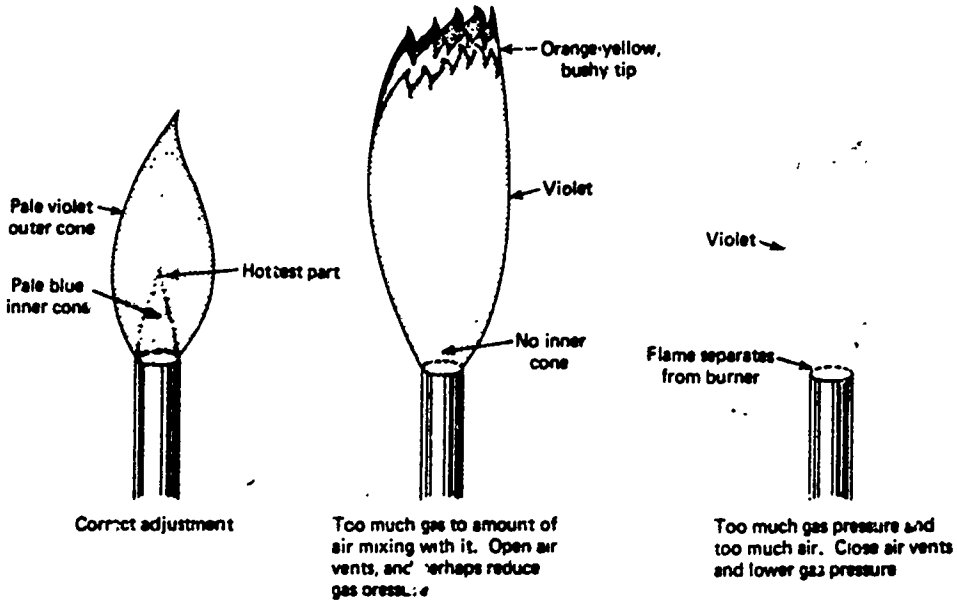


Figure 3. Various flame adjustments for Laboratory Burners

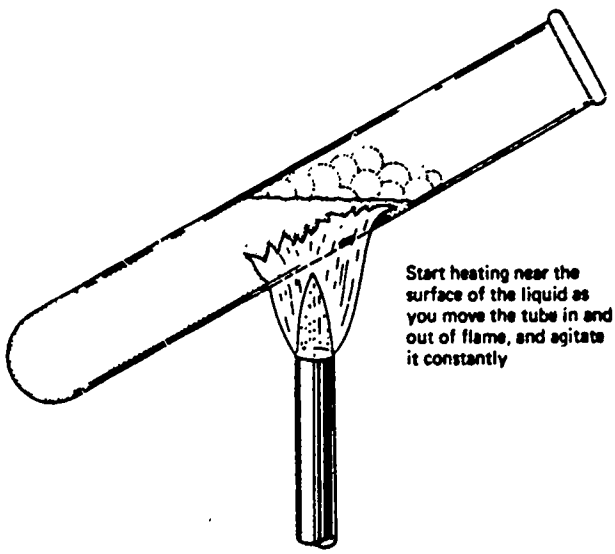


Figure 4. Heating the Contents of a Test Tube

EXPERIMENT B
GLASSWORKING

Many experiments call for the use of glass tubing that is bent to a desired shape. This experiment is designed to help you learn how to handle and shape glass tubing properly.

1. CUTTING GLASS TUBING

Obtain a two-foot section of 6mm-glass tubing from your laboratory instructor. Cut the tubing into four sections with your triangular file. (See Fig. 5.) This is done by placing the tubing flat on the laboratory bench and bringing the edge of the file sharply across the tubing. Never saw the glass tubing with the file. It is not necessary and can cause the tubing to shatter. The single movement of the file will create a small scratch in the glass. Now with your thumbs directly behind the scratch mark (Fig.6), very sharply pull both ends of the tubing toward your body. A sharp break will result. Describe the newly cut edge of the tube. _____

_____

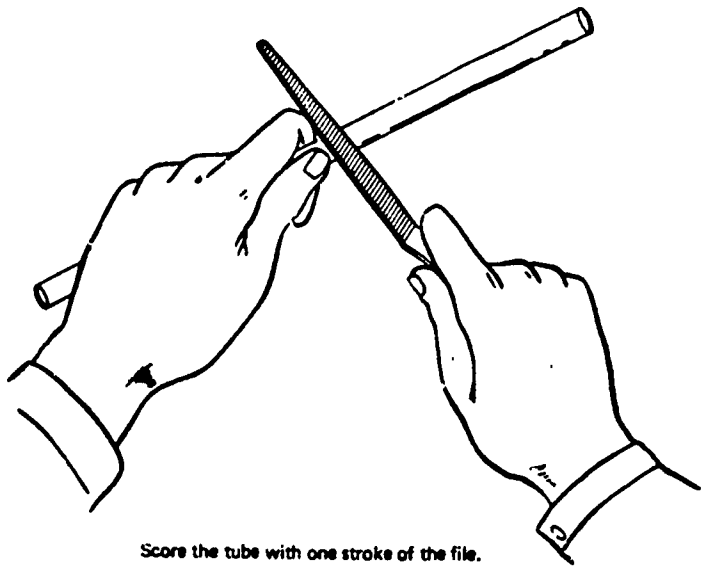
2. FIRE POLISHING

Place the end of the cut glass tubing in the hottest part of the burner flame and rotate it slowly until the edges become rounded. This is called fire polishing and is necessary to prevent damage to rubber tubing or stoppers into which the tubing may be placed as well as to prevent possible cuts during the handling of the tubing.

Be careful not to heat the glass in the flame too long as a closed or restricted end may result.

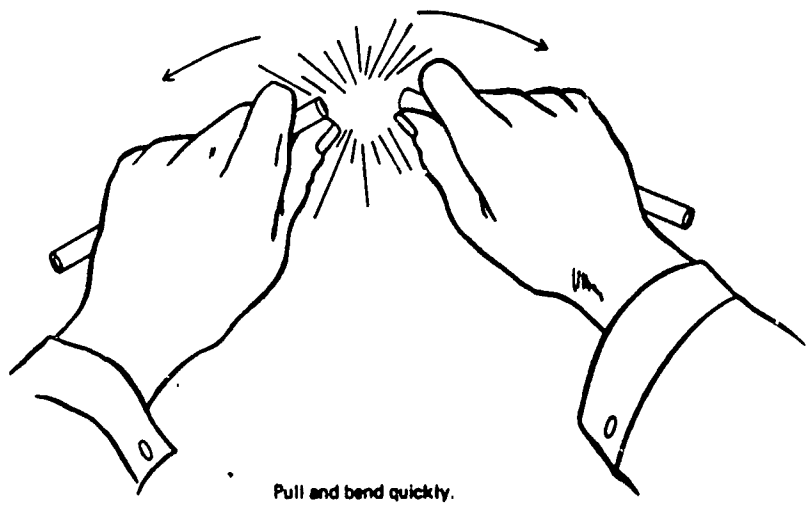
3. BENDING GLASS

With the gas supply to the burner shut off, place a wing top on the burner and adjust the flame to the hottest possible temperature. (See Fig. 7.) Holding a section of the glass tubing in both hands, rotate it while moving the tubing back and forth in the flame until the tubing feels flexible. Remove the tubing from the flame and pull the tubing into a right angle bend. It is very important to heat a large area of the glass tubing if a smooth bend is to be obtained.



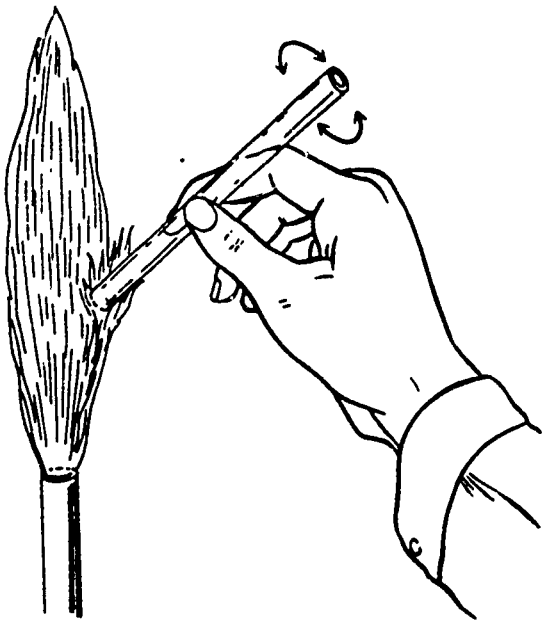
Score the tube with one stroke of the file.

Place the thumbs together behind the scratch.

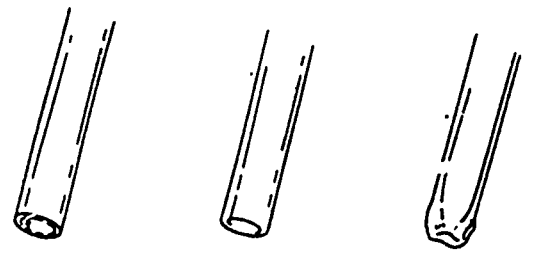


Pull and bend quickly.

Figure 5. Cutting Glass Tubing



Rotate the cut end of glass tubing in the flame until the sharp edges are rounded.

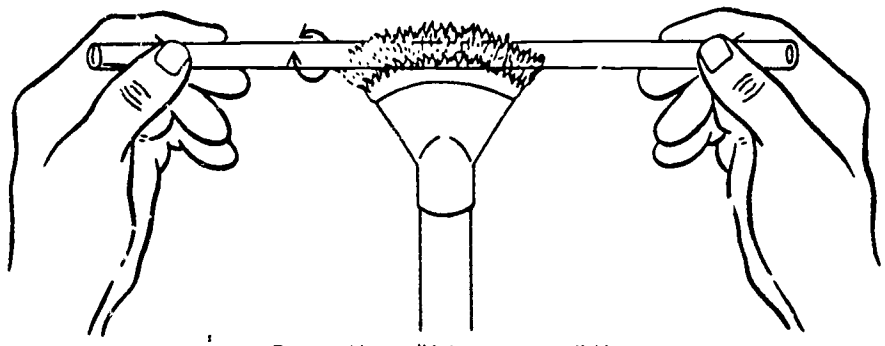


Cut End

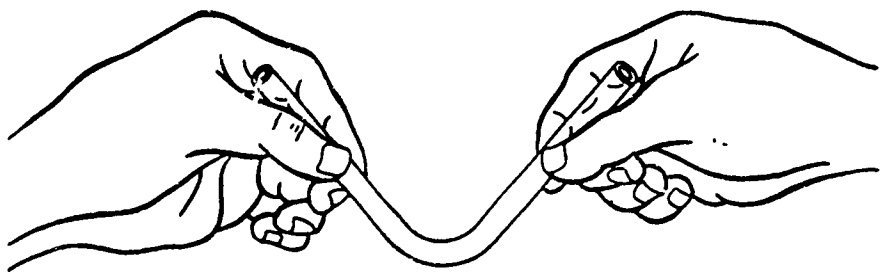
Proper Fire Polishing

Tube which has been left in flame too long.

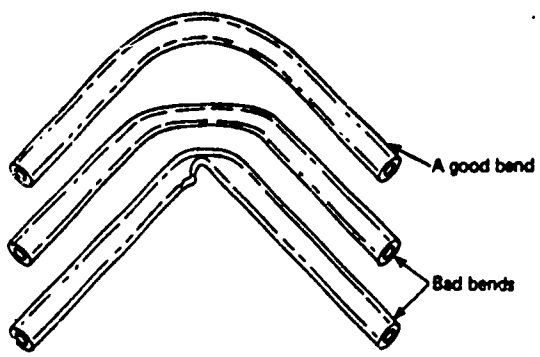
Figure 6. Fire Polishing



Rotate tubing until it becomes very pliable.



Remove from flame, wait a few seconds for the heat to distribute evenly and pull into the desired shape.



Examples of good and bad bends.

Figure 7. Bending Glass Tubing

EXPERIMENT C
THE USE OF THE LABORATORY BALANCE

A good rule to follow:
Never place chemicals directly on the pan of a balance.
To become acquainted with the balance, perform the following:

1. Find the mass of a rubber stopper. _____ g

2. Find the mass of 50 ml of water.

   a. Mass of 100-ml beaker dry. _____ g
   (This mass should be found before the water is weighed.)

   b. Mass of 100-ml beaker containing 50 ml of water. _____ g

   c. Mass of the 50 ml of water (b – a). _____ g

3. Pour 50 ml of methyl alcohol into a 100-ml beaker and weigh the beaker and contents immediately.

   Weight of methyl alcohol and beaker. _____ g

   Wait 1 minute and reweigh the beaker and methyl alcohol.

   Weight of methyl alcohol and beaker after 1 minute. _____ g

   Wait 4 additional minutes and reweigh the beaker and methyl alcohol.

   Weight of methyl alcohol and beaker after 5 minutes. _____ g

   Based on the observations in part 3, what problems may be encountered in weighing some liquids? _____

   _____

   _____

4. Place 10 sodium hydroxide pellets (NaOH) in a 100-ml beaker and weigh immediately. *Sodium hydroxide is extremely caustic. Do not handle with your hands.*

   Weight of beaker and NaOH. _____ g

   Wait 1 minute and reweigh the beaker and NaOH.

   Weight of beaker and NaOH after 1 minute. _____ g

   Wait 4 additional minutes and reweigh the beaker and NaOH.

   Weight of beaker and NaOH after 5 minutes. _____ g

   Based on the observations in part 4, what problems may be encountered in weighing solids? _____

   _____

   _____

5. Can you think of other problems that might be encountered when weighing different materials? _____

   _____

   _____

   _____

   _____

EXPERIMENT D
MEASURING LENGTH

This experiment is designed to familiarize you with the metric system of length measurement. This will be accomplished by allowing you to measure with a meter stick.

1. What is the length of the laboratory bench? _____ yd
   _____ ft
   _____ in
   _____ mm
   _____ cm
   _____ m

2. Use the measurements found in no. 1 to find the following:

   a. Number of centimeters per inch

   $$\frac{\text{(length of laboratory table in centimeters)}}{\text{(length of laboratory table in inches)}}$$ _____ cm/in

   b. Number of feet per meter

   $$\frac{\text{(length of laboratory table in feet)}}{\text{(length of laboratory table in meters)}}$$ _____ ft/m

   c. Number of meters per yard

   $$\frac{\text{(length of laboratory table in meters)}}{\text{(length of laboratory table in yards)}}$$ _____ m/yd

3. What is the relationship between meters and centimeters _____? Between centimeters and millimeters _____? Between centimeters and inches _____?

4. What is the diameter of a 100-ml beaker? _____ mm _____ cm

5. What is the height of a 100-ml beaker? _____ mm _____ cm

6. What is the volume of a 100-ml beaker? _____ mm^3 _____ cm^3

   $$\text{Volume} = (3.14) \times \left(\frac{\text{diameter}}{2}\right)^2 \times \text{height}$$

7. If 1 ml is equal to 1 cm^3, calculate the number of cubic centimeters in the 100-ml beaker. _____ cc

8. Explain the difference between the calculated value and the indicated value of the 100-ml beaker. _____

EXPERIMENT E
DENSITY

You have probably heard the question: "Which is heavier, a pound of lead or a pound of feathers?" Since a pound weighs a pound, the question is trivial. However, the question attempts to mix the concept of weight and density. Density is defined as mass divided by volume $D = \frac{M}{V}$ (D = density, M = mass, V = volume) and is a very useful and descriptive measurement when the properties of different materials are being discussed. This experiment is designed to acquaint you with density.

DENSITY OF A REGULAR SOLID

1. Obtain a piece of wood and a piece of metal from your laboratory instructor and weigh each material carefully,

Weight of wood _____ g

Weight of metal _____ g

2. Measure the length, width, and height of each object in centimeters. From these measurements calculate the volume of each object. (Length X width X height = volume)

Wood length _____ cm

width _____ cm

height _____ cm

volume _____ cm^3

Metal length _____ cm

width _____ cm

height _____ cm

volume _____ cm^3

3. Find the density of each object by dividing the mass in grams by the volume in cm^3.

Wood _____ g/cm^3

Metal _____ g/cm^3

DENSITY OF A LIQUID

4. Weigh a dry graduated cylinder, pour 50 ml of water into the cylinder, and then reweigh the cylinder and water. Notice that the top of the liquid in the graduated cylinder has a curved surface. This is called the meniscus. To read the graduated cylinder properly, hold the cylinder level with your eye and read across the bottom of the curved region as shown in Figure 8.

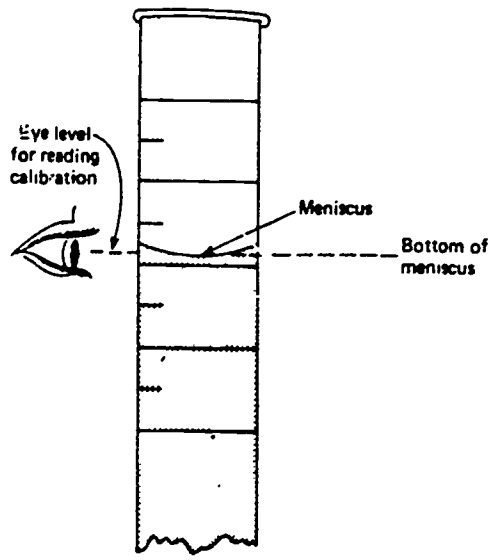


Figure 8. Reading the Volume of a Liquid in a Graduated Cylinder. The meniscus is easier to read if some material darker than the liquid is held behind the cylinder

a. Mass in grams of graduated cylinder and 50 ml of water. _____ g

b. Mass in grams of dry graduated cylinder. _____ g

c. Mass of 50 ml of water (a-b) _____ g

d. Density of water $\frac{\text{mass in grams}}{\text{volume in milliliters}}$ _____ g/ml

5. The terms ml and cm^3 are, for all practical purposes, the same and may be used interchangeably; thus, the density of water may also be expressed as g/cm^3. Everyone knows that wood will float and metal will sink when placed in water. What relationship can you propose between the densities of wood, water, and metal and the tendency of wood to float and metal to sink in water?

_____

_____

_____

_____

_____

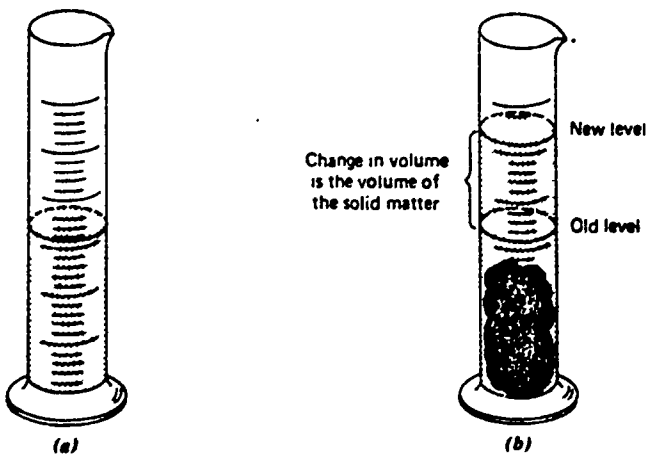
Most pieces of wood eventually sink when placed in water. Propose an explanation. _____

_____

_____

DENSITY OF AN IRREGULAR SOLID

6. Very often it is difficult to measure the volume of a material by measuring its length, width, and height. It is still possible, however, to find the volume of the material by a water displacement method. For example, if a piece of iron is added to a graduated cylinder holding 20 ml of water, the volume read on the cylinder will be greater than before the addition of iron. If the new reading is 30 ml, the iron has displaced 10 ml (30 ml – 20 ml = 10 ml) of water. This is the volume of the iron. (See Fig. 9.)



To determine the volume of an irregularly shaped object; record the volume of a given amount of water in a graduated cylinder (a) then add the object to the cylinder and find the change in volume (b).

Figure 9.

Weigh out approximately 10 g of coarse sand or other irregularly shaped material in a 100-ml beaker. Place approximately 20 ml of water in a graduated cylinder and record the volume. Pour the weighed sand into the graduated cylinder and record the new volume. Calculate the density of the sand.

Mass of 100-ml beaker and sand _____ g

Mass of 100-ml beaker _____ g

Mass of sand _____ g

Graduated cylinder reading (water and sand) _____ ml

Graduated cylinder reading (water only) _____ ml

Volume of sand in milliliters _____ ml

Density (g/ml) _____ g/ml

How could this method of finding volume be modified if the volume of table salt which is soluble in water were to be determined? _____

_____

_____

_____

EXPERIMENT F
MEASUREMENT OF HEAT

The object of this experiment is to determine the specific heat of lead. If a hot object is left standing in an open room, the temperature of that object will soon drop to the temperature of the room. In the same manner, a very cold object when placed in the room will warm up to room temperature. In the first instance, heat is lost by the object to the room. In the second instance, heat is absorbed from the room by the object.

The amount of heat lost or absorbed by objects can be measured. The unit used to measure this heat is called the calorie. One calorie is defined as the amount of heat required to raise the temperature of one gram of water one degree centigrade. Water is then said to have a specific heat of 1 calorie/g °C. Putting this in the form of an equation,

Heat gained or lost (cal) = (mass of water) X (specific heat of water) X (change in temperature)

$$\frac{\text{cal}}{\text{g °C}} \times \text{g} \times \text{°C} = \text{cal}$$

Thus, if 10 g of water were *heated* from 20°C to 30°C, the number of calories required would be

$$10\text{g} \times \frac{1\ \text{cal}}{\text{g °C}} \times 10\text{° C} = 100\ \text{cal}$$

If the water *cools* from 30°C to 20°C, it loses 100 cal.

Specific heat may also be associated with materials other than water. It does not take as much heat to raise the temperature of 1 g of copper 1° C as it does to raise the temperature of 1 g of water 1° C. In fact, it requires only 0.092 cal to raise the temperature of 1 g of copper 1° C. If 10 g of copper were cooled 10°C the amount of heat lost would be

Heat lost (calories) = (10 g) X (0.092 cal/g° C) X (10°C)

Heat lost = 9.2 cal

If a quantity of hot lead is dropped into cool water, the water will absorb the heat from the lead and warm up. The lead will lose heat to the water and will cool down. Eventually, the lead and the water will be at the same temperature. The heat lost by the lead must be equal to the heat gained by the water.

Heat gained by water = (mass H_2O) X (specific heat water) X (change in water temperature)

Heat lost by lead = (mass lead) X (specific heat lead) X (change in lead temperature)

Heat gained by water = heat lost by lead

(mass H_2O) X (specific heat H_2O) X (change in H_2O temperature) = (mass lead) X (specific heat lead) X (change in lead temperature)

The specific heat of the lead can now be found.

Specific heat lead =

$$\frac{(\text{mass } H_2O) \times (\text{specific heat } H_2O) \times (\text{change in } H_2O \text{ temperature})}{(\text{mass lead}) \times (\text{change in lead temperature})}$$

(Whether temperature changes are positive or negative, always treat them as positive in this calculation.)

1. Measure approximately 20 g of water into a styrofoam cup and record the temperature of the water. Weigh approximately 20 g of lead and place the lead in a beaker of boiling water. The temperature of the boiling water will be the initial temperature of the lead. Allow the lead to remain in the boiling water for 15 minutes to be sure that it is the same temperature throughout. With tongs, remove the lead from the water and drop it into the styrofoam cup of cool water and record the highest temperature reached by the water. Calculate the specific heat of the lead.

   a. Weight of water _____

   b. Initial temperature of water _____

   c. Weight of lead _____

   d. Initial temperature of lead _____
      (temperature of boiling water)

   e. Final temperature of lead and water _____

   f. Change in temperature of water (e − b) _____

      Change in temperature of lead (d − e) _____

      Specific heat of lead _____

2. The actual value for the specific heat of lead is 0.031 cal/g° C. How can you account for the difference between the value you obtained and the true value?

   _____

   _____

   _____

   _____

   _____

3. How would your answer have changed if the lead had not been left in the boiling water long enough to reach the same temperature as the water?

   _____

   _____

   _____

4. What could be done to improve the experiment to get a better value for the specific heat of lead? _____

   _____

   _____

   _____

EXPERIMENT G
PHYSICAL AND CHEMICAL CHANGES

In this experiment you will:

a) cause changes to occur in several substances by various methods.
b) test and observe the substances before and after you change them.
c) interpret the test results and decide if composition changes took place in the original substances.
d) classify the changes that took place as physical or chemical.

INTRODUCTION

Most changes that occur in substances can be classified as physical or chemical changes. Physical changes occur without any accompanying changes in composition. Chemical changes result in composition changes; i.e., a substance is converted into one or more new substances.

In this experiment you will subject a number of substances to conditions that will cause changes to occur. You will observe the changes, and test the substances before and after the changes have occurred. You will use the observations and test results to classify the changes as physical or chemical. The tests are not exhaustive, but they will provide you with sufficient information to decide whether or not changes in composition have taken place. However, you must be sure to record everything you see, including color changes, other changes in appearance, and the evolution of gases (fizzing).

EXPERIMENTAL PROCEDURE

A. Solution Formation

Solutions result when one or more substances, called solutes, are dissolved in another substance called the solvent. In liquid solutions the solutes may be gases, liquids, or solids; the solvent is a liquid. Some solid solutes can be recovered from liquid solutions by evaporating away the solvent.

In this part of the experiment you will test sodium chloride before and after it is dissolved in water. You will use the test results to decide the type of change (physical or chemical) that takes place in sodium chloride when it is dissolved in water.

PROCEDURE

1. Place about 0.5 g of solid sodium chloride (NaCl) into each of two 6-inch test tubes.
2. Test the sample in one tube as follows: moisten the end of a clean stirring rod with distilled water. Dip the moist rod into the sample so that a few crystals of solid adhere to it. Put the stirring rod with salt crystals into the flame of your burner.

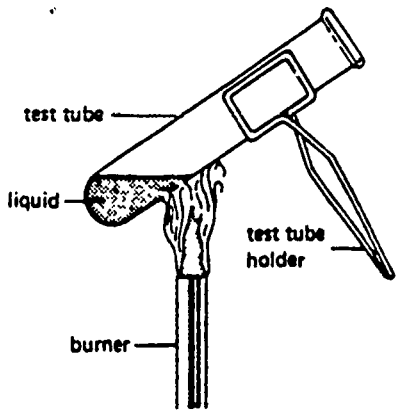


Figure 10. Evaporation of liquids

3. Note and record in Table G.1 (under the "Original Solute" heading) the color of the flame that results in step 2.
4. Form solutions by adding about 5 ml of distilled water to the sample in each test tube. Shake each tube to dissolve the salt.
5. Add 10 drops of 0.1 *M* silver nitrate solution ($AgNO_3$) to the solution in one of the test tubes. Stir well, and record the results of this test under the "Original Solute" heading.
6. Recover the solute sample from the solution in the other test tube by evaporating the solvent. This can be done by heating the test tube slightly above the liquid level, and gently shaking the tube to bring the liquid into contact with the hot portion. Figure 10 illustrates this technique. Caution: *This must be done correctly to prevent hot solution from spattering out of the test tube.*
7. Test a small portion of the recovered solid solute in a flame as you did in step 2. Record the test results.
8. Add 5 ml of distilled water to the recovered solid solute in the test tube. Shake to dissolve, and test the resulting solution with silver nitrate solution as you did in step 5. Record the test results.

B. Heating Copper Carbonate

Upon being heated, some substances undergo chemical changes. Some are changed physically, and others do not change at all. In this part and Part C, you will investigate the effect of heating substances.

PROCEDURE

1. Place approximately 0.1 g of solid copper carbonate ($CuCO_3$) into each of two small, dry test tubes. Note the color of the solid and record it in Table G.2.
2. Tap the tubes on the bench top so any sample clinging to the sides falls to the bottom.
3. Test one sample by adding dilute (6*M*) hydrochloric acid (HCl) dropwise until the resulting reaction is completed. Record the test results in Table G.2.
4. Heat the other sample *very* strongly with a burner for a minimum of 5 minutes.
5. Record the color of the sample after heating.
6. Allow the tube to cool for about 10 minutes.
7. Add dilute (6*M*) HCl dropwise until the cool solid dissolves. Note and record the behavior of the solid toward the HCl.

C. Melting Iron Chloride

PROCEDURE

1. Place approximately 0.1 g of solid iron chloride ($FeCl_3$) into each of two dry 6-inch test tubes.

2. Add about 6 ml of distilled water to one solid sample, and shake until the solid dissolves completely. Record the color of the resulting solution in Table G.3.
3. Make 3 test solutions by pouring 1/3 of the solution prepared in step 2 into each of two other test tubes.
4. Add 5 drops of 0.1 *M* silver nitrate ($AgNO_3$) solution to one test solution, mix well, and record the results.
5. Add 5 drops of 0.1 *M* ammonium thiocyanate (NH_4SCN) to the second test solution, mix well, and record the results.
6. Add 5 drops of 0.1 *M* potassium ferrocyanide ($K_4Fe(CN)_6$) to the third test solution, mix well, and record the results.
7. Heat the other solid sample of $FeCl_3$ *very gently* until it just melts. Do not overheat the sample.
3. Allow the melt to cool for about 5 minutes. The sample might remain in the liquid form even when cool.
9. Add about 6 ml of distilled water to the cool sample and shake until the sample dissolves. Note and record the color of the resulting solution.
10. Divide the resulting solution into 3 equal portions as you did in step 3.
11. Conduct the tests described in steps 4, 5, and 6 on the three separate portions of the solution. Record the test results.

D. Sodium Bicarbonate plus Hydrochloric Acid

Substances may also undergo physical or chemical changes when brought together. The formation of a solution in Part A was an example of such a process; here you will investigate another example.

PROCEDURE

1. Place approximately 0.2 g of solid sodium bicarbonate ($NaHCO_3$) into each of two dry 6-inch test tubes. Record the color of this unreacted solid in Table G.4.
2. Add about 5 ml of distilled water to one sample, and shake until the solid dissolves completely.
3. Test the solution formed in step 2 by adding 15 drops of 0.1 *M* calcium nitrate solution ($Ca(NO_3)_2$). Mix well and record the results.
4. Slowly and carefully add 1 ml of dilute (6*M*) hydrochloric acid (HCl) to the second solid sample.
5. Evaporate the resulting solution from step 4 and recover the solid solute by the method described in step 6 of Part A and illustrated in Figure 11. Record the color of the recovered solid in Table G.4.
6. Allow the test tube to cool. Then add 5 ml of distilled water to the recovered solid and shake until it dissolves.
7. Test the resulting solution by adding 15 drops of 0.1 *M* calcium nitrate solution. Mix well and record the test results.

E. Sublimation and Condensation

The change of a solid directly to a vapor is called sublimation. The change from vapor back to solid is condensation. These changes can be brought about in certain substances by heating and cooling.

PROCEDURE

1. Place approximately 0.1 g of solid ammonium chloride (NH_4Cl) into a clean, small test tube, and about 1.5 g of the solid into a 250 ml beaker. Record the appearance of the solid in Table G.5.
2. Add 2–3 ml of distilled water to the sample in the test tube and allow the solid to dissolve.

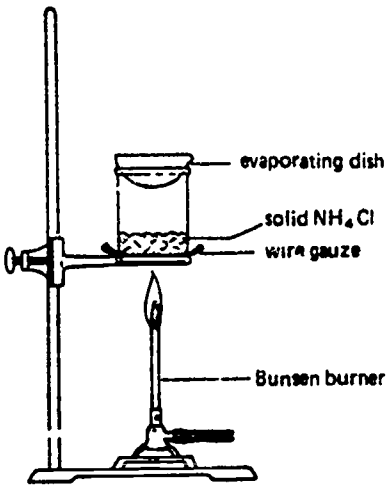


Figure 11. Apparatus for subliming NH_4Cl

3. Add 5 drops of 0.1 *M* silver nitrate ($AgNO_3$) to the resulting solution. Mix well and record the results of this test in Table G.5.
4. Place the 250 ml beaker containing NH_4Cl on the wire gauze of a ringstand-mounted ring. Place a clean, dry evaporating dish over the mouth of the beaker as illustrated in Figure 11.
5. Heat the beaker until you can see that a layer of solid has collected on the bottom of the evaporating dish, or until most of the solid is gone from the bottom of the beaker.
6. Discontinue heating the beaker, allow it to cool for 2–3 minutes, and carefully remove the evaporating dish.
7. Scrape the solid from the evaporating dish onto a piece of filter paper. Record the appearance of the collected solid.
8. Put about 0.1 g of the collected solid into a clean, small test tube and add 2–3 ml of distilled water.
9. After the solid dissolves, test it with 0.1 *M* $AgNO_3$ as you did in step 3. Record the test results.

F. Combustion of Magnesium

Combustion is a familiar process to most of us. It is a source of energy used to move vehicles and generate most of the electricity we use.

PROCEDURE

1. Obtain two 5-cm strips of magnesium ribbon (Mg). Record the appearance of the metal in Table G.6.
2. Place one strip in a 6-inch test tube and cautiously add 10 drops of dilute (6*M*) HCl. Record your observations of the reaction that takes place.
3. Grasp one end of the other strip with your crucible tongs, and hold the strip in the flame of your burner until the magnesium ignites.
   Caution: *Do not look directly at the burning metal.*
4. Collect the combustion product (exclude any unburned metal) and record its appearance.
5. Put the product in a small test tube and treat it with dilute HCl as you did in step 2. Record the results of this treatment.

REPORT

Review the observations and test results recorded in Tables G.1 through G.6. Decide which of these is different before and after attempts were made to change the original substance. Any such differences indicate that a composition change has taken place in the original substance. Decide which test results or observations indicate composition changes, and record your conclusions in Tables G.7 through G.12 by writing *yes* or *no* in the blanks under the heading "Indicates a Composition Change." Then in Table G.13, classify the change that took place in each process as physical or chemical. In the event that some of your tests or observations indicate a physical change for a process while others indicate a chemical change, classify the change as chemical. The reason for this is that some characteristics (such as color) might not change even though the composition of a substance does change. Thus, any indication of chemical change must take precedence over indications of only physical change.

Experiment G/PRE-LAB REVIEW

NAME _____ SECTION _____ DATE _____

PHYSICAL AND CHEMICAL CHANGES

1. What safety precautions are given in this experiment? _____

2. What type of characteristics or behavior will you look for in substances as you perform this experiment? _____

3. What is the difference between a physical change and a chemical change? _____

4. Are solid samples weighed accurately or approximately in this experiment? How can you tell?

5. Describe the process used to recover solid solutes from liquid solutions. _____

Experiment G/DATA & REPORT SHEET

PHYSICAL AND CHEMICAL CHANGES

DATA

A. Solution Formation

Table G.1

	Original Solute	Recovered Solute
Flame color		
Result of adding $AgNO_3$ to dissolved sample		

B. Heating Copper Carbonate

Table G.2

	Unheated Sample	Heated Sample
Sample color		
Result of adding HCl to sample		

C. Melting Iron Chloride

Table G.3

	Unmelted Sample	Melted Sample
Solution color		
Result of adding $AgNO_3$ to test solution		
Result of adding NH_4SCN to test solution		
Result of adding $K_4Fe(CN)_6$ to test solution		

D. Sodium Bicarbonate plus Hydrochloric Acid

Table G.4

	Unreacted Solid	Recovered Solid
Color of sample		
Result of adding $Ca(NO_3)_2$ to dissolved sample		

E. Sublimation and Condensation

Table G.5

	Before Sublimation and Condensation	After Sublimation and Condensation
Appearance of sample		
Result of adding $AgNO_3$ to dissolved sample		

F. Combustion of Magnesium

Table G.6

	Before Combustion	After Combustion
Appearance of sample		
Results of adding HCl to sample		

Experiment G/DATA & REPORT SHEET

NAME _____ SECTION _____ DATE _____

REPORT

A. Solution Formation

Table G.7

Test or Observation	Indicates a Composition Change
Flame color	
Addition of $AgNO_3$	

B. Heating Copper Carbonate

Table G.8

Test or Observation	Indicates a Composition Change
Sample color	
Addition of HCl	

C. Melting Iron Chlorids

Table G.9

Test or Observation	Indicates a Composition Change
Solution color	
Addition of $AgNO_3$	
Addition of NH_4SCN	
Addition of $K_4Fe(CN)_6$	

D. Sodium Bicarbonate plus Hydrochloric Acid

Table G.10

Test or Observation	Indicates a Composition Change
Sample color	
Addition of $Ca(NO_3)_2$	

E. Sublimation and Condensation

Table G.11

Test or Observation	Indicates a Composition Change
Sample appearance	
Addition of $AgNO_3$	

F. Combustion of Magnesium

Table G.12

Test or Observation	Indicates a Composition Change
Sample appearance	
Addition of HCl	

Table G.13

Process Studied	Type of Change
A. Solution Formation	
B. Heating Copper Carbonate	
C. Melting Iron Chloride	
D. Sodium Bicarbonate plus Hydrochloric Acid	
E. Sublimation and Condensation	
F. Combustion of Magnesium	

QUESTIONS

1. Certain popular antacids are dissolved in water (with much fizzing) and are taken in the form of a solution. When the antacid and water are mixed, what kind of change occurs?

   a) physical b) chemical c) can't tell from the information given

   Explain your answer: _____

2. A sample of solid potassium chlorate is heated strongly for 30 minutes. The sample melts and bubbles of gas escape during the heating. Upon cooling, the heated sample becomes solid. The solid is white in color before and after heating. A sample of unheated solid is dissolved in water and 10 drops of silver nitrate are added. Nothing happens. A sample of the heated solid is also dissolved in water and treated with 10 drops of silver nitrate. The solution becomes very cloudy. What classification should be given to the change that occurs when potassium chlorate is heated?

   a) physical b) chemical c) can't be determined from the observations and tests

   Explain your answer: _____

3. Oxygen gas dissolved in water can be used by fish which remove it from the water by means of their gills. Classify the change that occurs when oxygen dissolves in water.

   a) physical b) chemical c) can't tell from the information given

   Explain your answer: _____

4. In Part D of the experiment, a large amount of fizzing took place when HCl was added to solid $NaHCO_3$. Is this observation consistent with the type of change listed for Part D in Table G.13?

   a) yes b) no c) can't be determined from the observation

   Explain your answer: _____

ABOUT THESE EXPERIMENTS (DEMONSTRATIONS)

These experiments (demonstrations) use consumer products (chemicals and equipment that are easy to find in grocery stores, drug stores, garden stores, etc. under consumer product names). For instance:

A plastic dish pan becomes a water bath.
An alcohol burner can be substituted for a Bunsen burner.
Baby food jars or oyster jars can be used instead of beakers.
A two-liter plastic pop bottle can be cut to serve as both a beaker and a funnel using coffee filters.
Vinegar is 5% acetic acid and can be used without dilution.
Baking soda is sodium bicarbonate.
Lye is sodium hydroxide.
Steel wool can be used as a source of iron.
Muriatic acid, readily available at swimming pool supply outlets, is the old, old name for hydrochloric acid.
Saran wrap or aluminum foil can be used instead of parafilm.

Sometimes chemicals and laboratory equipment are available either in the science storeroom of the school or through the district warehouse. It is, however, much more effective for younger students to see every day items used in these experiments. Information on obtaining many of the supplies needed for the experiments described here are given in Appendix II.

In the Materials Sections of the writeups certain common useful items are not always listed. The following should be available for all experiments:

one steam tray per setup	safety glasses	razor blade or utility knife
abundance of paper towels	scissors	spatula or scoopula (or both)
rags or towels for clean up	stirring rods*	hammer or mallet

The experiments (demonstrations) can be conveniently set up and performed in a "stream tray", an item that is readily available in middle school supply rooms. It is used in the earth science curriculum. A stream tray is not necessary, but it will protect the table or desk top and contain any liquid that is accidentally dripped or spilled. Paper towels and rags are handy items for even the skilled experimenter to have nearby.

Safety glasses (safety goggles) should always be worn when performing experiments involving any chemicals.

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* See Proper Technique E, Appendix I to make your own stirring rods.

TABLE OF CONTENTS

EXPERIMENT I: RUSTING OF IRON IN AIR

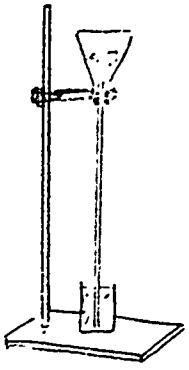
ELEMENT + ELEMENT —> COMPOUND

Purpose: To observe the rusting of iron in the air (21% oxygen).

steel wool + air $\xrightarrow{\text{(yields)}}$ iron oxide (rust)

Description: This experiment exemplifies the rusting of any iron object in air (just lying around). Under controlled conditions the rusting process of a piece of steel wool can be accelerated. [Iron is the major component of steel; technology has produced steel, an alloy of iron with other elements, which is stronger (harder) than iron.]

Materials*:



steel wool, fine grade
ring stand
clamp to hold erlenmeyer flask
250-mL erlenmeyer flask
#6 one-hole rubber stopper to fit 250-mL erlenmeyer
one length (2-4 ft) soft glass tubing, 6-mm diameter
small amount (30 mL) of vinegar (acetic acid)
250-mL beaker
240 mL water
food coloring (optional)
dropping bottle containing glycerol
alcohol (or Bunsen) burner
triangular file

Procedure: NOTE: If Experiments I and III are to be performed on the same day (easily done when pure oxygen is available for Experiment III), prepare two identical setups, i.e., Steps 1 - 5.

1. Prepare a piece of steel wool (approximately 1-inch cube) by slightly pulling it (to spread it a bit).
2. Pour 30 mL vinegar into a 250-mL beaker.
3. Place the steel wool in the vinegar and 'clean it' (stir with fingers - or use a glass stirring rod). This is to remove the protective coating that the manufacturer has put on the steel wool to prevent oxidation by the air. Allow steel wool to remain in vinegar.
4. FOLLOW CAREFULLY THE DIRECTIONS GIVEN UNDER PROPER TECHNIQUE A (in Appendix I) FOR THIS STEP. Cut a 16" length of glass tubing, fire polish both ends of the tubing, and insert the glass tubing into the larger end of the rubber stopper until 1/2-3/4" extends beyond the smaller end of the stopper. Place a drop of glycerol in the hole in the rubber stopper before attempting to insert tubing. Cloth towels may be used to protect hand.

* See Supplies Lists, Appendix II.

Procedure: - continued

5. Place a clean 250-mL beaker on ringstand base. If experiment is to be stored for a week (before next class period), cover beaker top with parafilm (saran wrap) with hole in center to insert tubing through. Covering is to slow down evaporation of liquid in beaker. Hole must be larger than tubing to maintain pressure equilibrium.
6. Squeeze the vinegar out of the steel wool, push steel wool into 250-mL erlenmeyer flask, insert rubber stopper with glass tubing into mouth of erlenmeyer flask.
7. Clamp erlenmeyer flask into place on the ring stand (see figure) with glass tubing suspended approximately 1/4 inch above bottom of beaker.
8. Fill beaker with water (coloring may be added in order to see more easily the water level in the glass tube but will detract somewhat from the observation of the rust).
9. Set entire experiment aside, but in full view of class.
10. Observe changes as the reaction progresses.
    a. Level of water in glass tube.
    b. Level of water in erlenmeyer flask.
    c. Production of Fe_2O_3 (rust): Day 1; Day 2, etc.

Discussion: This is a Direct Combination Reaction. Specifically

an element + an element --> a compound where --> means 'yields'

A piece of steel wool (iron) reacts with the air in the flask

iron + air --> iron oxide (rust)

but air is 21% oxygen (the active ingredient) and rust (iron oxide) is always found in the hydrated form. Thus the chemical reaction can be written as

$$Fe + O_2 \rightarrow Fe_2O_3 \cdot (H_2O)_x \quad x = \text{unknown amount of water}$$

Then, to satisfy the Law of Conservation of Matter the equation can be balanced by including water (H_2O) as one of the reactants and making certain that there are equal numbers of atoms of each element on both sides of the equation

$$4Fe + 3O_2 + xH_2O \rightarrow 2Fe_2O_3 \cdot (H_2O)_x$$

This reaction is slightly exothermic. The rusting of iron proceeds more quickly in pure oxygen [See Experiment III].

Observations: Liquid from the beaker will only fill 1/5 of the erlenmeyer flask with water. Why? (Remember that air is approximately 21% oxygen.)

Second day: Note rust in erlenmeyer.

Save this experimental setup. Later compare the results made here with those of Experiment III.

Precautions: Follow safety procedures for Step 4 above.

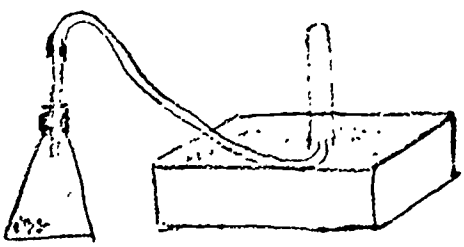
EXPERIMENT II: GENERATION AND PROPERTIES OF OXYGEN

COMPOUND ---> ELEMENT + COMPOUND

Purpose: To generate oxygen by the decomposition of hydrogen peroxide and to demonstrate the properties of pure oxygen gas.

Description: Oxygen is generated by the decomposition of hydrogen peroxide (hair bleach) catalyzed by a very small piece of meat in the flask. Before adding the meat to the peroxide, a small amount of isopropyl alcohol is added to prevent frothing. Oxygen is generated rapidly and stored in test tubes stoppered with corks, in 250-mL beakers ('stoppered' under water with petri dishes), in a 250-mL erlenmeyer flask [stoppered (sealed) with saran wrap (or parafilm) (This flask of oxygen is needed for Experiment III.)].

Materials*:
steel wool, fine grade
2 250-mL erlenmeyer flasks
one #6 one-hole rubber stopper to fit 250-mL erlenmeyer
one length (2-4 ft) soft glass tubing, 6-mm diameter
dropping bottle with glycerol
triangular file
hydrogen peroxide, 3% solution (commercial hair bleach)
liver or ground meat, very small amount (1/2-inch cube)
10 mL isopropyl alcohol (to prevent frothing)
4 test tubes (18 mm x 150 mm)
corks to fit test tubes
3 250-mL beakers
2 disposable petri dishes
16"-18" length of surgical tubing (3/16 inch I.D.)
plastic dish pan (12 x 8 x 5 in)
water
matches
several birthday candles
6 wooden splints
test tube holder
beaker tongs, if available
scoopula
sulfur (1/3 tsp)



Procedure:

1. Fill dish pan 2/3 full with tap water.
2. Immerse test tubes in water in dish pan; fill completely with water; remove all air bubbles. Leave in dish pan. Also fill two 250-mL beakers and one 250-mL erlenmeyer flask with water; allow to remain in dish pan.
3. Cut a 3" length of glass tubing; fire polish both ends. FOLLOW INSTRUCTIONS GIVEN IN PROPER TECHNIQUE A, Appendix I.

* See Supplies Lists, Appendix II.

Procedure: - continued

4. Use glycerol to help insert glass tubing into the larger end of a #6 one-hole rubber stopper (that fits erlenmeyer flask) until approximately 1" protrudes beyond smaller end of stopper. USE PRECAUTIONS DESCRIBED IN PROPER TECHNIQUE A, Appendix I.
5. Attach the 16-18" length of surgical tubing to the glass tubing protruding from the larger end of the stopper. USE GLYCEROL to aid the slipping of the surgical tubing over glass tubing.
6. Add 50 ml of 3% hydrogen peroxide (hair bleach) to contents of flask. If solution is more concentrated, dilute with water to approximately 3%.
7. Set erlenmeyer on ring stand base; clamp in place.
8. Add 5-10 mL isopropyl alcohol to flask (to prevent frothing when meat is added).
9. Obtain a <u>small</u> piece of liver or ground meat (liver works best; approx 1/2 inch cube); pull lightly to spread. Drop meat into erlenmeyer flask.
10. Quickly place rubber stopper containing short glass tubing attached to surgical tubing into mouth of erlenmeyer flask. Direct other end of surgical tubing into water in dish pan. A clamp attached to the edge of the dish pan could be used to help hold the tubing in place. Be careful not to pinch the tubing; make certain there are no kinks in the tubing.
11. Permit reaction to proceed for about 10 seconds to purge the generating system of air.
12. Under water, direct the surgical tubing into the mouth of one of the test tubes (that is completely filled with water). Keep mouth of test tube below surface of water.
13. Use water displacement to fill the test tube with oxygen (the gas being generated). Completely fill the test tube with oxygen gas (no water remaining in tube) and stopper under water tightly with one of the corks.
14. Repeat STEPS 12 and 13 and fill the other three test tubes. Also fill three 250-mL beakers and one 250-mL erlenmeyer flask. 'Stopper' the beakers under water with the disposable petri dishes (leave a little water in the petri dish to complete the 'seal') and set on working surface; stopper erlenmeyer flask with saran wrap (can use parafilm or aluminum foil).

STOP AT THIS POINT: As soon as the 250-mL flask is filled with oxygen, go to Experiment III! Set up the RUSTING OF IRON IN PURE OXYGEN experiment; then return to Step 15.

NOTE: More product (oxygen gas) may be produced by shaking (swirling the contents of) the flask, or, if necessary, by adding more 3% hydrogen peroxide (even after the reaction has stopped). Allow a brief period of time for reaction to remove air from generating system before collecting additional oxygen gas.

Procedure: - continued

Chemical Reactions With Oxygen:

15. Hold one of the test tubes filled with oxygen horizontally in one hand. Hold a wooden splint in the other hand. Have someone light the wooden splint. Blow out burning splint. Remove cork from test tube. Insert glowing splint into test tube. Remove splint from test tube. Blow it out again. Insert splint into test tube; remove, blow out again. Repeat as long as the oxygen supply lasts in the test tube. [HINT: Each time insert splint slowly (only a short distance) into the test tube until it flares up; remove quickly and blow out. It will be necessary to insert splint further into tube with each successive trial.]

16. Light a birthday candle. This should be free standing (melt a little wax and insert base of candle into it). Lift beaker of oxygen out of petri dish; keep in inverted position; quickly place over lighted candle. Note what happens.

17. On a wire gauze or ceramic tile light a small loosely balled piece of steel wool. (It will barely burn.) Before the steel wool stops glowing, place the second beaker of oxygen over steel wool. NOTE: Hold beaker with beaker tongs or quickly set inverted beaker on working surface over the sparkling steel wool. Coolest part is near the rim of beaker; experimenter should be able to grasp it there with bare hands.

18. Ignite sulfur in air by placing a small amount (1/3 tsp) of yellow sulfur on a wire gauze or ceramic surface and torching it with a match. The sulfur will burn but only with difficulty. As the sulfur slowly burns, place the third beaker of oxygen over it. Observe the result. [NOTE: DO NOT REMOVE the beaker after the reaction. Carry the entire system (beaker and wire gauze) to a hood or an open window before opening to the atmosphere.]

Discussion: Generation of oxygen by a decomposition reaction

compound $\xrightarrow[\text{presence of a catalyst}]{\text{yields in the}}$ compound + element

hydrogen peroxide $\xrightarrow{\text{liver}}$ water + oxygen gas

$$H_2O_2(aq) \xrightarrow{\text{catalyst}} H_2O + O_2(g)\uparrow$$

To satisfy Law of Conservation of Matter, balance the equation:

$$2H_2O_2(aq) \xrightarrow{\text{cat.}} 2H_2O + O_2(g)\uparrow$$

Chemical reactions of oxygen: Examples of direct combination

element + element ---> compound

a. iron + oxygen ---> iron oxide

$$4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s) \qquad (s = \text{solid})$$

b. solid sulfur + oxygen gas ---> sulfur dioxide gas

$$S(s) + O_2(g) \xrightarrow[\Delta]{} SO_2(g)$$ heat (Δ) only necessary to start reaction

Observations: Note what happens to candle when it burns in pure oxygen.

Note what happens to steel wool (that would barely burn in air) when it is lit in a pure oxygen atmosphere.

Describe the reaction when sulfur burns in pure oxygen. Compare with burning of sulfur in air.

Precautions: CAUTION: Beaker in STEP 19 becomes very hot.

CAUTION: In STEP 20 DO NOT ALLOW THE sulfur dioxide (SO_2) to escape into the room. It is a suffocating poisonous gas.

EXPERIMENT III: RUSTING OF IRON IN PURE OXYGEN

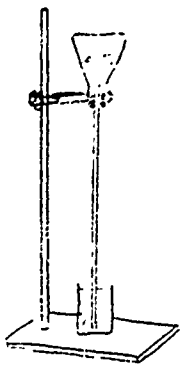
ELEMENT + ELEMENT --> COMPOUND

Purpose: To observe the rusting of iron in pure oxygen.

steel wool + oxygen $\xrightarrow{\text{(yields)}}$ iron oxide (rust)

Description: In pure oxygen the rusting process is greatly accelerated. Heat is given off.

Materials*:



steel wool, fine grade
ring stand
clamp to hold erlenmeyer flask
250-mL erlenmeyer flask filled with oxygen (generated in Exp. II)
#6 one-hole rubber stopper to fit 250-mL erlenmeyer
one length (2-4 ft) soft glass tubing, 6-mm diameter
small amount (30 mL) vinegar (acetic acid)
250-mL beaker
250 mL water
glycerol (in dropping bottle)
food coloring (optional)
Bunsen (or alcohol) burner
triangular file
pure oxygen (250-mL flask, generated in Experiment II)

Procedure: This is the same experimental setup as in Experiment I. The same equipment can be used here.

1. Prepare a piece of steel wool (approximately 1-inch cube) by slightly pulling it (to spread it a bit).
2. Pour 30 mL vinegar into a 250-mL beaker.
3. Place the steel wool in the vinegar and 'clean it' (stir with fingers - or use a glass stirring rod). This is to remove the protective coating that the manufacturer has put on the steel wool to prevent oxidation by the air. Allow steel wool to remain in vinegar.
4. Cut a 16" length of glass tubing, fire polish both ends of the tubing, and insert the glass tubing into the larger end of the rubber stopper until 1/2-3/4" extends beyond the smaller end of the stopper. FOLLOW CAREFULLY THE DIRECTIONS GIVEN UNDER PROPER TECHNIQUE A (Appendix I) FOR INSERTING A GLASS TUBE INTO A RUBBER STOPPER.
5. Place 250-mL beaker on ringstand base. Fill with water. Cover top of beaker with parafilm (saran wrap) with hole in center to insert tubing through later. This is to slow down evaporation. Hole must be slightly larger than tubing to maintain pressure equilibrium.

* See Supplies Lists, Appendix II.

EXPERIMENT III: RUSTING OF IRON IN PURE OXYGEN - continued

Procedure: - continued

6. Squeeze the vinegar out of the steel wool, quickly remove parafilm (i.e., saran wrap seal) from 250-mL flask containing oxygen (see Experiment II), quickly insert steel wool into 250-mL erlenmeyer flask, insert rubber stopper with glass tubing into mouth of erlenmeyer flask.

7. Clamp erlenmeyer flask into place on the ring stand (see figure) with bottom of glass tubing inside beaker and approximately 1/4 inch above bottom of beaker.

8. Set entire experiment aside, but in full view of class.

REMEMBER to refill beaker with water before leaving classroom or when level of water in beaker drops to 1/4 full. Recover with parafilm. Coloring may be added to the water.

IF APPROPRIATE, return now to Experiment II, Step 15. From time to time observe this experiment. The reaction proceeds more quickly than the reaction in Experiment I.

9. Observe and record the changes as the reaction progresses.

   a. Level of water in glass tube.
   b. Level of water in erlenmeyer flask.
   c. Production of $Fe_2O_3 \cdot (H_2O)_x$ (rust) in erlenmeyer flask.

Discussion: Direct Combination Reaction

element + element --> compound where --> means 'yields'

iron + oxygen --> iron oxide (rust)

Rust (iron oxide) is always found in the hydrated form, thus

$$Fe + O_2 \longrightarrow Fe_2O_3 \cdot (H_2O)_x \quad x = \text{unknown amount of water}$$

Finally, the Law of Conservation of Matter states that matter is neither created nor destroyed in a chemical reaction.

Thus the equation must be balanced by including water (H_2O) as one of the reactants and making certain that there are equal numbers of atoms of each element on both sides of the equation

$$4Fe + 3O_2 + xH_2O \longrightarrow 2Fe_2O_3 \cdot (H_2O)_x$$

The reaction of iron with oxygen is exothermic. (Heat is released.)

Observations: Liquid from beaker should completely fill erlenmeyer flask.

Compare this with observations made during Experiment I.

Precautions: Follow Safety Procedures for Step 4 above.

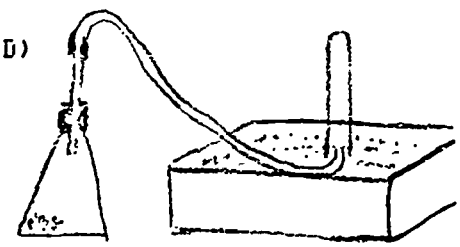
EXPERIMENT IV: GENERATION AND PROPERTIES OF HYDROGEN

ELEMENT + COMPOUND --> ELEMENT + COMPOUND

Purpose: To generate hydrogen by a direct combination reaction and to demonstrate some properties of hydrogen gas.

Description: Hydrogen gas is generated by pouring muriatic acid over a piece of steel wool. Samples are collected by water displacement and then ignited with a match. This is a "fun" experiment.

Materials*:
steel wool, fine grade
250-mL erlenmeyer flask
#6 one-hole rubber stopper to fit 250-mL erlenmeyer
one length (2-4 ft) soft glass tubing, 6-mm diameter
triangular file
Bunsen or alcohol burner
dropping bottle with glycerol
50 ml concentrated muriatic acid (to be diluted 2:1)
100-mL or 150-mL beaker
4 test tubes (18 mm x 150 mm)
corks to fit test tubes
16"-18" length of surgical tubing (3/16-inch ID)
plastic dish pan (12 x 8 x 5 in)
ring stand and clamp to hold flask
bubble generating solution
wooden safety matches



Procedure:

1. Fill dish pan 1/2-2/3 full with tap water.
2. Immerse four test tubes in the water; fill tubes completely with water; remove all air bubbles.

The generating system from Experiment II can be used here or prepare a new setup as follows:

3. Cut a 3" length of glass tubing; fire polish both ends. FOLLOW INSTRUCTIONS GIVEN IN PROPER TECHNIQUE I.
4. Use glycerol to help insert glass tubing into the larger end of a #6 one-hole rubber stopper (that fits the 250-mL erlenmeyer flask) until approximately 1" protrudes beyond smaller end of stopper. USE PRECAUTIONS DESCRIBED IN PROPER TECHNIQUE I.
5. Attach 16-18" length of surgical tubing to end of glass tubing. protruding from larger side of rubber stopper. USE GLYCEROL to aid slipping of surgical tubing over glass tubing.
6. Dilute concentrated muriactic acid (hydrochloric acid) by adding 50 ml of conc acid slowly TO 25 ml of water in a small beaker.
7. Set erlenmeyer flask on ring stand base; clamp in place.
8. Obtain a piece of steel wool (approx 1 inch cube); pull lightly to spread. Insert into erlenmeyer flask.

* See Supplies Lists, Appendix II.

Procedure: - continued

9. Pour the diluted (2:1) muriatic acid (hydrochloric acid) into the generator flask and quickly place rubber stopper containing short glass tubing attached to surgical tubing into mouth of erlenmeyer flask.

10. Direct the open end of surgical tubing into the water in the dish pan. A clamp (clothes pin) attached to the edge of the dish pan could be used to help hold the hose in place. Be careful not to pinch the tube; make certain there are no kinks in the tubing.

11. Permit reaction to proceed about 30 seconds to purge the flask of air. (Several small bubles should be generated each second.)

12. Under water, direct surgical tubing into mouth of one of the test tubes (that is completely filled with water).

13. Use water displacement to fill test tube with hydrogen (the gas being generated). Completely fill the test tube with hydrogen gas (no water remaining in tube), stopper tightly under water with cork, and store under water.

14. Repeat Steps 12 and 13 to fill other three (or more) test tubes.

15. While the generator is still producing hydrogen, put some bubble solution in a small amount of water in a plastic petri dish. Direct the generator hose into the solution to blow some bubbles of hydrogen. The bubbles will stick to the top of the bubble solution. After you have a nice collection of the bubbles, remove the hose from the bubble solution and place it back into the dish pan. Then remove the petri dish far from the generator (a few feet). Proceed immediately to Step 17.

More product (hydrogen gas) can be produced by shaking (swirling the contents) the flask, or, if necessary, by adding more concentrated acid. After each addition of acid allow a brief period of time for reaction to remove air from the generating system before collecting additional gas.

16. After all samples have been collected and the reaction has slowed down, remove the stopper and tubing from the flask. Cover the mouth of the flask lightly with saran wrap or aluminum foil, set flask aside, and save for Experiment VII. DO NOT STOPPER AS GAS BUILD UP IN FLASK MAY CAUSE THE FLASK TO BLOW UP.

Chemical Reactions of Hydrogen

17. Light the bubbles 'blown' in Step 15 above with a match.

18. Hold one of the corked test tubes almost parallel to the working surface with the mouth tilted downward. [Remember: hydrogen gas is much lighter than air.] With other hand strike a match.

19. Have someone remove the cork from the test tube in your hand.

20. Hold lighted match to mouth of test tube. [CAUTION: Make certain open end of test tube is directed away from everyone.]

21. Repeat Steps 18-20.

Discussion: Hydrogen gas is the most prevalent material in the universe. It is the lightest element (much lighter than air). It is easy to generate and it is easy to ignite. It must be handled properly in small quantities as directed here. Large quantities of hydrogen and confined quantities of hydrogen, however, are dangerous. The most famous hydrogen explosion was the destruction of the Hindinberg dirigible in 1928.

Generation of hydrogen by a combination reaction

element + compound $\xrightarrow{\text{(yields)}}$ element + compound

steel wool + muriatic acid --> hydrogen gas + a salt

iron + hydrochloric acid -> hydrogen gas + iron chloride

$Fe(s) + HCl(aq) \longrightarrow H_2(g)\uparrow + FeCl_2(aq)$

Note: gas (g) is evolved (given off) ↑; (s) = solid; (aq) = aqueous.

To conform with the Law of Conservation of Matter, balance the equation:

$$Fe(s) + 2HCl(aq) \longrightarrow H_2(g)\uparrow + FeCl_2(aq)$$

Chemical reaction of hydrogen with air (oxygen)

element + element -----> compound

hydrogen + oxygen (air) ---> water

$$H_2(gas) + O_2(gas) \longrightarrow H_2O(gas, \text{ i.e., steam})$$

and the balanced equation is: $2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$

Remember hydrogen is lighter than air. Always aim the mouth of the test tube downward before removing the cork to prevent the hydrogen gas from escaping.

Observations: When the hydrogen 'popped', a small amount of water has formed in the test tube, but this may be difficult to see because the gas was collected under water and the tube may be wet already. The magnitude of the W-O-O-F will depend upon the amount of air that mixed with the hydrogen in the test tube.

Next day: Note contents of the 'covered' erlenmeyer flask. The steel wool is gone; iron chloride was produced and remains dissolved in the excess acid in the flask. [SAVE THIS FLASK AND CONTENTS for Experiment VII.]

Precautions: When lighting the hydrogen gas, always direct the test tube away from you and from others. DO NOT COLLECT OR LIGHT LARGE QUANTITIES OF HYDROGEN. [EVEN a beaker full could be very dangerous.]

DO NOT STOPPER the generating flask from Step 16 that is being saved for Experiment VII. Cover with saran wrap or foil.

EXPERIMENT V: GENERATION AND PROPERTIES OF CARBON DIOXIDE

Purpose: To generate carbon dioxide gas by various methods and demonstrate some of its chemical and physical properties.

Description: Several of the properties of carbon dioxide are illustrated in this experiment. First the reaction of carbon dioxide (CO_2) with calcium oxide (lime) is demonstrated (Exp. V.A). Then, the generation of CO_2 from household baking soda and vinegar is carried out (Exp. V.B). The CO_2 that is generated is shown to be much heavier than air and also to be able to extinguish candles. The production of CO_2 by the sublimation of Dry Ice is also shown, and two simple methods for proving that the density of carbon dioxide is much greater than that of air are given (Exp. V.C). Finally, the experimenter is asked to devise a simple splint test for CO_2, i.e., to show that it will not support combustion (Exp. V.D).

Materials: See Experiments V.A -V.D for materials needed for each experiment.

- -

Experiment V.A: Chemical Reaction of Carbon Dioxide in Solution

Materials A: lime (CaO)
water
1-L erlenmeyer flask
rubber stopper to fit 1-L flask (or saran wrap or aluminum foil)
250-mL erlenmeyer flask
one or two 'soda' straws

Procedure A:

A1. In advance, prepare lime water. Add approximately 1/2 cup of lime (CaO) to 800 mL of water in the 1000-mL erlenmeyer flask. Stopper or cover tightly with saran wrap or foil. Shake well. Allow mixture to sit overnight. LABEL THIS FLASK [lime water or $Ca(OH)_2$].

A2. Next day decant about 200 mL of "clear" top solution into a 250-mL beaker. [Save leftover lime water for Experiments VI and VIII. It will keep for several months.]

A3. Insert one of the straws into the solution in the beaker.

A4. Take a deep breath and blow as hard and as long as you can through the straw into the solution. When you must take another breath, remove your mouth from the straw while you inhale. Exhale again through the straw into the solution. Continue to blow into the beaker until a noticeable reaction occurs.

NOTE: With 'bendable' straws two people could exhale into the solution at the same time -- for a faster reaction.

Discussion A: Man exhales carbon dioxide (CO_2). The CO_2 reacts with the lime water [$Ca(OH)_2$] to produce calcium carbonate ($CaCO_3$), which precipitates out of solution ($\downarrow$) and causes the liquid to turn cloudy.

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3\downarrow + H_2O$$

This reaction is a common test for carbon dioxide gas.

Experiment V.A: Chemical Reaction of Carbon Dioxide in Solution - continued

If one continues to blow into the cloudy solution, it will eventually turn clear. The insoluble calcium carbonate (the white precipitate that made the solution turn cloudy) reacts with more carbon dioxide to form soluble calcium bicarbonate. The reaction is:

$$CaCO_3(s) + H_2O + CO_2(g) \rightarrow Ca(HCO_3)_2(aq)$$

Observations A: The liquid (lime water) becomes cloudy when CO_2 is exhaled into the beaker.

Experiment V.B: Generation of Carbon Dioxide; Density of Carbon Dioxide

Materials B: 1/2 cup baking soda ($NaHCO_3$)
100 mL vinegar (5% acetic acid)
2 birthday candles
wooden matches
plastic, glass, or cardboard tube, 12" or longer, at least 1-inch diameter
1-L beaker
saran wrap or aluminum foil to partially cover top of beaker

Procedure B: B1. Place about 1/2 cup baking soda into the 1-L beaker.

B2. Partially cover beaker with foil or saran wrap; do not cover spout (see figure).

B3. Prepare a free-standing birthday candle (melt a little wax and stick lighted candle in soft wax).

B4. Add 50 mL vinegar to the partially covered beaker containing the baking soda.

B5. Hold the 1"-diameter tube at about a 45^0 angle, aim bottom end of tube at lighted candle, 'pour' carbon dioxide gas that is being generated in the beaker down the tube. Be careful not to pour any liquid down the tube! [NOTE: Because the reaction occurs very fast, be ready to 'pour' the CO_2 gas as soon as the vinegar is added.]

Discussion B: Carbon dioxide is quickly generated when vinegar is added to baking soda.

baking soda + vinegar ---> carbon dioxide + a salt + water

$$NaHCO_3 + H(C_2H_3O_2) \rightarrow CO_2(g)\uparrow + Na(C_2H_3O_2) + H_2O$$

The equation is balanced.

Carbon dioxide (CO_2) gas is heavier than air and therefore can be 'poured' down the tube. The CO_2 slowly replaces the air (oxygen) around the candle and extinguishes the flame, which requires oxygen to burn.

Observations B: Watch closely the shape of the candle flame as it is extinguished.

Experiment V.C: Sublimation of Dry Ice; Density of Carbon Dioxide

Materials C: aquarium (fish tank)(or other very large glass container)
1 lb Dry Ice (optional; see ** below)
hammer or mallet
wooden blocks, small boxes, 1-1 1/2 inch
6 birthday candles
wooden safety matches
bubble maker (Miracle Bubble or equivalent)

Procedure C:

C1. Place three free standing candles at three different levels in the aquarium. A candle is placed on the bottom of the vessel. Use wooden blocks or other convenient items to raise the other two candles in steps of 1 to 1 1/2". The top of the highest candle should still be 2-3 inches below the top of aquarium.

C2. Break Dry Ice into chunks (1" to 3" in size).** CAUTION: Dry Ice is very cold and can freeze fingers. Handle with gloves or a towel. Wrap Dry Ice in lab (cloth) towel and hit toweling with a hammer or mallet to break the Dry Ice.

C3. Light the candles.

C4. Carefully and quickly place Dry Ice chunks on bottom of aquarium tank with beaker tongs, gloves, or toweling.

C5. When aquarium is "full" of carbon dioxide (candles have gone out), 'blow' bubbles, using a commerical (toy) preparation or other soapy solution, and allow the bubbles to float over and into the aquarium. [Pull the wand lengthwise over the 'empty-looking' tank.]

** If Dry Ice is not available a large beaker containing baking soda can be placed on the bottom of the tank and vinegar can be added after the candles are lit. [Carbon dioxide will be generated, will fill the beaker, 'roll out over the sides' of the beaker, and 'fill' the tank.]

Discussion C: Dry Ice is cooled, compressed carbon dioxide gas. The reverse reaction that occurs here, i.e., the solid Dry Ice turns to carbon dioxide gas, is called sublimation. Sublimation is the process by which a solid goes directly to the gaseous phase (by-passing the liquid stage.)

Carbon dioxide is heavier than air. Thus, as the Dry Ice sublimes, the carbon dioxide gas settles first on the bottom of the aquarium and as more gas is generated begins to replace the air (oxygen supply) in the tank until it fills the tank (with carbon dioxide).

Observations C: Note closely the shape of the flames as they are slowly, in turn, extinguished.

Note what happens when bubbles are 'blown' over the aquarium and allowed to float downward.

Experiment V-D: Will Carbon Dioxide Support Combustion?

Materials D: 3 wooden splints
wooden safety matches
250-mL erlenmeyer
one #6 one-hole rubber stopper, fitted with short glass rod and a 16"-18" length of 6-mm diameter surgical tubing (see Exp. II)

Procedure D: D1. Fill a test tube with carbon dioxide.

a. Devise a method to fill the tube by directing the gas generated in one of the above ways into a test tube.
b. If all else fails, construct a generating system, such as was used in Experiments II or IV. Add baking soda and vinegar to the flask, direct hose downward into empty test tube.

D2. Allow sufficient time for tube to fill (will depend mostly upon the rate of generation of carbon dioxide).

D3. Light a wooden splint. Turn test tube of carbon dioxide gas horizontally and insert the flaming splint into test tube.

D4. Steps D1-D3 can be repeated.

Discussion D: Since carbon dioxide is heavier than air, it is not necessary to use water displacement to collect it. In fact, one can just direct the tube from the generating flask into a test tube or a flask and the CO_2 will fill the container and expel the air. The difficulty is that one cannot really tell when the vessel is full.

A very simple way to generate CO_2 is to put a few chunks of Dry Ice into a flask and connect a hose to it in the usual way. The CO_2 slowly sublimes and the gas can be directed into any vessel at will.

Observations D: Note what happens when a burning splint is inserted into a test tube of carbon dioxide gas.

How does this 'splint test' differ when oxygen or hydrogen is present instead of carbon dioxide?

Precautions: Be careful when handling Dry Ice in Experiment V.C. Dry Ice is very cold and could freeze fingers and hands under prolonged contact. Use gloves or tongs when handling Dry Ice.

Questions: What is the function of baking soda in 'cooking'?

What is sublimation?

What would happen to a lime water solution if the gas from a CO_2 generator were directed into the solution? Why not try the experiment?

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EXPERIMENT VI: SIMPLE ACID/BASE CHEMISTRY

COMPOUND + COMPOUND ---> COMPOUND + COMPOUND

Purpose: To investigate the properties of acids and bases.

acid + base ---> salt + water

Description: The fundamental reaction of an acid with a base is carried out with two different acids and two different bases. This NEUTRALIZATION reaction will be monitored with an INDICATOR.

Materials:
lime water [$Ca(OH)_2$] (see Exp V)
lye (NaOH)
vinegar [$H(C_2H_3O_2)$]
muriatic acid (HCl)
1 250-mL erlenmeyer flask
solid rubber stopper (or saran wrap or foil) to fit 250-mL flask
4 'medicine' droppers
4 400-mL beakers
250-mL beaker
100-mL beaker
indicators in dropping bottles
phenolphthalein, Phenol Red, etc.
cabbage indicator (see preparation below, Experiment VIII)

Procedure:

1. Prepare a saturated solution of lime water, $Ca(OH)_2$, as directed in Experiment V. Use the clear, supernatant liquid below.
2. Place about 10 mL of the $Ca(OH)_2$ (clear supernatant) solution in a 400-mL beaker and add 100 mL of water. Then add an indicator, either Phenol Red or phenolphthalein. Just a few drops of the indicator is enough. Label the beaker B1 (Base #1) Record the color of the solution.
3. In the 250-mL flask prepare a solution of sodium hydroxide. Add a heaping teaspoon of household LYE slowly, while stirring, to 150 mL of cold water until the lye dissolves. This is a concentrated solution of sodium hydroxide, NaOH. [LABEL IT; it will be needed in Experiments VII and VIII.] [This solution will keep indefinitely, but it will 'eat' (etch) the glass. Store for long periods of time in a plastic bottle; LABEL it.]
4. Take 1 mL of the concentrated NaOH solution prepared in Step 3 and add it to 100 mL of water in a 400-mL beaker. This is a dilute solution of NaOH. Add a few drops of available indicator to this solution. Label the beaker B2 (Base #2) Record the color of the solution.
5. (a) Pour some vinegar into a small beaker. (b) Use a medicine dropper to add vinegar (acid), drop by drop, to **beaker B1** until a change in color occurs. Swirl the solution to obtain a uniform color.
6. Carefully add a <u>little</u> more of the concentrated limewater (base) solution to B1 until the color switches back to the original one. Then repeat Step 5b. With a little practice this color change can be run back and forth any number of times.

Procedure: - continued

7. Now add vinegar (acid), drop by drop, to solution B2 until the indicator switches. Then carefully (use a dropper) switch the color back by adding a very small amount of the concentrated lye (base) solution. Add vinegar (acid) again and switch the color back. With practice you can run this reaction back and forth for as long as the reagents last.
8. Repeat Steps 2 and 4 above, except label the beakers, B3 and B4, respectively.
9. Repeat Steps 5, 6, and 7, except use dilute HCl (muriatic acid) instead of vinegar to effect the color changes. Prepare the dilute HCl by adding 1 mL of concentrated muriatic acid to 100 mL of water. (Add acid to the water, SEE PROPER TECHNIQUE B.)
10. Wash your hands and dry them. Then place a few drops of the concentrated NaOH solution on your index finger and feel its properties. Wash the lye off in cold water. Test the lime water in the same way.
11. Pour some vinegar on your fingers and note its 'feel'. Wash it off with cold water. Dilute a few milliliters of concentrated muriatic acid with about twice the volume of water and feel the solution. Wash your hands in cold water.

Discussion: Acids and bases are chemical opposites. Each has its own set of properties. When added together, acids and bases react by a process that is called 'neutralization'. After neutralization both the acidic and basic properties disappear and a new substance is generated. This is called a salt. An INDICATOR is a substance that has the special property of being one color (or colorless) in an acid solution and another color in a basic solution.

In this experiment you carried out the following reactions:

acid + base --> water + a salt

NOTE: water can be written as H_2O or HOH.

(a) vinegar + lime water --> water + a salt

$2H(C_2H_3O_2) + Ca(OH)_2 \rightarrow 2HOH + Ca(C_2H_3O_2)_2$

acetic acid + calcium hydroxide -> water + calcium acetate

(b) vinegar + lye --> water + salt

$H(C_2H_3O_2) + NaOH \rightarrow HOH + Na(C_2H_3O_2)$

acetic acid + sodium hydroxide -> water + sodium acetate

(c) muriatic acid + lime water --> water + salt

$2HCl + Ca(OH)_2 \rightarrow 2HOH + Ca(C_2H_3O_2)_2$

hydrochloric acid + calcium hydroxide -> water + calcium acetate

(d) muriatic acid + lye --> water + salt

$HCl + NaOH \rightarrow HOH + NaCl$

hydrochloric acid + sodium hydroxide --> water + sodium chloride

Discussion: - continued

When the indicator switches, the solution goes from being acidic (basic) to basic (acidic). At the switching point the solution is neither acidic nor basic; it is 'neutral'. It contains only the salt dissolved in water.

Observations: Notice that water is generated in all these acid/base reactions. Water is always one of the products of a neutralization reaction. The other substance is always called a 'salt' although table salt is only produced when HCl and NaOH are the acid and base used.

What was the 'feel' of an acid solution?

What was the 'feel' of a basic solution?

What was the 'acid' color of your indicator?

What was the 'base' color of your indicator?

Was the process of dissolving lye in water exothermic?

Do you think that the neutralization reaction is exothermic? How could you prove that it was (was not)?

Precautions: Although you were instructed to feel both the acid and base solutions, this is not normal practice. Strong acids and strong bases can damage tissue badly if left in contact with the skin. If an acid or a base is spilled on you or your clothes, it is always wise to flood the contaminated area with water.

EXPERIMENT VII: EXPERIMENTS WITH IRON

Purpose: To demonstrate a few of the properties of iron.

Description: In this set of activities some properties of iron are investigated. In the first experiment the iron that 'disappears' when steel wool is used to produce hydrogen is finally recovered as 'rust'. In the second experiment iron is mixed with sulfur and the difference between a chemical and a physical change is shown. A new compound of iron with sulfur (FeS) is shown to have properties different from both iron and sulfur.

Materials: Materials needed are listed under Experiments VII.A and VII.B.

Experiment VII.A: Chemical Reactions With Iron

Materials A:
steel wool
muriatic acid
lye
coffee filters
plastic soft drink bottle

Procedure A: A1. Dissolve some steel wool in concentrated muriatic acid. Place a 1" cube of steel wool in a 250-mL erlenmeyer flask and add 30 mL of concentrated HCL. Cover the flask lightly with saran wrap and allow it to set overnight until all the steel wool dissolves. Hydrogen will be generated and the flask should be out on the desk so that the gas dissipates quickly into the atmosphere.

NOTE: If you saved the contents of the generation flask in Experiment IV, then use that solution here.

A2. Pour the contents of the flask containing the dissolved iron into a 400-mL beaker. Add concentrated lye (NaOH) solution [Experiment VI, Step 3] to the iron solution until a deep green precipitate forms. It is good technique to add the concentrated lye solution with a dropper since it is then easy to see the precipitate form and to observe when the precipitation is complete. Continue to add the lye solution until no more precipitate forms.

A3. Prepare a filtering apparatus from a plastic bottle and coffee filters. With razor blade or utility knife make a horizontal cut in the plastic bottle about 1/3 down from the top. Cut the bottle into two pieces with scissors. The bottom becomes a 750-mL beaker and the top portion becomes the filter funnel. Set the filter funnel into a ring on the ringstand, if available. If not, set filter on top of 500-mL or other beaker whose diameter is smaller than that of the plastic bottle. Place coffee filter in filter funnel.

A4. Filter the green precipitate from the solution prepared in Step 2 above. The precipitate will remain on the filter paper and the filtrate will go through it.

Procedure: - continued

A5. Add a few drops of 3% H_2O_2 to the precipitate on the paper. It will turn red.

A6. Add a few drops of the H_2O_2 to the filtrate. What happens?

Discussion A: When iron (steel wool) reacts with HCl (muriatic acid) to produce H_2 (hydrogen) gas, the other product of the reaction is iron chloride, $FeCl_2$. This substance remains dissolved in the solution. The equation is:

$$Fe(solid) + 2HCl(liquid) \rightarrow H_2(gas) + FeCl_2(aqueous)$$

When concentrated NaOH (lye) is added to the $FeCl_2$ solution, it first neutralizes any excess acid (HCl) that is there and then precipitates iron hydroxide, $Fe(OH)_2$. This equation is:

$$FeCl_2(aq) + 2NaOH(aq) \rightarrow Fe(OH)_2\downarrow + 2NaCl(aq)$$

The green iron hydroxide precipitate (↓) can then be filtered off. Addition of hydrogen peroxide converts (oxidizes) the iron to 'rust'. This equation is

$$2Fe(OH)_2 + H_2O_2 + xH_2O \rightarrow Fe_2O_3 \cdot (H_2O)_x + 3H_2O$$

The oxygen of the air can also oxidize the green $Fe(OH)_2$ precipitate. If allowed to set around overnight without addition of hydrogen peroxide, the rust color can be noted around the edges of the precipitate on the filter paper. This reaction could be written:

$$4Fe(OH)_2 + O_2 + H_2Ox \rightarrow 2Fe_2O_3 \cdot (H_2O)_x + 4H_2O$$

Recall: x signifies an unknown number of waters of hydration.

Experiment VII.B: Physical and Chemical Experiments With Iron and Sulfur

Materials B: iron filings (fine grade)
sulfur
magnet
small test tube (10 x 75 mm)
test tube holder (tongs)
burner
scoopula
several sheets of paper
dilute muriatic acid (HCl)(1:10)

Procedure B: B1. Place 1/2 tsp of iron filings on one of the sheets of paper.

B2. Wrap the magnet in saran wrap. Hold magnet near filings.

Experiment VII.B: Physical & Chemical Experiments With Iron & Sulfur - continued

Procedure B: - continued

B3. Remove filings from magnet. This is a lot easier to do if the magnet is first wrapped in saran wrap.

B4. Place 1/2 tsp of sulfur on a second piece of paper. Hold the magnet close to the sulfur. What happens?

B5. Place 1/2 tsp of iron filings on the paper with the 1 tsp of sulfur. Mix the two substances well by rolling the paper back and forth. A stirring rod or scoopula can also be used.

B5. Hold the magnet wrapped in the saran wrap near the mixture of iron and sulfur. Note what happens.

B6. Remove filings from magnet. Mix the filings again thoroughly with the sulfur.

B7. With the scoopula, or by making a 'funnel' out of a piece of paper place the thoroughly-mixed iron and sulfur mixture into a small test tube. Keep the test tube vertical and tap the mixture to the bottom. Fill the test tube almost to the top.

B8. Use the test tube holder! Heat the very bottom of the tube over a burner until a reaction commences, as evidenced by a red glow in the contents. Remove from heat source, and watch the reaction progress. To start the reaction a Bunsen burner is best; it just takes much longer with an alcohol burner. Always DIRECT the OPEN END of a test tube away from all ovservers and the experimenter.

B9. When the reaction in the small test tube is over, set the tube aside and wait for it to cool. Then remove some of the dark reaction product and place it on a watch glass. (Note: It may be necessary to break the test tube to remove the contents.)

B10. Test the new substance formed with the magnet. Is it attracted to the magnet?

B11. Add ONE DROP of dilute HCl to a little sulfur on a watch glass. Does anything happen?

B12. Now add ONE DROP of dilute HCl to the new substance that you made from iron and sulfur. Do you notice anything? Do you smell anything? Record your observations.

Discussion B: Iron is an element. Sulfur is an element. When the two are mixed together, a mixture results. The mixture is not a compound. The two elements can easily be separated by holding a magnet near the mixture. Iron is magnetic and is attracted to the magnet; sulfur is not magnetic. If the mixture of the two elements is heated, a compound forms. This reaction of iron with sulfur is very <u>exothermic</u>. The burner only supplies enough heat to start the reaction.. Then it runs by itself and <u>produces</u> heat.

Experiment VII.B: Physical & Chemical Experiments With Iron & Sulfur - continued

Discussion B: - continued

$$\text{iron} + \text{sulfur} \xrightarrow[\text{heated}]{\text{-------}} \text{iron sulfide} + \text{heat}$$

$$Fe + S \xrightarrow[\Delta]{\text{-----}} FeS + \text{heat}$$

The gas generated in Step B12 with the addition of HCl to the dark iron sulfide is hydrogen sulfide. It is a foul-smelling poisonous gas. Few people are ever poisioned by it, however, for a very small amount sends out a very obvious warning.

$$FeS + 2HCl \rightarrow H_2S\uparrow + FeCl_2$$

Observations B: What edible object often has an odor of hydrogen sulfide?

Precautions B: In Step B8 direct the open end of the test tube away from everyone.

Add only enough HCl to the iron sulfide to obtain a noticeable odor of hydrogen sulfide gas. DO THIS EXPERIMENT IN A WELL VENTILATED ROOM.

NOTE: At high concentrations hydrogen sulfide deadens your sense of smell.

EXPERIMENT VIII: PREPARATION OF NATURAL INDICATORS

Purpose: To show color changes using natural products as indicators.

Description: Experiments to show pH changes from acidic to basic and back are performed using consumer products as the acids and bases and natural products as indicators that display color changes.

Materials:
red cabbage
blueberries
beets
other available edible products or certain flowers

Procedure:

1. Chop the material (see suggestions above). Place about 1/2 cup of chopped material in a 400-mL beaker.

2. Add 100 mL of a solution of approximately 50% water/50% isopropyl alcohol to the chopped material. (Pure water will work but the extraction goes faster with alcohol added.)

3. Place a watch glass over the beaker. Heat for approximately 30 minutes. Allow to boil very slowly.

4. Decant off colored solution into a 250-mL beaker.

5. Add 100-mL water to colored solution. Add concentrated HCl (muriatic acid) dropwise until the solution turns bright red. Add concentrated NaOH (Lye, See Experiment VI, Step 3) dropwise until there is a definite color change.

6. Proceed to change the color of the solution back and forth from dark blue-green (basic) to red (acidic) by adding concentrated base and acid, respectively.

Discussion: You have produced your own acid-base indicator.

A red cabbage solution turns a dark blue-green when the solution is basic and back to red when acid is added.

Most colorful, edible foods make interesting indicators. Try grape juice (it must be diluted). Some flowers can also be used as indicators. The supply is infinite.

Observations: The possibilites are endless. Try some.

Precautions: One should always be careful when handling concentrated acids or bases. Safety goggles should be warn to protect the eyes in case of a freak accident (such as a splattering from a spill).

APPENDIX I

PROPER TECHNIQUE A: INSERTION OF GLASS TUBING INTO RUBBER STOPPER

(1) Select the proper size glass tubing for the hole in the stopper (generally 6 mm for #6 pre-holed stopper).

(2) To cut the glass tubing to a specified length:

(a) Use a triangular file to scratch the tubing at the proper length (as deeply as possible with one pass of the file over the tubing).

(b) Grasp the tubing with both hands about 1" from the scratch (one hand on each side of the scratch) with the scratch away from you.

(c) Snap the tubing as you would a twig - quick, firm action of the wrists. [To prevent a possible nasty cut due to broken glass, grip the tubing with a towel.]

(3) Fire polish both ends of the tubing by holding the cut edge just above the tip of the small inner blue flame of a Bunsen or alcohol burner. A Bunsen burner is hotter therefore easier and faster to use. An alcohol burner will work but will take much longer. A butane or propane torch would also work well. CAUTION: Allow glass to cool before touching.

(4) Place a drop of glycerol in the hole of the rubber stopper.

(5) Grasp the glass tubing within 1-1/2 to 2 inches of the end to be inserted into the rubber stopper, insert the tubing into the hole on the large diameter end of the stopper, and firmly push until tubing extends 1/2" beyond the smaller end of the stopper (or the length specified for the particular experimental setup). [To prevent a possible nasty cut due to broken glass, grip the tubing with a towel.]

PROPER TECHNIQUE B: DILUTION OF AN ACID

Concentrated acids must <u>always</u> be diluted by pouring the acid solutions INTO THE WATER and NOT the other way around.

When concentrated acid is added to water, the reaction can be highly exothermic.

PROPER TECHNIQUE C: PREPARATION OR DILUTION OF A BASE

Concentrated bases should always be diluted by pouring the base solution INTO THE WATER.

Bases (such as sodium hydroxide,. i.e., lye) are prepared by adding the solid material TO THE WATER. DO NOT POUR WATER OVER THE SOLID.

Dissolution of bases is also an exothermic reaction.

PROPER TECHNIQUE D: SMELLING CHEMICALS

Wafting is the way to detect (and identify) the aroma of any chemical.

(1) Start with the container a foot or two from your nose.

(2) Use your open hand to "waft" the air over the container gently toward you.

(3) Allow sufficient time before attempting a second waft.

(4) If the aroma is not offensive or irritating to your nose, repeat the process, with a less gentle motion, if necessary.

(5) NEVER STICK YOUR NOSE DIRECTLY OVER A CONTAINER OF AN UNKNOWN SUBSTANCE.

PROPER TECHNIQUE E: MAKING STIRRING RODS

One 4-foot length of 4 or 5-mm soft glass rod can be cut into six or more rods of convenient lengths (6" to 10" long).

(1) To cut the glass rod at a desired length:

(a) Use a triangular file to scratch the rod at the selected length (as deeply as possible with one pass of the file over the rod).

(b) Grasp the rod with both hands about 1" from the scratch (one hand on each side of the scratch) with the scratch away from you.

(c) Snap the rod as you would a twig - quick, firm action of the wrists. [To prevent a possible nasty cut due to broken glass, grip the rod with a towel.]

(2) Fire polish both ends of the rod by holding the cut edge just above the tip of the small inner blue flame of a Bunsen or alcohol burner. A Bunsen burner is hotter, therefore easier and faster to use. An alcohol burner will work but will take much longer. A butane or propane torch would also work well. CAUTION: Allow glass to cool before touching.

APPENDIX II

SUPPLIES LISTS (for 6 groups)

CHEMICALS (easily obtained consumer products)

Steel Wool, 1 pkg. Purchase at discount stores and hardware shops. It comes in long cardboard cards. Several pads are needed. A fine grade, not coarse.

Vinegar (5% acetic acid), 1 qt. Grocery store.

Hydrogen Peroxide (generic)(3%), 3 1-pt bottles. Can be found under various trade names, including 'hydrogen peroxide' (least expensive), in drug stores. CLAIROXIDE is an example. NOTE: Hydrogen peroxide has a relatively short shelf-life. Purchase only amount needed.

Hamburger, 1/4 lb or less. Liver will also do. Need this to catalyze the decomposition of hydrogen peroxide.

Denatured Alcohol, 100 mL. Available as isopropyl alcohol in drug store. Not absolutely necessary but stops frothing in flask when peroxide decomposes.

Sulfur. Need less than a pint. Sold in garden supply stores.

Bubble Maker. A kid's toy--a soap solution that makes good bubbles. Miracle Bubble is one of them.

Iron Filings. Don't know where to get these, except at a chemical supply house. Edmunds Scientific sells them. Need a cupful. (Very <u>fine</u>)

Muriatic Acid (30% hydrochloric acid), 1/2 gal. Sold in discount and hardware stores for swimming pool care (about $3/gallon). It is concentrated hydrochloric acid, which can also be purchased at a chemical supply house.

Baking soda ($NaHCO_3$), 2-lb box.

Dry Ice, 1 lb. Buy on day needed.

Lime Water (1 liter). Prepare by shaking an excess of lime (CaO) in water and allowing the mixture to sit overnight. Use the clear liquid at the top. Lime (CaO) can be bought in hardware stores, garden shops, and lumber yards.

LYE (NaOH pellets, 1 container). Grocery stores. LYE is better than DRANO and similar brand-name products, since the latter varieties contain other elements in addition to sodium hydroxide.

SUPPLIES LISTS (for 6 groups) — continued

EQUIPMENT (usually available in school stockrooms or in District Warehouses)

6 stream trays (6 large trays for work spaces)
surgical tubing (4 meters)(3/16 inch ID)
24 erlenmeyer flasks (250 mL) (small mouth)
24 stoppers (1-hole) for erlenmeyers (No. 6)
10 (4 ft) lengths of glass tubing (6 mm)(soft)
2 doz test tubes (18 mm x 150 mm)
2 doz corks for test tubes (solid; no holes)
6 small burners (Bunsen would be best; spirit burners ok)
6 medium ring stands
12 clamps that will conveniently clamp the necks of the erlenmeyer flasks
2 dozen beakers (250 mL) (can use oyster jars or baby food jars)
1 doz watch glasses (must be able to cover mouth of 250-mL beaker
6 wire gauzes (with asbestos center) (ceramic tiles could be used)
pkg of plastic petri dishes
6 droppers
6 spatulas
miscellaneous (scissors, razor blades, utility knife, safety goggles)
6 triangular files
6 dropping bottles with glycerol (glycerol is also called glycerine)
6 test tube holders

12 small vials with plastic tops (8 mL plastic snap tops)
6 bar magnets

MISCELLANEOUS MATERIALS

candles (small birthday type OK; need several dozen)
wood splints (need several dozen)
6 plastic dish pans (12 x 8 x 5 in)
6 small boxes of safety matches (wooden)
abundance of paper towels
rags for clean up
Saran wrap
aluminum foil (heavy duty kitchen type, a few feet is plenty)
coffee filters (Mr. Coffee brand is best)
6 empty plastic soft drink bottles
aquarium or other very large glass container
straws, 1 box
plastic, glass, or cardboard tube, approximately 1-inch diameter, 12" or longer (ScotTowel Junior adapter is a little short, tape two together)

ASTR 301 EXAM #1 NAME _____

Crosby Sept 28, 1987 ID # _____

USEFUL INFORMATION See also PERIODIC TABLE attached.

$N_A = 6.02 \times 10^{23}$ 1 lb = 454 g 1 in. = 2.54 cm

$^{o}F = \frac{9}{5}(^{o}C) + 32$ $M_1V_1 = M_2V_2$

1. Calculate $\dfrac{(6.2 \times 10^{1})(3.5 \times 10^{2})}{(8.4 + 2.5 \times 10^{-1})}$ and express your answer with one digit before the decimal point.

2. How many atoms are there in 3.5 moles of sodium metal? Express your answer with one digit before the decimal point.

3. Mercury has a density of 13.5 grams per cubic centimeter. What is this density expressed in pounds per cubic inch?

4. On a hot day in Tucson the temperature can reach 113°F. What is the temperature in °C?

5. Identify each material below as an (E)lement, a (C)ompound or a (M)ixture:

___ water ___ cement ___ sodium ___ a martini ___ ethanol ___ air

6. Using your astounding knowledge of the Periodic Table, write formulas for the compounds listed below:

sodium bromide _____ sulfur trioxide _____

calcium fluoride _____ magnesium phosphide _____

lithium oxide _____

7. On a distant planet the inhabitants have assigned the atomic weight of oxygen to be 4.00. What is the molecular weight of water on this planet?

8. Using the s, p, d, . . . nomenclature, write electronic configurations for:

Li:

O^{2-}: [CAREFUL!]

Cl:

**Consider the list of stable molecules given below:

HNO_3, NaBr, $HC_2H_3O_2$, HCl, KOH, Na_2SO_4

9. Which one(s) of the above are strong acids?

10. Which one(s) on the list are salts?

11. Which one(s) of the above would produce a soapy-feeling solution when dissolved in water?

12. Which one(s) above are weak acids?

13. Draw an electron-dot diagram for the water molecule.

**Select the answers for the next three questions from this list of compounds:

$NaCl$, NH_4Br, CO_2, H_2S, NH_3

14. Which one of the compounds listed above contains a coordinate-covalent bond?

15. One of the compounds listed above has no dipole moment. Which one is it?

16. When one of the compounds listed above is dissolved in water, the solution becomes basic. Which one is it?

**Balance the two chemical equations given below:

17. ___ Ca + ___ HCl ---> ___ $CaCl_2$ + ___ H_2

18. ___ C_2H_4 + ___ O_2 ---> ___ CO_2 + ___ H_2O

**Write formulas for the products of the three reactions given below. DO NOT BALANCE the equations.

19. $C_{10}H_{20}$ + O_2 ---> _____ + _____

20. hydrochloric acid plus sodium hydroxide yields _____ + _____

21. Fe + HCl ---> _____ + _____

**Consider the reaction of aluminum metal with sulfuric acid. The equation is

$$2Al + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2$$

22. If 3 moles of aluminum metal dissolve in an excess of sulfuric acid, how many moles of hydrogen will be produced?

23. If 1/2 mole of aluminum metal dissolves in an excess of H_2SO_4, how many grams of hydrogen will be produced?

24. Classify the solutions below as Acidic, Basic, or Neutral:

_____ sodium bromide in water

_____ hydrogen chloride gas dissolved in water

_____ carbon dioxide dissolved in water

_____ magnesium oxide dissolved in water

25. Classify the reactions below as EXothermic or ENdothermic:

_____ $C + O_2 \longrightarrow$

_____ $CH_4 + O_2 \longrightarrow$

_____ H_2O (liquid) $\longrightarrow$ H_2O (gas)

_____ H_2O (g) $\longrightarrow$ H_2(g) + $\frac{1}{2}O_2$(g)

26. A chemist wishes to make up 2 liters of a 4 molar solution of potassium hydroxide. How many grams of KOH must he weigh out?

27. A chemist needs 500 mL of 4 M HCl. He finds 6 M HCl on the shelf. How much of the stock solution (in mL) must he dilute to 500 mL to obtain the required concentration?

28. The pH of the blood is approximately 7.3. Is the blood slightly acidic, neutral, slightly basic or very basic?

Answer: _____

PERIODIC TABLE OF THE ELEMENTS

Number above symbol = atomic weight
Number below symbol = atomic number

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1.0 H 1																	4.0 He 2
7.0 Li 3	9.0 Be 4											10.8 B 5	12.0 C 6	14.0 N 7	16.0 O 8	19.0 F 9	20.0 Ne 10
23.0 Na 11	24.3 Mg 12											27.0 Al 13	28.0 Si 14	31.0 P 15	32.0 S 16	35.5 Cl 17	40.0 Ar 18
39.0 K 19	40.0 Ca 20	45.0 Sc 21	48.0 Ti 22	51.0 V 23	52.0 Cr 24	55.0 Mn 25	56.0 Fe 26	59.0 Co 27	58.7 Ni 28	63.5 Cu 29	65.4 Zn 30	69.7 Ga 31	72.6 Ge 32	75.0 As 33	79.0 Se 34	80.0 Br 35	84.0 Kr 36
85.5 Rb 37	87.6 Sr 38	89.0 Y 39	91.0 Zr 40	93.0 Nb 41	96.0 Mo 42	99 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 49	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
133 Cs 55	137. Ba 56	139 La* 57-71	178. Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	210 Po 84	210 At 85	222 Rn 86
223 Fr 87	226 Ra 88	227 Ac** 89-103	257 Rf 104	260 Ha													

*Lanthenide Series	140.1 Ce 58	140.9 Pr 59	144.2 Nd 60	147 Pm 61	150.4 Sm 62	152.0 Eu 63	157.3 Gd 64	158.9 Tb 65	162.5 Dy 66	164.9 Ho 67	167.3 Er 68	168.9 Tm 69	173.0 Yb 70	175.0 Lu 71
**Actinide Series	232.0 Th 90	231 Pa 91	238.0 U 92	237 Np 93	242 Pu 94	243 Am 95	247 Cm 96	249 Bk 97	251 Cf 98	254 Es 99	253 Fm 100	256 Md 101	254 No 102	257 Lw 103

ASTRONOMY 301
BIOCHEMISTRY SECTION

Instructor: Ron Brosemer, 212 Morrill Hall, 335-5548. There are no specific office hours, but do not hesitate to use the phone to talk with me or to set up an appointment.

The theme for this section centers around the biochemistry of constituents in food. No reading assignments in the text are specified, since the presentation is very lecture-oriented. Similarly, the problems in the text are not suitable for the type of presentation to be made.

Many structures will be included in the lecture material; it is not possible to discuss the constituents in food without an idea of what those constituents are. Do not attempt to write down these structures during the lecture; unless I state otherwise, all the structures shown are in the text. Spend your lecture time listening to the points being made, not writing down structures that are readily available to you elsewhere. You will not be responsible for memorizing any of the structures, but you should be able to recognize their general features. More specifics about the structures will be presented in lecture. In all cases, the function of the molecules will be emphasized.

Topics to be covered:

PROTEINS--amino acids; peptides; primary sequence; conformation; hemoglobin; denaturation; enzymes.

CARBOHYDRATES--simple sugars: glucose, fructose; disaccharides: sucrose, lactose; polysaccharides: starch and cellulose.

SICKLE CELL ANEMIA

Below is an outline of the six lectures as well as copies of overhead projections used in these lectures.
Theme of lectures:

Biochemistry as illustrated by food.

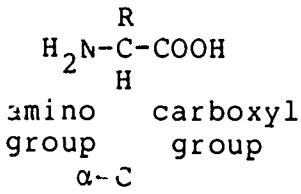
Biochemistry = study of chemical changes that occur in living systems.
Letters: 3 bio + 9 chemistry illustrate relative importance

Will look at:
1) Proteins
2) Carbohydrates

Ask - What are they?
What do they do?

Amino Acids

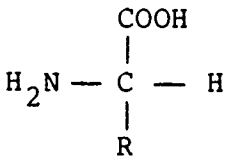
α-amino acids



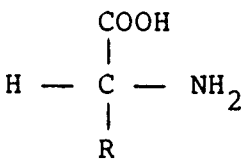
20 a.a. in proteins - show structures of the 20 a.a.

Chirality (optical isomerism)

Optical Isomers



L-a.a.



show models

D-a.a. - found in some bacterial and fungal cell walls, antibiotics. None in proteins.

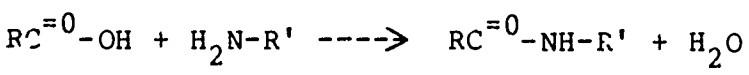
Glycine not optically active.

Look for D or L a.a. in meteors

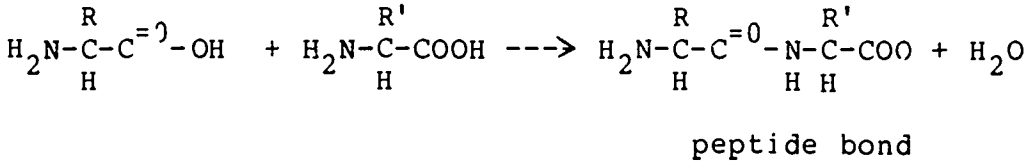
Don't know origin of L a.a., but once started is self selecting. E.g., place glove on one hand only. Life as we know it would not be possible without optical isomers.

Peptides

Amide - dehydration product between acid and amine.



Peptide - dehydration product between carboxylic acid of an a.a. and amino group of an a.a.



peptide bond

Dipeptide
Tripeptide
Polypeptide

Define: N-terminal, C-terminal

Residue = moiety = building block of a macromolecule, e.g., a.a. residue (moiety) of a protein. For most biological macromolecules the building block loses the elements of H_2O.

Show numbering system of a protein

1° sequence = 1° structure = a.a. sequence of a protein or peptide.

Properties of a peptide are determined by its 1° sequence.

Show NutraSweet (= aspartame)

e.g. Asp-Phe-Me is sweet, Phe-Asp-Me is tasteless
Searle Pharmaceutical - p. 502 Bettelheim

Two peptide hormones from the posterior lobe of the pituitary gland--7 out of 9 a.a. residues are identical in the two hormones. Show structures.

Oxytocin: enhances contraction of smooth muscle in the uterus and breast (birth + milk ejection).

Cys-Tyr-Ile-Gln-Asn-Cys-Pro-Leu-Gly-NH_2

Vasopressin: constricts blood vessels (thus increases blood pressure), increases water retained by the kidneys (= antidiuretic hormone)

Cys-Tyr-Phe-Gln-Asn-Cys-Pro-Arg-Gly-NH_2

An example of the general rule that the primary structure (or sequence) determines the function of a protein (or peptide).

Proteins

Large peptides synthesized from the 20 a.a. we have seen.

In each cell there are a few thousand different proteins. Each cell type has a different complement of proteins.

Classification of Proteins According to Function

1. Structural proteins - e.g., collagen (skin, cartilage, etc.)
2. Contractile proteins - e.g., actomyosin in muscle
3. Enzymes - catalyze rxs., ≃ 2000 known
4. Hormones - synthesized in one tissue, control functions in another tissue, e.g., insulin. (N.B. - not all hormones are peptides, e.g., steroids)
5. Antibodies - e.g., gamma globulins
6. Storage - e.g., casein (milk), ovalbumin (eggs)
7. Carriers - e.g., hemoglobin (O_2), HDL and LDL (cholesterol)
8. etc.

Proteins	MW	# of a.a. residues
Insulin	6,300	51
Ribonuclease	12,640	124
Hemoglobin	68,000	574
γ-Globulin	149,900	1320
Fibrinogen	450,000	∿ 4000
Hemocyanin	9,000,000	∿ 80,000

Note: $\frac{\text{MW of protein}}{110} \approx$ # of a.a. residues

$110 \approx$ ave. MW of an a.a. residue

Why 20 a.a.? Gives ∞ number of possible structures.

If dipeptide with 20 a.a., have $20^2 = 400$ possibilities

If tripeptide with 20 a.a., have $20^3 = 8000$ possibilities

300 a.a. with 20 a.a., have 20^{300} possibilities

Therefore can design protein to fulfill just about any function.

Introduce hemoglobin and myoglobin.

Both are conjugated proteins: a globin (protein portion) + heme (= "blood"; contains Fe, structure to be seen later)

Hb: transports O_2 from lungs to tissues.

$$Hb + O_2 \underset{\text{other tissues}}{\overset{\text{lungs}}{\rightleftharpoons}} Hb - O_2$$

O_2 capacity of blood from 5 to 250 ml O_2/l blood

Hb found only in red blood cells (= erythrocytes). Show electron micrograph

5 billion rbc/ml of blood; replace 2.5 million cells/sec

If blood vessels in a single adult were stretched out, would reach $\sim$ 1/4 of distance to the moon.

Protein portion of Hb has 2α and 2β chains.

Myoglobin (= muscle globin)
Also a globin protein + heme.
1° structure of protein portion of myoglobin is similar to but distinctly different from that of hemoglobin.

Found in muscle - among other functions, stores O_2.

$$Mb + O_2 \rightleftharpoons Mb - O_2$$

In deep-diving mammals.

Red vs. white muscles.
1° sequence of protein portions of both Hb and Mb have been determined.

Overheads - 1° structure of α and β chains of human Hb A, Mb.

Enzymes

-ase ending
About 2000 known enzyme - catalyzed rxs.
Not all occur in all cells (e.g., photosynthesis)
Maybe 200 rxs. in a typical cell.

Proteases:
catalyze Proteins + H_2O ---> a.a.

1 made in stomach: pepsin

Several synthesized and stored in pancreas, secreted into small intestine.

Meat tenderizer-papain
Different specificities - e.g., trypsin
Only a.a. can be absorbed. Are used to make new proteins.
Why can't take insulin by mouth?
1) Denatured - acid
2) Degraded by proteases

Why denature proteins in food by cooking and by acid?
Make peptide bonds accessible to proteases

Show myoglobin film.

Carbohydrates

hydrated C: $(CH_2O)x$
= saccharide (= sweet)
Not all are sweet (e.g., starch).
If CHO cannot be hydrolyzed to smaller units = monosaccharide
If contains more than 1 unit chemically linked to one another = polysaccharide.

Can have 2 to several thousand units

2 important monosaccharides: glucose (dextrose, blood sugar); fructose (fruit sugar)

2 Disaccharides of importance
Sucrose (table sugar - "sugar" in Rosauers)
Made only by some plants, e.g., sugar cane, sugar beets.
Storage form of CHO in these plants.

Show structure

Glc + Fru are absorbed

Reason why take dextrose (= Glc) for "quick" energy - absorbed immediately.

Honey contains Glc and Fru.

Lactose = milk sugar
Made only by lactating mammary glands.
Show structures

All normal infants must have intestinal lactase.
Most people lose lactase around puberty.
Reason unknown. Leads to GI problems.
Only major exceptions: Caucasians, especially northern Europeans.
Fulani (migratory cattle raisers) tribe in Nigeria - sell nono to Yoruba.
Up to 90% of African and Oriental adults lack lactase.
Eat fermented milk products.

Milk can be treated with harmless bacteria
Also occurs with intestinal disease - watch your milk consumption if you get Palouse lightning.

Polysaccharides - starch and cellulose
Starch - storage form of CHO in many plants

Show structure

Cellulose - structural backbone for most plants

Show structure

Starch + H_2O ---(in saliva and intestine: several enzymes)---> Glc

Hydrolysis slower than for sucrose. Therefore don't get insulin hypoglycemia after ingestion.

Cellulose + H_2O ---(cellulase in micro-organisms only, ruminents)---> Glc

Enzyme specificity

High fructose corn syrup (glucose isomerase)

Starch ----> Glc ----> Glc + Fru

Functions of CHO:

1) Source of energy:

Starch or sucrose in plants - $0 < n < 10^6$
Glycogen in animals
Glc - (not stored as such)
Sucrose
Lactose - milk only

2) Structural elements:

Cellulose

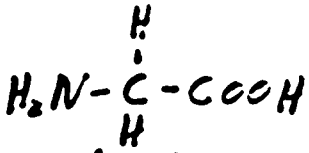
3) Parts of proteins:

e.g., antibodies

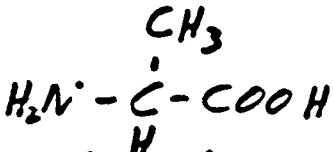
etc.

Sickle cell anemia
Structural basis (Hb-S vs. Hb-A).
Explain basis of symptoms.
Explain connection with malaria.

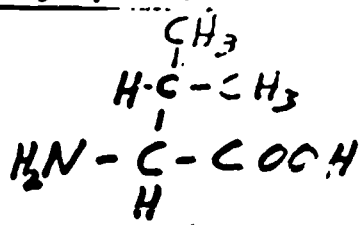
Aliphatic Amino Acids



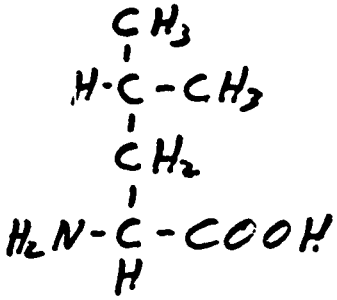
Glycine



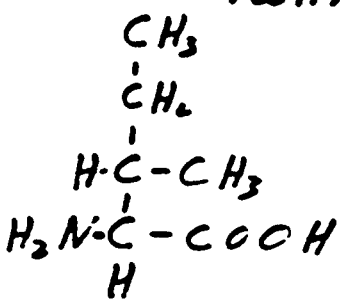
Alanine



Valine

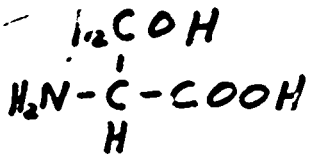


Leucine

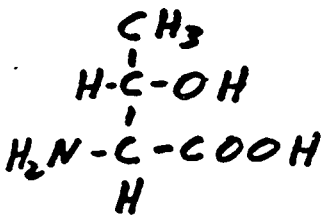


Isoleucine

Hydroxyl Amino Acids

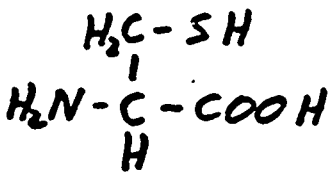


Serine

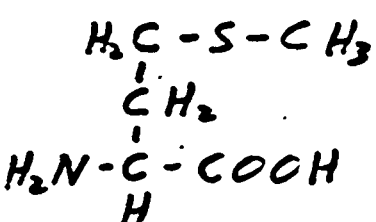


Threonine

Sulfur Amino Acids

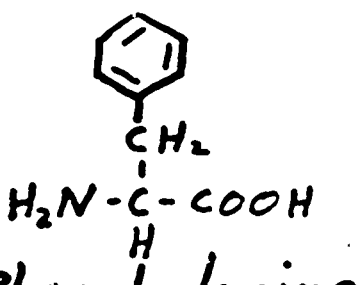


Cysteine

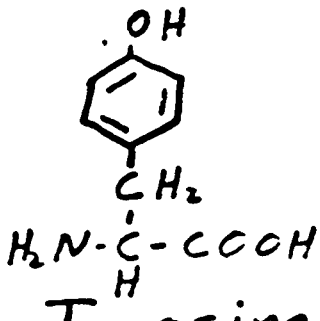


Methionine

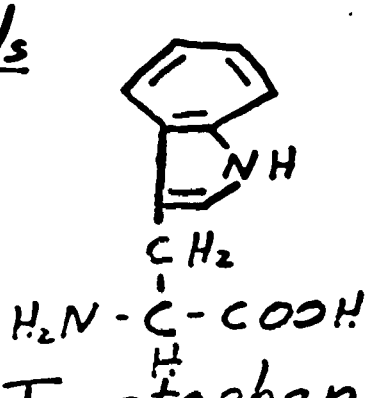
Aromatic Amino Acids



Phenylalanine

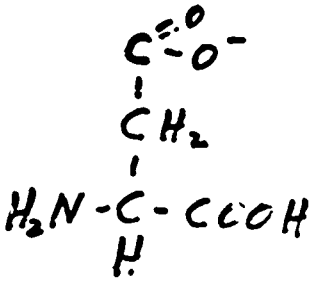


Tyrosine

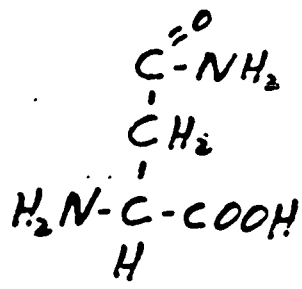


Tryptophan

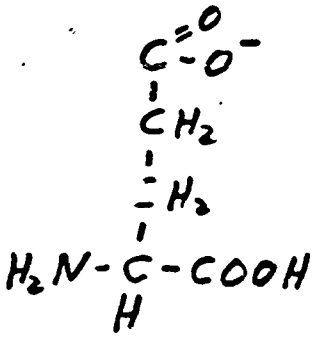
Acidic Amino Acids and Amide Derivatives



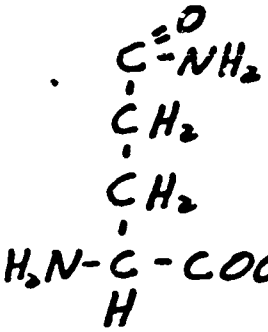
Aspartic Acid



Asparagine

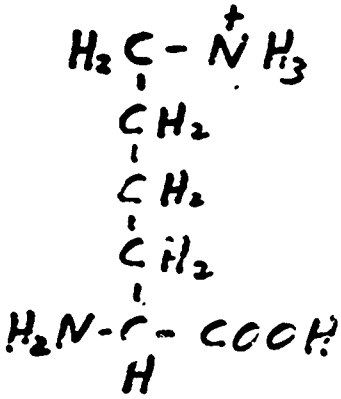


Glutamic Acid

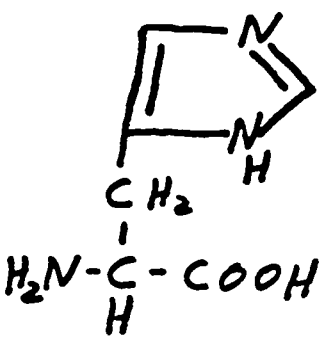


Glutamin

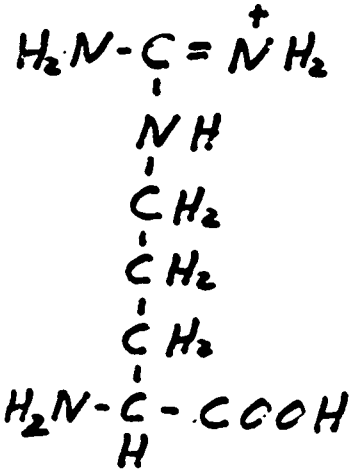
Basic Amino Acids



Lysine

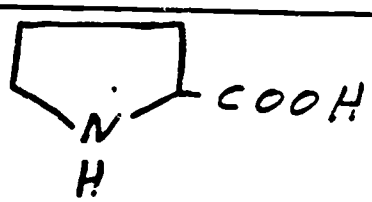


Histidine



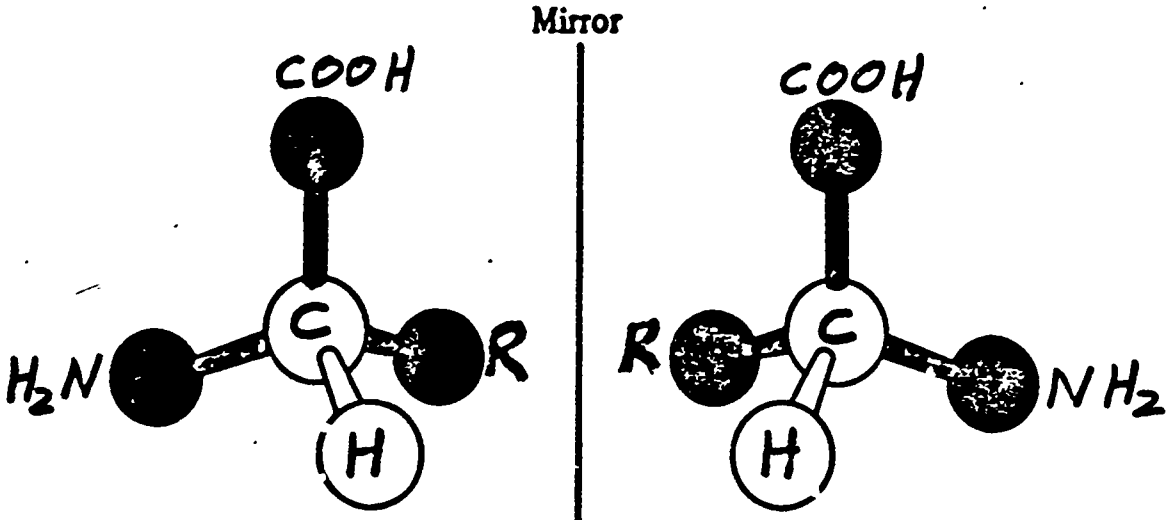
Arginine

Imino Acid (= Secondary Amino Acid)



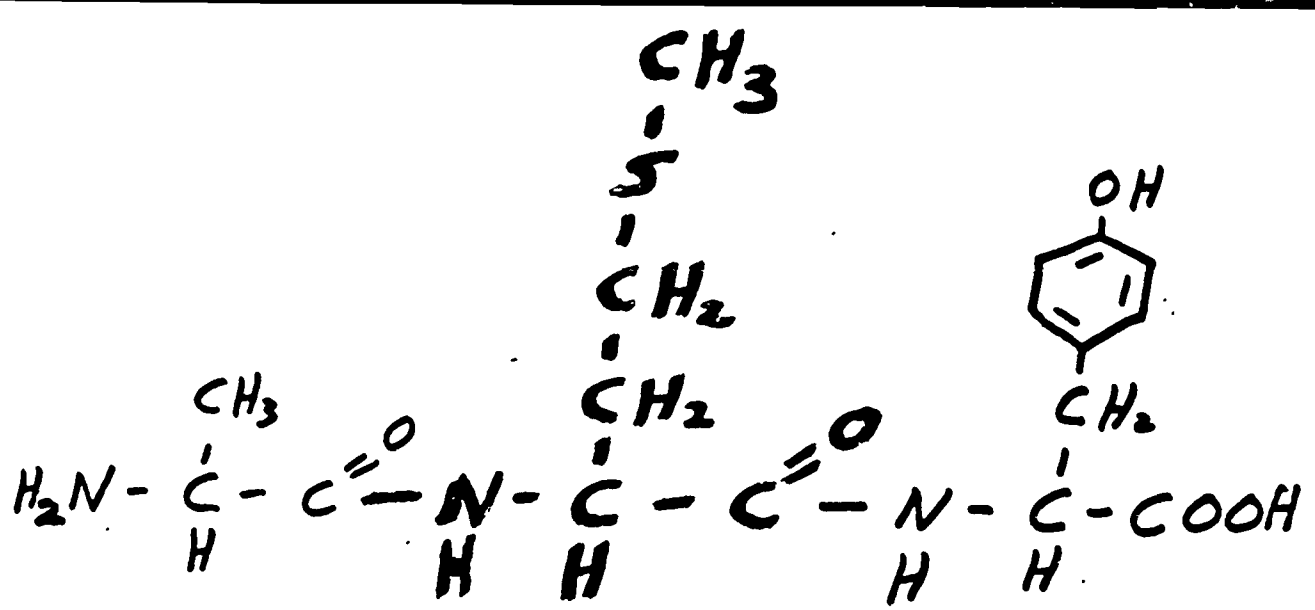
Proline

Optical Isomers of Amino Acids

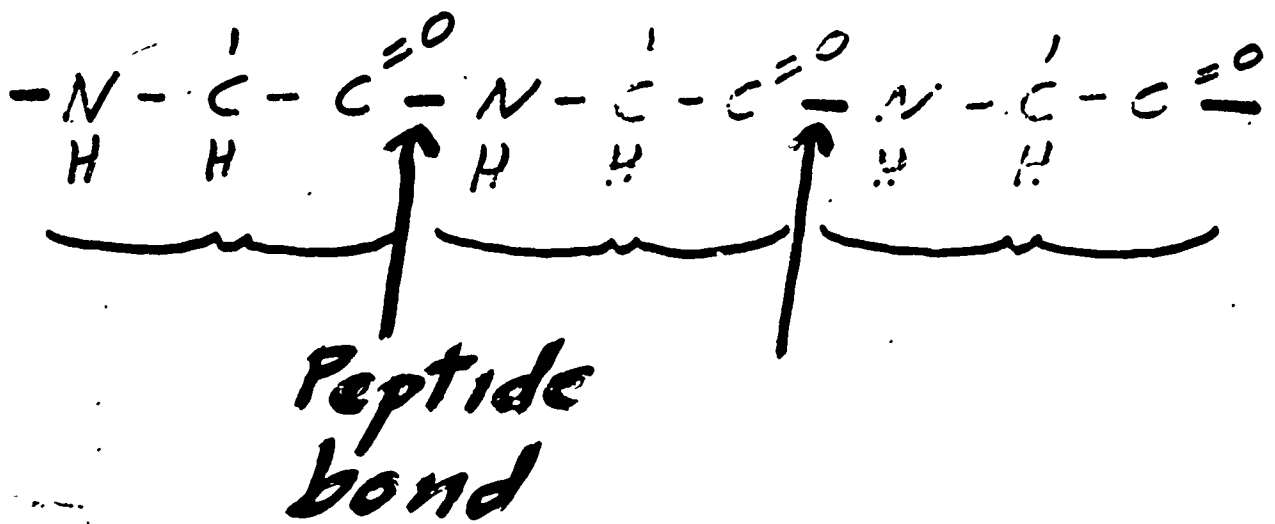


L-amino acid (in proteins)

D-amino acid



Alanyl - methionyl - tyrosine

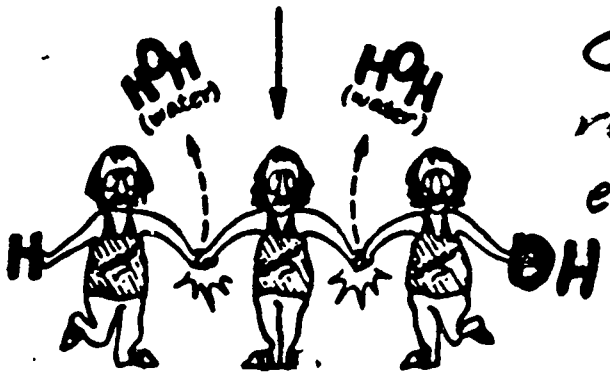


Peptide bond

Convention:
N-terminal

C-terminal

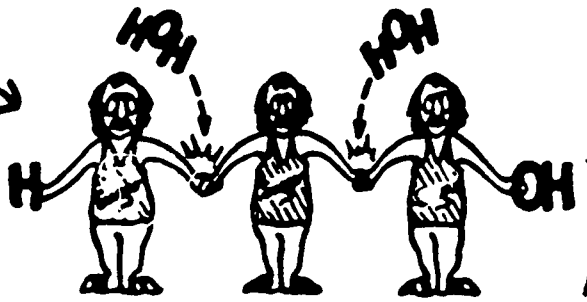
Primary structure = primary sequence = amino acid sequence of protein or peptide.



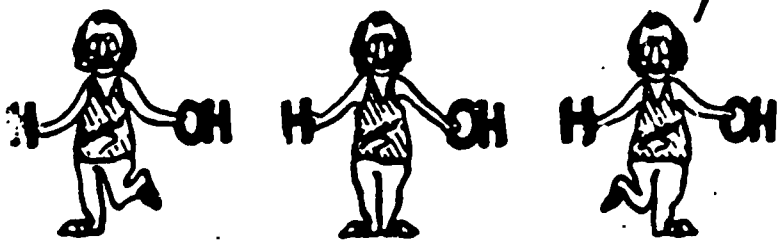
Chain elongat. requires energy

Each person is now a "residue" or "moiety" in the macromolecule

a Dehydration synthesis of large molecule from monomer subunits



Hydrolysis is energetically spontaneous.



b Hydrolysis of large molecule into monomer subunits

Figure 3.8 (a) In dehydration synthesis, many monomers (only three are shown here) are bonded covalently to form a polymer. A hydrogen atom must be stripped from one monomer and an —OH group stripped from another for bonding to occur. (b) Hydrolysis is basically the reverse of dehydration synthesis: the covalent bond is broken, a hydrogen atom is attached to one monomer, and an —OH group is attached to its previous partner. Although sugar molecules are used in this example, the processes apply to other large molecules of life, too. (These cartoon molecules obviously are simplified versions of the real thing—but then, so are structural formulas.)

Human hemoglobin - alpha chain

```
                                                  10                  15
  1 VAL LEU SER PRO ALA ASP LYS THR ASN VAL LYS ALA ALA TRP GL
 16 LYS VAL GLY ALA HIS ALA GLY GLU TYR GLY ALA GLU ALA LEU GLU
 31 ARG MET PHE LEU SER PHE PRO THR THR LYS THR TYR PHE PRO HI
 46 PHE ASP LEU SER HIS GLY SER ALA GLN VAL LYS GLY HIS GLY LY
 61 LYS VAL ALA ASP ALA LEU THR ASN ALA VAL ALA HIS VAL ASP AS
 76 MET PRO ASN ALA LEU SER ALA LEU SER ASP LEU HIS ALA HIS LY
 91 LEU ARG VAL ASP PRO VAL ASN PHE LYS LEU LEU SER HIS CYS LEU
106 LEU VAL THR LEU ALA ALA HIS LEU PRO ALA GLU PHE THR PRO AL
121 VAL HIS ALA SER LEU ASP LYS PHE LEU ALA SER VAL SER THR VA
136 LEU THR SER LYS TYR ARG
```

COMPOSITION

21	ALA	A	1	GLN	Q	18	LEU	L	11 SER S
3	ARG	R	4	GLU	E	11	LYS	K	9 THR T
4	ASN	N	7	GLY	G	2	MET	M	1 TRP W
8	ASP	D	10	HIS	H	7	PHE	F	3 TYR Y
1	CYS	C	0	ILE	I	7	PRO	P	13 VAL V

MOL. WT.= 15,126 TOTAL NO. OF RESIDUES = 141

Human hemoglobin - beta chain

```
                  5                   10                  15
  1 VAL HIS LEU THR PRO GLU GLU LYS SER ALA VAL THR ALA LEU TRP
 16 GLY LYS VAL ASN VAL ASP GLU VAL GLY GLY GLU ALA LEU GLY AR
 31 LEU LEU VAL VAL TYR PRO TRP THR GLN ARG PHE PHE GLU SER PH
 46 GLY ASP LEU SER THR PRO ASP ALA VAL MET GLY ASN PRO LYS VAL
 61 LYS ALA HIS GLY LYS LYS VAL LEU GLY ALA PHE SER ASP GLY LE
 76 ALA HIS LEU ASP ASN LEU LYS GLY THR PHE ALA THR LEU SER GL
 91 LEU HIS CYS ASP LYS LEU HIS VAL ASP PRO GLU ASN PHE ARG LEU
106 LEU GLY ASN VAL LEU VAL CYS VAL LEU ALA HIS HIS PHE GLY LY
121 GLU PHE THR PRO PRO VAL GLN ALA ALA TYR GLN LYS VAL VAL AL
136 GLY VAL ALA ASN ALA LEU ALA HIS LYS TYR HIS
```

COMPOSITION

15	ALA	A	3	GLN	Q	18	LEU	L	5 SER S
3	ARG	R	8	GLU	E	11	LYS	K	7 THR T
6	ASN	N	13	GLY	G	1	MET	M	2 TRP W
7	ASP	D	9	HIS	H	8	PHE	F	3 TYR Y
2	CYS	C	0	ILE	I	7	PRO	P	18 VAL V

MOL. WT.= 15,867 TOTAL NO. OF RESIDUES = 146

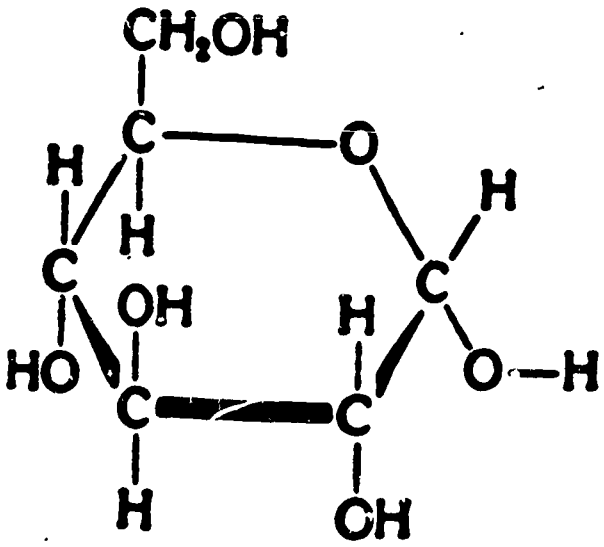
Primary Sequence of Whale Myoglobin

```
                      5                  10                  15
  1 VAL LEU SER GLU GLY GLU TRP GLN LEU VAL LEU HIS VAL TRP AL
 16 LYS VAL GLU ALA ASP VAL ALA GLY HIS GLY GLN ASP ILE LEU IL
 31 ARG LEU PHE LYS SER HIS PRO GLU THR LEU GLU LYS PHE ASP AR
 46 PHE LYS HIS LEU LYS THR GLU ALA GLU MET LYS ALA SER GLU AS
 61 LEU LYS LYS HIS GLY VAL THR VAL LEU THR ALA LEU GLY ALA IL
 76 LEU LYS LYS LYS GLY HIS HIS GLU ALA GLU LEU LYS PRO LEU AL
 91 GLN SER HIS ALA THR LYS HIS LYS ILE PRO ILE LYS TYR LEU GL
106 PHE ILE SER GLU ALA ILE ILE HIS VAL LEU HIS SER ARG HIS PR
121 GLY ASN PHE GLY ALA ASP ALA GLN GLY ALA MET ASN LYS ALA LE
136 GLU LEU PHE ARG LYS ASP ILE ALA ALA LYS TYR LYS GLU LEU GL
151 TYR GLN GLY
```

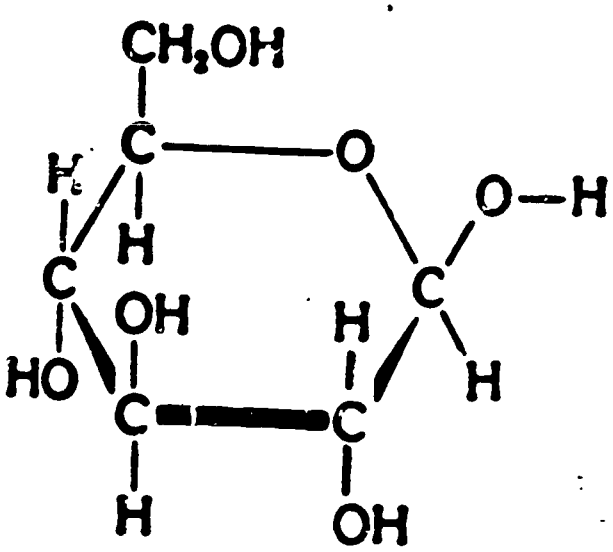
COMPOSITION

17	ALA	A	5	GLN	Q	18	LEU	L	6	SER	S
4	ARG	R	14	GLU	E	19	LYS	K	5	THR	T
2	ASN	N	11	GLY	G	2	MET	M	2	TRP	W
6	ASP	D	12	HIS	H	6	PHE	F	3	TYR	Y
0	CYS	C	9	ILE	I	4	PRO	P	8	VAL	V

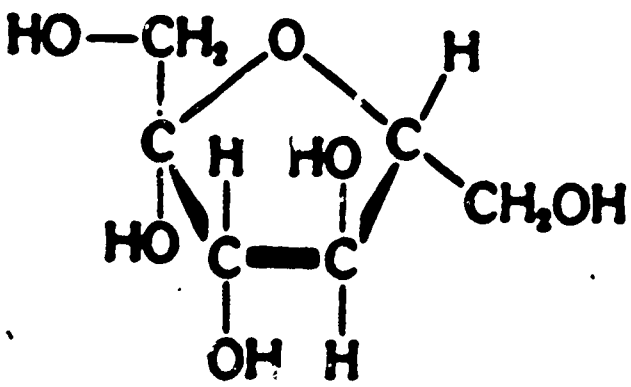
MOL. WT.= 17,199 TOTAL NO. OF RESIDUES = 153



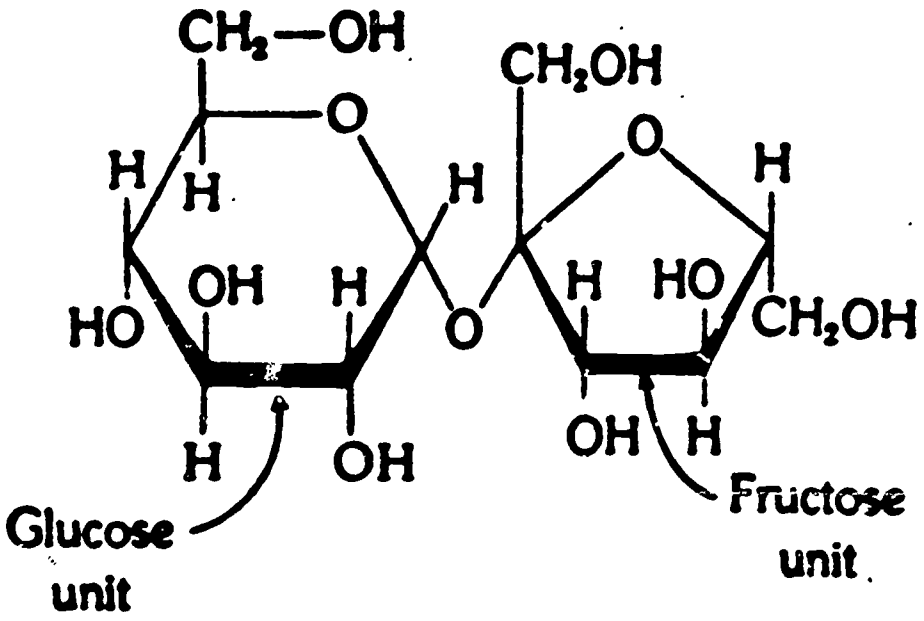
α-Glucose



β-Glucose



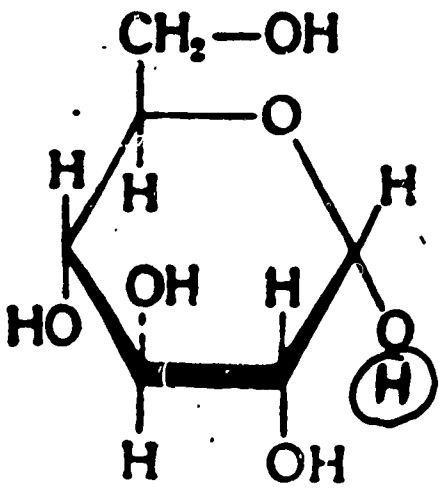
Fructose



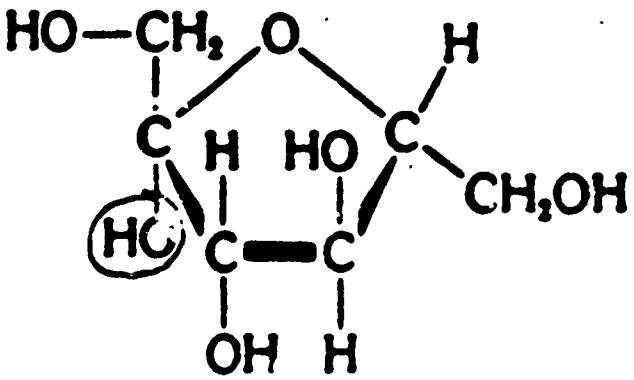
Sucrose

$+ H_2O$

Catalyzed by the enzyme sucrase

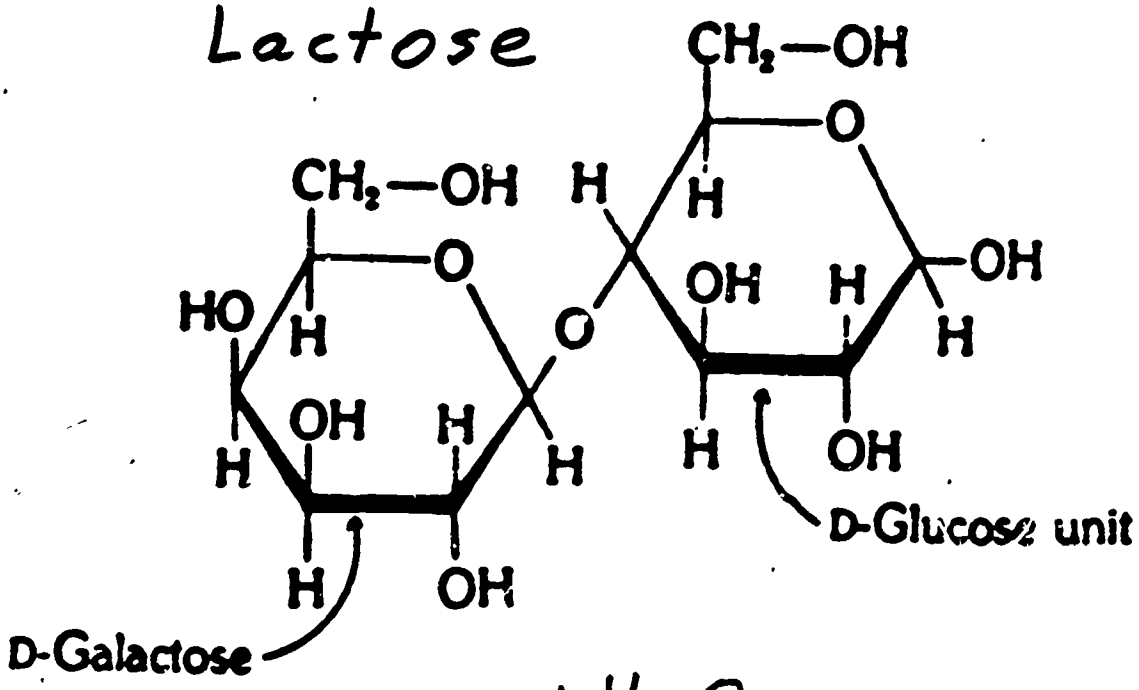


Glucose



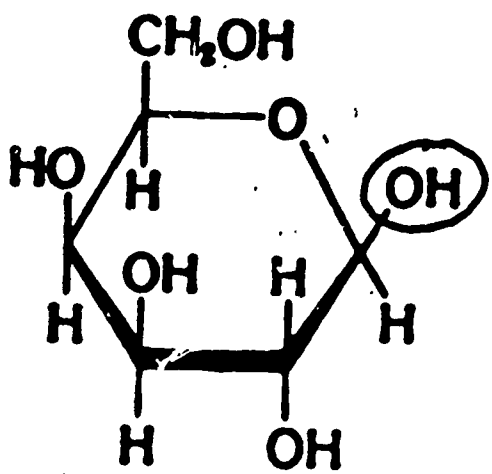
Fructose

Lactose

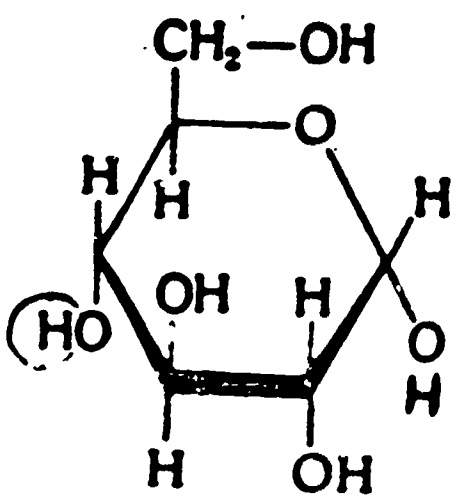


$+H_2O$

Catalzed by the enzyme lactase

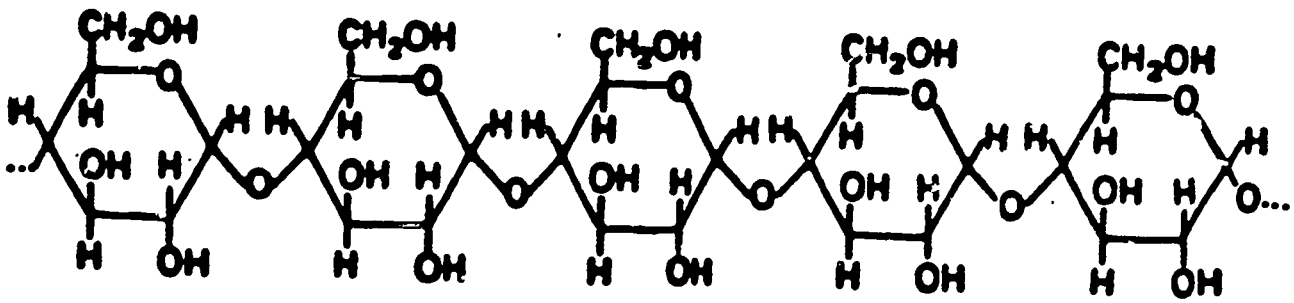


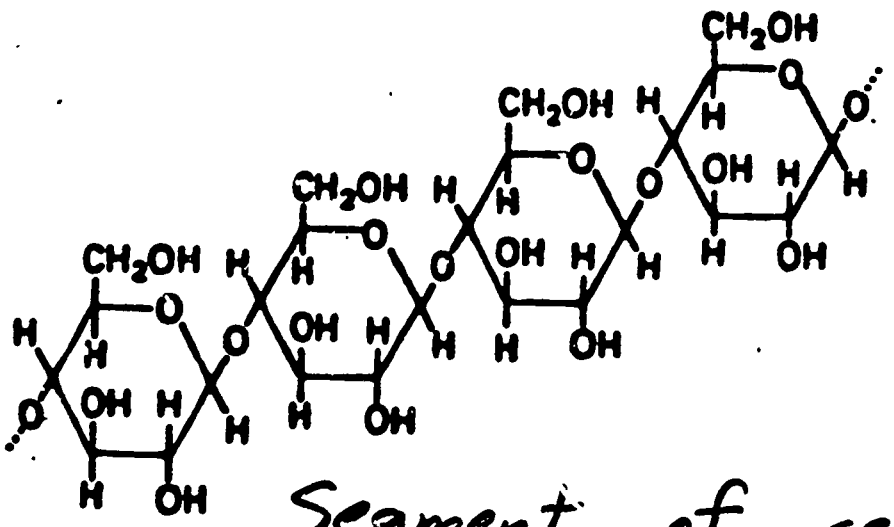
Galactose



Glucose

Simplified starch or glycogen structure





Segment of cellulose

TABLE 16.1 Comparative Sweetness of Some Sugars and Artificial Sweeteners

Sugar or Artificial Sweetener	Sweetness Relative to Sucrose	Type
Lactose	0.16	Disaccharide
Galactose	0.32	Monosaccharide
Maltose	0.33	Disaccharide
Glucose	0.74	Monosaccharide
Sucrose	1.00	Disaccharide (table sugar)
Invert sugar	1.25	Mixture of glucose and fructose
Fructose	1.74	Monosaccharide
Aspartame	100–150	Artificial sweetener
Saccharin	450	Artificial sweetener

Human hemoglobin - alpha chain

```
                    5                  10                  15
  1 VAL LEU SER PRO ALA ASP LYS THR ASN VAL LYS ALA ALA TRP GLY
 16 LYS VAL GLY ALA HIS ALA GLY GLU TYR GLY ALA GLU ALA LEU GLU
 31 ARG MET PHE LEU SER PHE PRO THR THR LYS THR TYR PHE PRO HIS
 46 PHE ASP LEU SER HIS GLY SER ALA GLN VAL LYS GLY HIS GLY LYS
 61 LYS VAL ALA ASP ALA LEU THR ASN ALA VAL ALA HIS VAL ASP ASP
 76 MET PRO ASN ALA LEU SER ALA LEU SER ASP LEU HIS ALA HIS LYS
 91 LEU ARG VAL ASP PRO VAL ASN PHE LYS LEU LEU SER HIS CYS LEU
106 LEU VAL THR LEU ALA ALA HIS LEU PRO ALA GLU PHE THR PRO ALA
121 VAL HIS ALA SER LEU ASP LYS PHE LEU ALA SER VAL SER THR VAL
136 LEU THR SER LYS TYR ARG
```

COMPOSITION

21	ALA	A	1	GLN	Q	18	LEU	L	11	SER	S
3	ARG	R	4	GLU	E	11	LYS	K	9	THR	T
4	ASN	N	7	GLY	G	2	MET	M	1	TRP	W
8	ASP	D	10	HIS	H	7	PHE	F	3	TYR	Y
1	CYS	C	0	ILE	I	7	PRO	P	13	VAL	V

MOL. WT.= 15,126

TOTAL NO. OF RESIDUES = 141

Human hemoglobin - beta chain

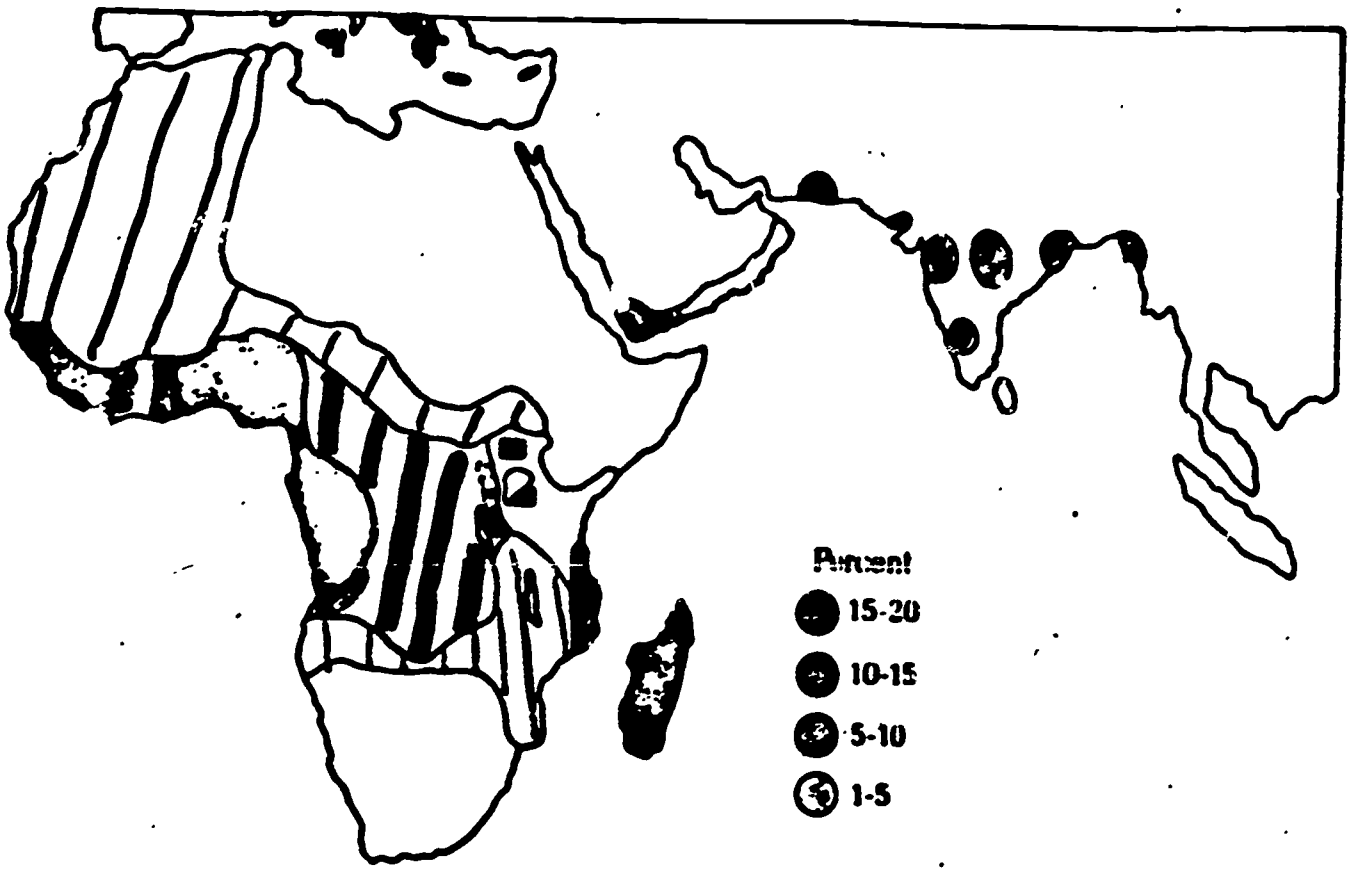
```
                    5                  10                  15
  1 VAL HIS LEU THR PRO GLU GLU LYS SER ALA VAL THR ALA LEU TRP
 16 GLY LYS VAL ASN VAL ASP GLU VAL GLY GLY GLU ALA LEU GLY ARG
 31 LEU LEU VAL VAL TYR PRO TRP THR GLN ARG PHE PHE GLU SER PHE
 46 GLY ASP LEU SER THR PRO ASP ALA VAL MET GLY ASN PRO LYS VAL
 61 LYS ALA HIS GLY LYS LYS VAL LEU GLY ALA PHE SER ASP GLY LEU
 76 ALA HIS LEU ASP ASN LEU LYS GLY THR PHE ALA THR LEU SER GLU
 91 LEU HIS CYS ASP LYS LEU HIS VAL ASP PRO GLU ASN PHE ARG LEU
106 LEU GLY ASN VAL LEU VAL CYS VAL LEU ALA HIS HIS PHE GLY LYS
121 GLU PHE THR PRO PRO VAL GLN ALA ALA TYR GLN LYS VAL VAL ALA
136 GLY VAL ALA ASN ALA LEU ALA HIS LYS TYR HIS
```

COMPOSITION

15	ALA	A	3	GLN	Q	18	LEU	L	5	SER	S
3	ARG	R	8	GLU	E	11	LYS	K	7	THR	T
6	ASN	N	13	GLY	G	1	MET	M	2	TRP	W
7	ASP	D	9	HIS	H	8	PHE	F	3	TYR	Y
2	CYS	C	0	ILE	I	7	PRO	P	18	VAL	V

MOL. WT.= 15,867

TOTAL NO. OF RESIDUES = 146



Distribution of sickle cell anemia in Africa. High rates of sickle cell anemia correspond to a high incidence of malaria.