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LABORATORY EXERCISES
FOR THE
FIRST YEAR OF SCIENCE
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HESSLER

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LABORATORY EXERCISES

OF

“THE FIRST YEAR OF SCIENCE”

BY

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INTRODUCTION

The laboratory exercises of the "First Year of Science" are, as the writer stated in the Preface to the text proper, such as can be performed with simple apparatus. To make the work of instruction easier, and to suggest substitutions of simpler forms of apparatus for those of the ordinary type, the following *preliminary directions* are given:

1. An alcohol lamp (Exercise 73), a gasoline torch, or even a metal kerosene lamp with a metal chimney, may be used in place of a Bunsen gas burner.

2. A ring stand can be made, if the laboratory has none (see Fig. 11, Exercise 16), out of telegraph wire and a wooden block.

3. A test tube holder can be made by folding a strip of paper lengthwise.

4. The only glass-working called for in these exercises is the bending of glass tubing. Tubing should be heated in a wing top or fish tail flame, if possible. An ordinary gas jet is excellent; so is the flame produced by a wide wick in a kerosene lamp. If an alcohol lamp must be used, the glass should be heated at one spot, then bent a little, then heated close by, and bent a little more, until a rounded bend is produced. If outspread flames are used, the glass should be held lengthwise with the flame. Sharp ends of tubing should be *fire-polished*, that is, the ends should be held in a flame until the glass just begins to melt.

5. Pieces of thin sheet glass (squares about 4 inches on a side) do very well as substitutes for watch glasses, if they are laid in a horizontal position.

6. Iron spoons ("tin" spoons) can be used for the heating of solids in the flame.

7. A *combustion spoon* can be made out of a strip of "tin," about $\frac{3}{4}$ of an inch wide, cut from a "tin" can. One end is rounded, and is bent up at right angles to the strip; the rounded end may be beaten into the shape of a shallow bowl.

8. Measuring cups can be used instead of beakers, except when alkalies or acids are to be employed.

9. Shot of two or three different sizes may be used instead of weights. If 100 of each size are weighed accurately, the student can take the average weight of each for his own weighings. The shot of each size should be kept in its own bottle, and the bottle should be properly labeled.

10. "Mossy" tin for Exercise 19 may be made from bar tin. The tin should be melted, and poured into a pail of water.

11. A "tin" test tube, for use in Exercise 37, may be made out of a strip about 3 x 5 inches cut from a "tin" can. The strip is rolled up into cylindrical form; then one end is pinched shut and turned upward.

12. Generating bottles for gases (also the bottle for the "Diver," Exercise 13) may be made from glass fruit-jars with metal covers. Make a hole in the cover, fit to it a bent glass tube, and fasten the tube in place by means of a paste made out of "red lead" and glycerine. When the paste hardens, the jar is ready for use. If a rubber ring is used on the can, the cover can be screwed down air tight.

13. For the color experiments (Exercises 52 and 53), the glazed paper used in kindergarten work is excellent. White paper may be colored by means of crayons, and used as a substitute.

14. Fehling's solution is often obtainable at a drug store. You can make a solution by dissolving 34.64 g. of copper

sulphate in 500 cu. cm. of water; also 180 g. of Rochelle salt and 70 g. of sodium hydroxide in 500 cu. cm. of water. Mix equal volumes of the two solutions just before using. Of course any fractional part of this amount may be prepared.

Part of the exercises of this manual have been gathered from existing sources; all have been simplified for the use of first-year students. The writer found many helpful suggestions for the exercises on "Soils" in a pamphlet entitled "Some Principles of Agriculture," presumably published by the Connecticut State Board of Education.

J. C. H.

Decatur, Illinois.

LABORATORY EXERCISES

EXERCISE 1

AIR TAKES UP ROOM

Apparatus and Materials.—Narrow-mouth bottle, water, thistle tube or funnel, wide-mouth bottle (about 250 cu.cm.), two-hole rubber stopper that fits the wide-mouth bottle, a glass plug or a round pencil, biscuit cutter, oil-can used for sewing machine (or a carpenter's oil-can), tin funnel.

a. Fill a narrow-mouth bottle with water, and invert it over a sink or a jar. Tell how the water comes out of the bottle. Why does it not come out in a stream?

b. Close the small end of the funnel or thistle tube tightly with your finger (Fig. 1), and put the large end into a deep pan or pail nearly filled with water. Does water enter? Remove your finger, and tell what happens. Tell why it happens.

N. B.—You can carry out this experiment with a piece of glass tubing open at both ends.

c. Now put the stem of the funnel (or thistle tube) through one of the holes of the two-hole rubber stopper (Fig. 2). The glass slips through the rubber easily if you wet the walls of the hole with water. Do not force the glass tube into the hole roughly, but give it a twisting motion.

Put into the wide-mouth bottle a layer of water so deep that the lower end of the funnel stem will reach just below the sur-

FIG. 1.

face of the water. Close the second hole in the rubber stopper by means of a glass plug or a round pencil. See that the rubber stopper is pressed tightly into the mouth of the bottle; then pour water into the funnel, keeping the funnel full.

FIG. 2.

Does any water run into the bottle? Does it continue to run in? Tell why. Now open the second hole of the stopper, and tell the result. Explain it.

How do these experiments show that air takes up room?

d. Examine a biscuit cutter. If you were making one out of a tin box cover, why would it be a good plan to make a hole in the top?

Where is the faucet inserted into a vinegar or molasses barrel? Why is a small hole (vent) drilled into the top of the barrel? Is there any similar opening in the sewing-machine oil-can or the oil-can used by carpenters? How is oil obtained from such a can? Why?

e. Simpler Form.— You can carry out the experiment of *c* with a small-mouth bottle, such as a vinegar or ketchup bottle, and a kitchen funnel (Fig. 3). Make the opening of the funnel stem smaller by closing it partly by means of a wooden plug, such as a pencil. Put the funnel stem loosely into the mouth of the bottle, and pour water into the funnel. How does the water run into the bottle, in a stream or by spurts? Now wind around the funnel stem a strip (about 1 cm. wide) of wet muslin, until the funnel stem can be fitted tightly into the mouth of the bottle. Then pour water into the funnel, and tell how the water enters the bottle.

FIG. 3.

EXERCISE 2

HOW TO MEASURE LENGTH AND AREA

Apparatus.— Meter stick, table.

a. Examine a meter stick. How many decimeters long is it? How many centimeters? How many millimeters? How many inches?

b. With a ruler graduated in English units draw in your notebook a horizontal line exactly 5 inches long. To make the length accurate put the edge of the ruler against the paper, and mark the ends of the line by means of a sharp-pointed pencil. Now measure the line with the metric rule, and state its length in centimeters and tenths of a centimeter.

c. Measure, in centimeters, the dimensions of the top of your laboratory table or of a kitchen table. Measure also the thickness of the table top. Calculate how large a piece of oilcloth, in square centimeters, you would need to cover the table top and its *edges*, including the necessary slight lapping at each of the four corners. From the table of equivalents given in the appendix of the text calculate the number of *square inches* of oilcloth needed. Change this area to square feet. To square yards. Give all your work.

d. Record your results thus:

Length of table top, in cm.

Width of table top, in cm.

Thickness of table top, in cm.

Length of oilcloth needed.

Width of oilcloth needed.

Area of oilcloth, in sq. cm.

Area of oilcloth, in sq. in.

Area of oilcloth, in sq. ft.

Area of oilcloth, in sq. yds.

EXERCISE 3

THE MEASURING OF VOLUME AND CAPACITY

Apparatus.—Two cubical blocks, metric rule, a marble about 1 in. in diameter, graduated cylinder, half-pint measuring cup with vertical sides.

a. The Volume of a Marble.—Place two cubical blocks tightly against the edge of a metric rule (Fig. 4), and between the blocks place a spherical marble. By measuring the distance between the two blocks get the diameter of the marble in centimeters and tenths. Mathematics teaches us that the volume of a sphere is very nearly $\frac{1}{6} \times \frac{22}{7} \times$ the *cube* of the

FIG. 4.

diameter. Suppose that the marble is 2 cm. in diameter; the volume of the marble would be $\frac{1}{6} \times \frac{22}{7} \times 8$, or 4.19+ cu. cm. In the same way calculate the volume of the marble given you, and record it, together with all your work.

Volume by Displacement.—We can also get the volume of the marble by finding out how much water the marble can push out of the way, or *displace*, (Fig. 5 of text). Half fill a graduated cylinder with water, and read the water level accurately. To do this, have your eye on a level with the water, and read the mark at the under edge of the curved surface (meniscus). Put down the reading. Now put the marble into the water, and read the new level. Subtract the first from the second reading. What is the volume of the marble by this method? Compare the two results.

Record your results systematically, as in Exercise 2.

b. The Capacity of a Measuring Cup.—Examine a measuring cup with vertical sides. We can calculate its *capacity*, or how much it holds, in cubic centimeters, as follows:—

Measure carefully the inside, vertical height, from the bottom of the cup to the lower edge of a ruler, or block, placed across the top. Have it accurate to 0.1 of a cm. Measure also the greatest inside distance across the top (the diameter). The capacity of the cup is equal to the height multiplied by $\frac{22}{7} \times \frac{1}{4} \times$ the *square* of the diameter. Suppose that a cup has a diameter of 3 cm., and a height of 4 cm. The capacity of the cup would be $4 \times \frac{22}{7} \times \frac{1}{4} \times 9$, or 28.28 + cu. cm.

How many cubic centimeters does your cup hold? Fill the cup with water, then pour the water carefully into a graduated cylinder. How does your calculated result compare with that shown by the cylinder?

Use the table of equivalents in the Appendix of the text to find the capacity of your cup in *cubic inches*. A gallon is equivalent to 231 cu. in. How many of your cupfuls are there in a gallon? In a quart? In a pint? Does your measuring cup seem to be fairly accurate, as judged by the number of cupfuls in a pint?

EXERCISE 4

HOW TO WEIGH

Apparatus and Materials.—Balances, weights, shot, graduated cylinder, measuring cup or beaker, water.

a. Balances.—We weigh objects by means of balances or scales (see Figs. 9, 10, and 11 of the text). Fig. 5 (this manual) represents some home-made scales; they can be hung from an overhead support, such as the edge of a shelf or the ring of a ring stand. The beam is of galvanized iron or sheet copper; the pans may be the covers of small baking-powder boxes; the

3 rings of the beam are made of metal (brass or plated iron), so that they shall have little friction against the beam. A convenient length for the beam is 18 cm. (7+ in.).

b. Rules for Weighing:

1. Put the object to be weighed on the left-hand pan, the weights on the right. Handle the weights with forceps if possible.

2. Do not *drop* the weights on the pan, but set them down carefully.

3. Do not leave the balance beam swinging when the balance is not in use.

4. Do not weigh an object directly upon the pan. Put a dish or a piece of paper on the left-hand pan, counterpoise, or balance, it exactly with weights or shot placed in the right-hand pan, and then put the object in the balanced pan or paper.

FIG. 5.

5. Learn just what weights ought to be in your case, and see that all are there before you begin weighing. When you have balanced the object you are weighing, count up what weights are

gone from your case; these should be the ones on the balance pan. Finally, take off all the weights used, set them in a row on a clean piece of paper, and count them up to see if you added them correctly before.

6. Record all your weights while you are at the balance. Do not try to carry the number "in your head" until you return to your desk. Put down all your weights in grams and decimals (tenths or hundredths).

7. Label all your figures *at once*, so that you will know to what object or material they belong.

8. When you are through weighing, return all weights to their proper places in the case, and leave the case and the balance in good condition.

c. **Weight of a Given Volume of Water.**—In a graduated

cylinder measure out carefully 25 cu. cm. of water. Get the weight of an empty dish, such as a measuring cup; then pour all of the water into it. Weigh the cup and the water, and calculate the weight of the 25 cu. cm. of water. How much would 1 cu. cm. of water weigh, according to your result? How much would a liter of water weigh? What is the accurate weight of 1 cu. cm. of water at $4^{\circ}\text{C}.$? Of a liter?

From the result of Exercise 3 tell how many cubic centimeters there are in a cupful. How many grams of water are there, consequently, in a cupful? From the Appendix (text) find out how many grams there are in an ounce. How many ounces of water, then, in a cupful? How many ounces in a pint?

Is it true that

“A pint’s a pound,
The world around”?

What fraction of a pint does a “4-oz.” bottle hold?

Record your results thus:—

Wt. of cup + 25 cu. cm. of water	=..... g.
Wt. of cup alone	=..... g.
Wt. of 25 cu. cm. of water	=..... g.
Wt. of 1 cu. cm. of water	=..... g.
Accurate wt. of 1 cu. cm. water at $4^{\circ}\text{C}.$	=..... g.
Accurate wt. of 1 liter water at $4^{\circ}\text{C}.$	=..... g.
Wt. of water in a cupful	=..... g.
Wt. of water in a cupful	=..... oz.
Wt. of water in a pint	=..... oz.

EXERCISE 5

PLUMB LINE AND PENDULUM

Apparatus.—A small, dense object, such as a metal ball, a bullet, a stone, or a key; also some thread.

a. Suspend the ball or other object by means of a light thread or string, so that it will swing freely. The thread may be tied to a gas fixture or a similar support. The ball or weight so suspended is called the "bob." What position do the bob and string take when left at rest? Why are they together called a plumb line? For what is a plumb line used? When does it become a pendulum? What is the meaning of pendulum?

b. Draw your plumb line aside, and let it go. What happens? When a body has been set in motion, the *amount* of the motion is called the **momentum** of the body. Momentum depends on both the mass (weight) of the body and its velocity. A body weighing 10 grams and having a velocity of 10 meters a second has the same momentum as a body weighing 1 gram and having a velocity of 100 meters a second. What makes the pendulum swing? Why does it not stop when the bob is at its lowest point? Will the pendulum ever stop swinging? What has the air to do with stopping it? If the pendulum string or thread rubs (has friction) against its support, what will the effect of this rubbing be? What device keeps a clock pendulum in motion?

Why is a hammock a pendulum? When you are swinging in a hammock, what do you do that corresponds to the slight push of the clock spring? When, in a swing, you "let the old cat die," what do you depend on to keep you swinging? What finally stops the swing?

c. Make the thread or string of a pendulum about 120 cm. (4 ft.) long, and tie it so that the distance from the point of suspension to the center of the bob is very close to 1 meter (39.37 in.). Set the pendulum swinging, and count the number of swings (vibrations) that the pendulum makes in 1 minute. Do this 3 times, add the results together, and divide by 3. What is the average number of swings per minute? Adjust the length of the thread so that the pendulum shall swing once

a second. About how long, then, is a pendulum that swings once a second?

Make the pendulum 25 cm. long (how many inches is this?), and count the number of vibrations in a second. Get the average of 3 trials, as before.

If you can find a high enough point of suspension (a stick placed horizontally out of an upper window will do), make a pendulum 4 meters long, and find out how many vibrations it makes in a minute. What is the time of one vibration? If we have two pendulums, and one is 4 times as long as the other, compare the amounts of time which they will take to swing.

EXERCISE 6

INERTIA AND CENTRIFUGAL FORCE

Apparatus and Materials.—Wooden blocks, calling card, coin, flatiron, strong cord, thread, ball with a rubber cord, small pail with a handle, water.

a. Try the experiment suggested in the text, § 29, exercise 4.

b. Hold out your left hand, palm upward. Near the tip of your first or your middle finger place a calling card, and on the card, just over your finger, put a coin, such as a nickel. Practice snapping the edge of the card with the thumb and a finger of your right hand, until you can drive the card away horizontally, leaving the coin on your finger. Explain why this is possible.

c. Suspend a flatiron by means of a stout cord, so that it escapes the floor by a few centimeters (an inch or two). Have the cord as long as is convenient. Tie a piece of thread (not too strong) to the flatiron, and by gentle pulling, properly timed, set the flatiron pendulum to swinging. When the

iron is swinging freely, try to stop it by a sudden pull on the thread. What happens? Why?

Now stop the flatiron, attach the thread once more, and try to set the iron to swinging by giving a sudden pull on the thread. What happens? Why?

d. Tie to a small ball a rubber band or cord, and (out of doors, or where you cannot break a window) whirl the ball slowly about your hand. What is the effect upon the rubber as you whirl the ball more and more rapidly? What does this indicate as to the intensity of the force exerted on the ball as the speed of the ball increases?

e. Into a small pail put about a cupful of water, and whirl the pail around rapidly in as large a circle as you can. Does the water fall out when the pail is upside down? How is it possible for a car to "loop the loop"?

EXERCISE 7

ADHESION OF LIQUIDS TO SOLIDS; LIQUID SURFACES

Apparatus and Materials.—Mercury, glass tube or rod, water, glass or beaker, vaseline (or grease or machine oil), nail, silver spoon, pencil, sheet of glass, iron stove lid or sheet of iron, graduated cylinder, needle, bowl.

a. Into a dish containing mercury dip a clean glass tube or rod; then remove it. Does the mercury *wet* the glass? What form has the surface of the mercury where the tube (or rod) enters it? Make a drawing of it. Now dip the glass tube into water. What is the form of the surface about the tube. Draw this surface also.

What is the shape of a water surface near the sides of a glass dish?

b. Thoroughly cover the inside of a water glass or beaker with a thin layer of vaseline or lard; then partly fill the glass

with water. What is the shape of the edge of the water surface? Dip into the water a glass tube or rod that is covered with grease or vaseline. What is the shape of the surface around the tube (or rod)?

If a liquid wets a solid, will the liquid surface be lifted up, or pushed down, next to the solid? If the liquid does not wet the solid, what will the result be? What is the effect on the liquid surface when you dip a nail into water? A silver spoon? A pencil?

c. Put a drop of water upon a freshly washed, but dry, piece of glass. What shape does the drop take? Draw a sketch showing this. Put a drop of water upon a greased paper. Its shape? On a kneading board dusted with flour. The result?

d. Put a drop of water on a stove top that is not red hot. What is the shape of the drop? Then put a drop of water upon a red-hot sheet of iron, such as a stove lid. What is the shape now? If your family uses a gas range, put a thin sheet of iron (a piece of "tinned" iron or a flat "tin" cover will do) over the gas flame until it is red hot; then add the water drop.

e. Let water drop into a graduated cylinder, and count the number of drops in 10 cu. cm. You can get water to form drops on a faucet, or you can make a tiny hole in the bottom of an empty tin can, so that the water will leak out drop by drop. Make at least three trials, and get the average. Calculate how many drops of water there are, under ordinary conditions, in 1 cu. cm. Put down all results in systematic form, as in Exercise 2. Make a sketch showing the stages in the formation of a water drop.

f. Wipe a needle clean, and then oil it very slightly with vaseline or machine oil. Hold the needle horizontal on a fork; then lower the fork carefully into a bowl or soup plate of water. The needle should float. Examine the water surface, and tell

why. If you do not succeed the first time, dry the needle and the fork carefully, and try again.

EXERCISE 8

CAPILLARY ACTION

Apparatus and Materials.—Bunsen burner, glass tube about 15 cm. long, colored water or ink, two glass vessels (beakers or water glasses), strip of cotton cloth (or of blotting paper), concentrated salt brine.

a. Heat the middle of a piece of glass tubing in a Bunsen flame until it is soft enough to be drawn out. You will need to hold both ends of the tube in your hands, and to turn the tube rapidly at first so that it can be heated evenly. Do not draw the tube out until its walls have almost melted together. Then remove the tube from the flame, and draw it out at once. In this way you can get a long tube of a very small diameter (a capillary tube).

b. When the tube is cool, break it carefully at its narrowest part, and then dip the small end into a dish of colored water, or into ink. Note how the liquid ascends into the tube. What is the shape of the liquid surface in the capillary tube? If different parts of the tube are of different diameters, break the tube so as to get two capillary tubes, one of a considerably larger diameter than the other. Dip both into the liquid. In which one does the water ascend to the greater height?

c. Try the experiment shown in Fig. 25, § 32, of the text. Use a wet cotton cloth, a wet strip of blotting paper, or a wet string.

d. Into a clean, dry water-glass pour carefully about 10 cu. cm. of a concentrated salt brine. Pour the salt solution down the side of a glass tube or rod (*cf.* § 84, Fig. 68, of text) so that the solution does not wet the sides of the glass above the liquid level. Mark the level of the liquid by means of a piece of paper

pasted on the outside of the glass. Now set the glass aside in a warm place, and watch it from day to day. What happens? Remembering that there is a narrow space between the crust of salt and the side of the glass, tell why the salt crawls up the glass. What is the shape of the salt crystals in the bottom of the glass?

EXERCISE 9

DENSITY

Apparatus and Materials.—Block of wood, metric rule, balances, graduated cylinder, kerosene, shot.

a. Density of Wood.—Measure carefully, to a millimeter, the dimensions of a block of wood. A toy block will do. The block must have rectangular or square faces. If, in measuring any one of the dimensions of the block, say, the length, you find that the distances along the four edges of the block are not equal, take the *mean* length. That is, add the 4 lengths together, and divide the sum by 4. In the same way get the other two dimensions of the block, and then calculate the volume of the block, in cubic centimeters. Now weigh the block carefully, in grams and tenths; then divide the weight, in grams, by the volume, in cubic centimeters.

How many grams are there for each cubic centimeter? This is the *density*, in grams per cu. cm. Of what kind of wood does the block consist? Compare the density you have found with that given in the Appendix of the text.

b. Density of Liquids.—Pour a little kerosene into a test tube, and add some water to the tube. Do the liquids become mixed? Which has the smaller density?

Whittle a stick of wood (pine or white wood) to about the thickness of a pencil and the length of a test tube. Put it into a test tube that is nearly full of water. Note how far it sinks

into the water, and mark this point on the stick. Then wipe the stick dry and put it into a test tube of kerosene. Does it sink farther than in water, or not so far? Why?

From Exercise 4, *b*, tell the density of water, under ordinary conditions, in grams per cubic centimeter. Using the method of Exercise 4, find the weight of 25 cu. cm. of kerosene. Calculate how many grams 1 cu. cm. weighs (the density). Compare your result with that in the Appendix.

c. Density of Shot.—Take shot enough to fill about $\frac{1}{4}$ of your graduated cylinder, and get the weight of the shot. Have the cylinder about half full of water, and get the volume accurately. Be sure to read to the bottom of the curved surface (meniscus). Then put the shot into the cylinder, and read the new height of the water. Be sure that no air bubbles are caught between the grains of shot. What is the volume of the shot? What was its weight? Calculate the weight of 1 cu. cm. Of what is shot made? What is its density?

Record all the results of this exercise systematically, as in Exercises 2 and 4.

EXERCISE 10

WEIGHT OF A STONE IN AIR AND IN WATER

Apparatus and Materials.—Balances (or scales), stone, thread, beaker (or glass), water.

a. In order to carry out this exercise we first weigh a stone in air, as usual; we then suspend it from a balance and get the weight it has when in water. The method of suspending the stone depends on the kind of a balance we use. Fig. 6 shows how to do it with a chemical balance; Fig. 7 is for a Trip scale; Fig. 28, in § 34 of the text, shows a third way. A spring balance (Fig. 11 of text) may also be used.

Get the weight, in grams and tenths, of the stone and a

piece of thread. Then tie the thread to the balance so that the stone is entirely immersed in water, but does not touch the sides or bottom of the vessel holding the water. Find the weight of the stone in this position; is it the same as before? What is the exact amount of difference?

FIG. 6.

FIG. 7.

b. Remember that water is pushed out of the way by the stone, and that this water exerts force in pushing up, or *buoying* up, the stone. How many grams of water, then, has the stone pushed out of the way? If this water were at 4°C. , what would its volume be? What, then, is the volume of the stone? Record your results systematically.

EXERCISE 11

CENTER OF MASS

Apparatus and Materials.—Cork, cork-borer or small file (rat-tail or triangular), shot, toy called a “tumbler,” Mason fruit jar, pail of water.

a. In a large cork bore a hole lengthwise, at one side of the center (Fig. 8). If you have no cork-borer, you can use a small file or the small blade of a penknife. Fill the hole with shot packed in tightly, and hold the shot in place with wads of paper

or cotton. What happens when you lay the cork on its side on the table? Try various positions. Account for what happens.

Examine the toy called a "tumbler"; why does it always come to an upright position?

FIG. 8.

b. Seal tightly an empty Mason fruit jar, and lay it on its side in a pail of water. Does the bottle rest equally well, however you place it, or does it come to rest in some preferred position? Tell why.

c. Take the cover off from a Mason fruit jar and try to stand the bottle upright on the water. Explain what happens.

Now put water into the jar until the jar floats right side up. Give the explanation.

Why do you hold out your hands when walking a rail? Why does a tight-rope performer carry a long pole? Why does a ship carry ballast?

EXERCISE 12

PRESSURE OF THE ATMOSPHERE

Apparatus and Materials.—Glass tube, medicine dropper, water, mercury, glass siphon (either prepared or to be made by the student; if to be made, a glass tube about 30 cm. long may be used).

a. Put one end of a glass tube into a glass of water, and by suction remove the air from the tube. What happens? Why?

b. Put the open end of a medicine dropper under water, and pinch the rubber bulb. What happens? Let go of the bulb, and state the result. Why does the bulb expand when released? What effect has this upon the pressure of the air in the bulb? What causes the water to rise?

c. If there is mercury in the laboratory, put the open end of

the medicine dropper under the mercury, pinch the bulb so as to expel the air as completely as possible, and then release it. Does the bulb expand completely? Why?

d. Siphon. Put the shorter arm of the bent tube (Fig. 9; make this, if necessary, as in § 4 of the Introduction) into a vessel of clean water, and suck the air out of the longer arm. What happens? Continue removing the air until the longer arm is full of water; then remove your mouth, and note what happens. Place an empty vessel under the longer arm. Have the top of the second vessel slightly higher than the bottom of the first

FIG. 9.

one. How long does the water run? The bent tube with the water flowing through it is a *siphon*. How far above the water level of the first vessel may the bend of the siphon be? What pushes the water up to the bend of the siphon? What pulls it down in the longer arm?

Pour the water back into the higher vessel, and fill the siphon with water by immersing it in a pail of water or by holding it under a faucet of running water. Close the opening of the longer arm with your finger, and put the shorter arm into the higher vessel; then remove your finger, and note the result.

For what purposes may a siphon be used?

EXERCISE 13

PRESSURE OF WATER AND OF AIR

Apparatus and Materials.—Deep glass vessel, small glass vial, wire, and stick (or glass tube); wide-mouth bottle, two-hole stopper (one hole plugged), bent glass tube.

a. Fill with water the deepest glass dish you can find. A

two-quart fruit jar or a tall vase will do. Fasten a small vial or test tube (mouth downward) to a wire or stick, and push it slowly to the bottom of the water. What happens to the volume of the air in the vial or test tube? Why? What relation does there seem to be between the depth of the water and the pressure of the water?

b. The Diver.—Arrange the bottle and other apparatus shown in Fig. 10. The vial is partly full of air and partly of water; it should just float. Put the stopper tightly into the bottle, and blow air through the tube. What is the result? Then let the extra air escape. What happens to the vial? Now, instead of blowing air into the bottle, remove air, by suction, from the bottle, and tell the result.

Fig. 10.

What is the explanation of the behavior of the vial? Draw three sketches showing the position of the vial, and of the air and water in it, at ordinary pressure, at increased pressure, and at reduced pressure. Compare the behavior of the diver with that of a submarine boat.

EXERCISE 14

COLLECTING A GAS OVER WATER

Apparatus and Materials.—Wide-mouth bottle (small), pan of water, glass tube, wooden splinter, test tube, illuminating gas.

a. Fill a wide-mouth bottle completely with water, and cover the mouth of the bottle with a piece of wet writing paper. With your hand hold the paper in place, so that no air bubbles remain in the bottle. Then invert the bottle over a pan of water, but do not, at first, put it into the water. If you are careful, you can remove your hand from the paper, and the water will not fall out. What supports the water?

Now put the mouth of the bottle under water, and remove the paper. Why does not the water fall out? How tall might the bottle be, and yet remain full of water when inverted in water?

Through a glass tube blow your breath (see Fig. 37, § 45, of the text), and catch the gas bubbles by the displacement of the water in the bottle. When the bottle is full, slip the wet piece of paper under it, hold the wet paper tightly against the bottle's mouth, and set the bottle upright on the table. Put into the bottle of gas a lighted splinter or match. Does the gas take fire? Does the splinter (or match) continue to burn in the gas?

b. In a similar way fill a test tube with water, and then fill the tube, by water displacement, with illuminating gas. Get the gas from a tube connected with the gas outlet. Carefully light the test tube of gas.

EXERCISE 15

SUBSTANCES PRODUCED IN BREATHING AND BURNING

Apparatus and Materials.—An acid (vinegar or hydrochloric acid), test tubes, limewater, glass tube, wide-mouth bottle, cardboard cover, splinter, candle, wire for a holder, marble or soda.

a. Prepare some carbon dioxide in a test tube by adding an acid, such as vinegar or dilute hydrochloric acid, to some marble or soda that is in the test tube. Hold the mouth of the test tube over the mouth of another test tube as if you were going to pour a liquid from the one into the other, but do not actually pour any of the liquid. The invisible gas carbon dioxide is thus poured over.

Add to the test tube that now contains carbon dioxide about 5 cu. cm. of limewater, close the test tube with the thumb, and shake the tube, so that the gas is mixed with the liquid. What

is the result? The fact that the limewater becomes milky serves as a test for carbon dioxide.

b. Through a glass tube blow your breath for some time into about 5 cu. cm. of limewater. Have the limewater in a test tube. What happens? What gas must be present in exhaled air?

c. Prepare a cardboard cover for a wide-mouth bottle, and make in the cardboard a hole just large enough to hold firmly a pine splinter about half as thick as a pencil. The splinter should be long enough to reach almost to the bottom of the bottle. Light the splinter, and put it into the bottle, using the cardboard both to cover the bottle and to hold the splinter.

Let the burning go on as long as it will. Why does the splinter not burn until it is all consumed? Is there any sign that water is formed in the burning? Now remove the splinter, put into the bottle about 5 cu. cm. of limewater, close the bottle, and shake it. What is the result? What gas must be formed when wood is burned?

d. Burn a small candle (use a wire as a holder) in a bottle of air, and make the same tests as in c. Give all the results, and explain them.

EXERCISE 16

HEATING OF TIN IN AIR

Apparatus and Materials.—Small iron dish (cake tin or cover of baking-powder box), stout wire or a small file, tin, ring stand, balances.

a. Weigh, all together, a small iron dish containing about 10 g. of tin, and a piece of stout iron wire that is to be used as a stirring rod. Instead of the wire a small file may be used. Support the dish on a ring stand (Fig. 11), and heat it strongly, stirring the melted tin with the wire or the reverse end of the file. What happens to the tin? If the wire or file becomes hot, put one end into a cork, or a spool, and use this as a handle.

Continue to push the scum to one side, so that the bright surface of the tin is kept in contact with the air. If the scum formed contains the tin and something taken from the air, do you think the dish, its contents, and the wire, taken together, will weigh more, or less, than they did before the heating? Keep up the heating for, say, 15 minutes, then let the apparatus cool, and weigh it again. What is the result? How much matter was taken from the air?

FIG. 11.
A Home-Made Ring Stand.

b. If you have no balances, carry out the heating without the weighing. You can do the experiment at home, if necessary, using a box cover for the iron dish, and the stove for the source of heat.

EXERCISE 17

PREPARING OXYGEN

Apparatus and Materials.— Wide-mouth bottle, stopper (two-hole), dropping funnel (or ordinary form), glass rod, delivery tube, pan of water; potassium permanganate or manganese dioxide, hydrogen peroxide, splinter, candle, limewater.

FIG. 12.

a. Prepare oxygen, if possible, in the apparatus shown in Fig. 44, § 51, of the text. If you have no dropping funnel, you can use an ordinary funnel with a glass rod to control the size of the opening into the stem (Fig. 12). A short piece of rubber tubing placed over the end of the rod will make a tighter joint than the glass alone.

b. **Simpler Form.**— You can make the oxygen more easily if you put the potassium permanganate

ate and hydrogen peroxide into a small, wide-mouth bottle. Use only a cardboard or glass cover. (See Fig. 18, Exercise 36.) The oxygen simply expels the air. About 3 cu. cm. of potassium permanganate is enough; the hydrogen peroxide can be added a few cu. cm. at a time. In place of the potassium permanganate you can use about 5 cu. cm. of *manganese dioxide*. Add the hydrogen peroxide as already directed.

c. In whatever way you prepare oxygen, put into a bottle of it a small burning candle supported by a wire. Describe the burning of the candle. Then remove the candle, and pour the gas in the bottle into a test tube containing a little limewater. Be sure you do not pour out any of the liquid (see Exercise 15). Shake the limewater and the gas. What is the result? Compare the product formed when the candle burns in oxygen with that formed when it burns in air. What conclusion can you draw from this fact?

d. Put into the bottle in which oxygen is being formed a pine splinter with a *glowing* (not a flaming) tip. What happens? How could you tell a bottle of oxygen from one of air?

Let the splinter burn for some time in the bottle of oxygen; then test the gas in the bottle to see if it contains carbon dioxide. Give your result.

EXERCISE 18

AIR DISSOLVES IN WATER

Apparatus and Materials.—A water glass, fruit jar, pan of water, burner or stove, pail of water, test tube, splinter.

a. Fill a glass or bottle with fresh, cold water, and let it stand in a warm place, near a stove or radiator, for an hour or two. What collects on the sides of the dish? Where did it come from?

b. Fill a glass fruit jar entirely with fresh, cold faucet or well water, cover the mouth of the jar with a wet paper (see Exer-

cise 14), and invert the jar in a pan containing water to the depth of an inch or two. Then raise the temperature of the water in the pan to boiling, and continue the boiling for 15 or 20 minutes. What collects in the upper part of the inverted glass jar?

Let the jar and its contents become moderately cool; then cover the mouth of the jar with moist paper, and remove the jar to a pail of water. Now transfer the gas, under water, from the jar to a test tube of water (see Fig. 78, § 102, of the text). Close the test tube with the thumb, invert it, and put into the gas a burning splinter. Does the gas act like air, or not?

EXERCISE 19

NITROGEN; THE COMPOSITION OF AIR

Apparatus and Materials.—Test tube, beaker, 10% solution of potassium hydroxide (or sodium hydroxide), “mossy” (granulated) tin (or iron filings), pail of water, graduated cylinder.

a. We can find out what the nitrogen of the air is like by removing the oxygen. Certain metals moistened with a solution of potassium hydroxide or sodium hydroxide readily unite with the oxygen. We make use of this fact in the following experiment (Fig. 13):

Into a test tube put a piece of “mossy” tin of such a size that it sticks slightly when pushed into the tube. Pour into the test tube about 10 cu. cm. of 10% potassium hydroxide solution, wetting the tin thoroughly; then pour the solution out into a small beaker. Now set the tube, mouth down and vertical, into the beaker, and let it stand over night.

b. What change do you notice? By holding your ruler upright beside the test tube estimate

FIG. 13.

what fractional part of the air has disappeared? Is it $\frac{1}{2}$, or $\frac{1}{3}$, or what? What gas was taken out of the air that was in the test tube? What gas remains?

c. Put the beaker and test tube into a pail of water, so that you can remove the test tube from the beaker without getting the mouth of the test tube above the liquid. Then close the mouth of the test tube with your thumb, remove the tube from the water, and turn the tube right side up. Put a burning match into the gas. Does the gas burn? Does the match continue to burn? How can you distinguish between nitrogen, air, oxygen, and illuminating gas?

d. If you wish to get a more exact result for the amount of oxygen in air, measure in a graduated cylinder the amount of water that entered the test tube. Then, leaving the tin in the tube, fill the tube entirely with water, and get the volume of the water. This equals the volume of the air originally in the tube. From the results find the *per cent* of oxygen in air; that is, the number of parts of oxygen in every 100 parts of air.

e. Iron filings and 10% sodium hydroxide solution may be used instead of tin and potassium hydroxide, but the reaction is somewhat more slow. Wet the inside of the test tube with 10 cu. cm. of 10% sodium hydroxide solution, and pour the solution into a beaker. Put into the tube about 1 cu. cm. of iron filings, spreading them out in the closed end of the tube. Then set the tube, mouth down, into the beaker, and let the apparatus stand for one or two days.

EXERCISE 20

EXPANSION AND CONTRACTION OF WATER

Apparatus and Materials.—Flask with one-hole stopper and long glass tube, gummed paper (or thread), ring stand, flame, pail of hot water, long-necked bottle.

a. Have a flask fitted with a one-hole stopper and a glass tube as shown in Fig. 14. Fill the flask with water, and press the stopper tightly into it; the water will rise part way up the tube. Mark the level of the water in the tube by means of a strip of gummed paper or a thread; then dry the flask and put it on wire gauze placed on a ring stand.

Heat the flask carefully with a small flame. Note all the changes that occur in the water level, and explain them. Do not heat the water to boiling, or until it actually overflows.

Let the flask cool, and then put it into a dish of cold water, or hold it under a cold-water faucet. What happens?

b. Instead of heating the flask over a flame you can plunge it into a pail of hot water. Note the first effect upon the level of the water, and the effect as heating is continued. Explain each effect.

c. **Simpler Form.**—Instead of a flask you can use a bottle with a long neck, such as a household-ammonia bottle, or a vinegar bottle. No stopper or tube will be needed. Mark the level of the water carefully (it should be a few centimeters below the mouth of the bottle), put the bottle in a pail of water, and heat the water in the pail; or you can set the bottle in a warm place, as, for example, near a radiator or a stove, for an hour or two. Note the change (or changes) in the level of the water, and explain. Then let the bottle cool, and note the results. If possible, set it in a cold place, but do not let it freeze.

FIG. 14.

EXERCISE 21

EXPANSION AND CONTRACTION OF AIR

Apparatus and Materials.—Flask or small-mouth bottle, pan of water, drinking glass, saucer.

a. Put a cold flask or small-mouth bottle (Fig. 52, § 61, of the text) mouth down in a pan of water, and grasp the flask in both hands, so as to warm it. What happens? Why?

Warm the flask more, either by heating it carefully, or by pouring warm water over it. Results? Then let the flask cool, and note what happens.

b. Set an empty drinking glass, mouth down, in a saucer or pan of hot water, as is often done when washed dishes are drained. Explain all that happens, both at first and afterward, when the glass and the water cool to the ordinary temperature.

c. A cup, upside down, is usually placed in the center of a meat pie. Find out why.

EXERCISE 22

MELTING POINT AND FREEZING POINT; A FREEZING MIXTURE

Apparatus and Materials.—Beaker or measuring cup, thermometer, crushed ice, salt, test tube.

a. Into a beaker or a measuring cup put about 30 to 50 cu. cm. of finely crushed ice, and stir it with a thermometer. Keep the thermometer bulb entirely in the ice. Stir the ice until the mercury stops shrinking; that is, until the thermometer ceases to "fall." Then get the exact reading, and put it down.

b. When you are sure that your reading of the melting point is final, add to the ice a tablespoonful of salt, and again stir the mixture with the thermometer. What is the lowest temperature reached by the thermometer? For what are freezing mixtures used?

c. Into the freezing mixture of *b* put a test tube containing about 5 cu. cm. of water. Rinse off any salt that may be on the thermometer, and with the thermometer gently stir the water in the test tube. Keep the bulb of the thermometer

immersed, and note the temperature of the water as it begins to freeze. Compare it with the temperature at which ice melts.

EXERCISE 23

BOILING POINTS OF WATER AND ALCOHOL

Apparatus and Materials.—A thermometer reading above 100°C ., a flask or cup, a beaker, a test tube, a ring stand or other support, water, salt, and alcohol.

a. Examine your thermometer, and be sure it reads above 100°C . Place a flask that is half full of water over a flame, and heat the water to boiling (see Fig. 54, § 62, of the text). Suspend, or hold, a thermometer in the flask. At first have the bulb in the boiling water; then hold it in the steam above the water. What is the boiling point of water, according to your thermometer?

b. After you have found the boiling point of ordinary water, put into the water about $\frac{1}{4}$ its volume of salt, and heat the water to boiling until as much as possible of the salt dissolves. What is the highest temperature reached now?

c. In a beaker, or cup, of boiling water put a test tube containing about 5 cu. cm. of alcohol, and hold a thermometer in the test tube so that the bulb is just below the surface of the alcohol. At what temperature does the alcohol boil?

EXERCISE 24

CONDUCTION OF HEAT

Apparatus and Materials.—Iron and copper wires about 15 cm. long, glass tube or rod of same length, burner, test tube of water, test tube holder.

a. **Conduction by Iron, Copper, and Glass.**—In a flame hold a piece of iron wire and one of copper, each about 15 cm. long.

Hold the wires horizontal, and place them so that they are heated equally. Which wire first feels hot to the hand, and is therefore the better conductor of heat?

Put one end of a piece of glass tubing (or a glass rod), about 15 cm. long, into the flame, and heat it until the end is melted. Does the end in your hand become hot? Is glass a good conductor of heat?

b. Conduction by Water.—Hold or support at an angle of about 45 degrees a test tube that is $\frac{3}{4}$ full of water (Fig. 15).

FIG. 15.

If you hold the tube, use a test tube holder (a folded strip of paper will do). Place the holder about the lower part of the tube, and hold the tube in a small flame so that the flame may strike the upper part of the tube, but may be below the level of the water. If the flame strikes the tube above the water level, the glass may be cracked. Heat the water to boiling. Is the lower part

of the test tube hot? Does water conduct heat as iron and copper do?

EXERCISE 25

CONVECTION

Apparatus and Materials.—Test tube and holder, burner, large beaker or flask, wire gauze and ring stand, fine sawdust, candle.

a. Convection in Water.—Take a test tube $\frac{5}{6}$ full of water, hold it by the upper part, and heat the lower part in a small flame. Is the heating now confined to the part near the burner? Tell why. Over a burner, and on a wire gauze, place a tall glass beaker or flask $\frac{5}{6}$ full of water. Put into the water a

small amount of fine sawdust or tiny shreds of paper. Warm the beaker slowly, and note any movements in the sawdust or paper. What is taking place in the water? What is the meaning of convection? How is the upper part of the liquid heated? Let the hot liquid cool, and note what movements take place. What is the direction taken by the cooler water? By the hotter water?

b. Convection in Air.—Open a door leading from a warm room into a cold room or hall. Hold a lighted candle at the top of the door opening; at the bottom. What is the direction of the air currents in each case? Tell why.

Hold the lighted candle near the incoming air register of your house or schoolroom. Near the outgoing register. Over the hot-water or steam coils. Give the results.

Why does so much dust collect on walls and ceilings over hot-air registers, and over steam and hot-water radiators? What does this show as to the direction taken by heated air?

EXERCISE 26

IS HEAT USED UP WHEN A LIQUID IS CHANGED TO A GAS?

Apparatus and Materials.—Ether or gasoline, water, thermometer, absorbent cotton, beaker or measuring cup, balances.

NOTE.—Ether and gasoline are very **inflammable**. Put out all flames when working with them.

a. Pour a few drops of ether or gasoline into the palm of your hand, and let the liquid evaporate. What is the result? Explain it.

Wet your hand with water having the temperature of the room, and wave it back and forth to make the water evaporate. Is there any change in temperature?

b. If you have a thermometer, find out if the result is only

imagination. Tie a bit of absorbent cotton about the bulb of the thermometer, put some gasoline on the thermometer, and wave the thermometer back and forth. Does the reading show any change? What is it?

c. Get the weight of a beaker half full of water, and keep the water boiling for 10 minutes. Does the temperature change during the boiling? Test it with a thermometer. Has the amount of water changed? How much?

If 536 calories of heat are needed to evaporate 1 gram of water at 100°C ., how many calories were added to the water in the beaker? Where did the heat come from? How was it produced?

EXERCISE 27

KINDLING TEMPERATURE

Apparatus.—Burner, wire gauze.

a. Hold or support a piece of wire gauze (it should be at least 10 cm. square) about 5 cm. above the top of a Bunsen burner. Have the air holes at the base of the burner open. Now turn on the gas supply, and bring a burning match over the middle of the gauze. Does the gas take fire above, or below, the gauze? Prove that there is gas below the gauze.

b. Let the gauze become cool, and then bring the middle of it down into a Bunsen flame. Does the flame go through the gauze? Why? Hold the gauze in the flame until it is red hot. Does the flame now go through the gauze? Tell why.

EXERCISE 28

MIXING MATERIALS OF DIFFERENT TEMPERATURES

Apparatus and Materials.—Measuring cup and woolen material to fasten around it, cardboard cover, thermometer, water, burner.

a. Make a simple *calorimeter* out of a measuring cup around the sides and bottom of which you have sewed or pinned some woolen material, such as flannel. A piece of cardboard, with a hole for a thermometer, will do for a cover. If the cup is graduated in fourths, you can measure the water that is used by looking at the marks inside the cup.

b. Put into the calorimeter $\frac{1}{4}$ of a cupful of water at the ordinary temperature, and get the temperature accurately. Remove the cover for a moment, and put in $\frac{1}{4}$ of a cupful of water at 50°C . Put on the cover, and stir the water with the thermometer. What is the temperature of the water now? How near does it come to the temperature midway between the ordinary temperature and 50°C .?

c. Now pour out the water, put in $\frac{1}{4}$ of a cupful at the ordinary temperature, and $\frac{1}{2}$ a cupful at 50°C . Put on the cover, and stir the water thoroughly. What is the resulting temperature? How near is it to the temperature $\frac{2}{3}$ of the way from the ordinary temperature to 50°C .?

EXERCISE 29

CONTENTS OF NATURAL WATER

Apparatus and Materials.—Beaker or measuring cup, flask (100 cu. cm.), cork stopper and glass delivery tube, test tube, watch glass or sheet of glass, tea kettle (?), water.

a. Boil some hydrant water vigorously for 10 minutes, and then let it stand. What settles out? Where did it come from? How is a deposit formed on the inside of tea kettles, etc.?

b. Distill water in the apparatus of Fig. 16. Half fill the flask with hydrant water, and support it in a ring stand. Have a piece of wire gauze between the flask and the flame. Use a cork stopper and a doubly bent delivery tube, and catch the distilled water in a test tube standing in a beaker of cold water.

What is a definition of *distillation*? What is the taste of distilled water?

If you have not the apparatus of Fig. 16, you can get some distilled water by inverting a small, clean pail over the nozzle of a tea kettle in which water is boiling. Catch the water that drops from the lower edge of the pail.

FIG. 16.

c. Evaporate about 5 cu. cm. of distilled water on a watch glass placed over a cup or beaker of boiling water. If you have no watch glass, use a piece of clean sheet glass. Lay it perfectly horizontal, and put the water to be evaporated, a few drops at a time, upon the center of its upper surface.

In the same way evaporate about 5 cu. cm. of hydrant water or well water. Which water leaves the greater residue? Why does distilled water leave any residue at all?

EXERCISE 30

WATER TESTS

Apparatus and Materials.—Beakers or bottles (3), graduated cylinder, cardboard or glass covers, dilute sulphuric acid, potassium permanganate solution, distilled water, natural water, powdered calcium sulphate (gypsum or plaster of Paris), soap.

a. **Organic Matter in Water.**—Measure out 50 cu. cm. of distilled water, and put it into a clean glass vessel, such as a beaker. Add to it 2 cu. cm. of dilute sulphuric acid and *one drop* of potassium permanganate solution.

Then add the same amount of dilute sulphuric acid and of potassium permanganate to 50 cu. cm. of hydrant or well water, and to 50 cu. cm. of ditch, pond, or aquarium water. Cover the 3 vessels with cardboard or glass covers, and set them aside in a warm place. Let them stand several hours. In which case is the pink color changed most? In which least? If it is the organic matter that changes the potassium permanganate, which water has the most of it?

b. Hardness of Water.—Put a small piece of a white soap, such as Ivory, Pearl, or Fairy soap, into a test tube half full of distilled water. Close the tube with your thumb, and shake it vigorously for 30 seconds. Then let it stand for 5 minutes.

Do the same with a test tube half full of hydrant or well water, and with one half full of a very hard water. Make the very hard water by shaking some powdered calcium sulphate (gypsum or plaster of Paris) with water and then filtering the solution. Compare the results in the 3 tubes; what differences do you see? Which forms the best and most lasting lather or suds? Which leaves a scum? If the ability to form a lasting suds is a test for a good laundry water, which of the 3 tried is the best? Which water would waste the most soap? Do you think the scum would be a good thing for the clothing washed?

EXERCISE 31

FILTERING AND PRECIPITATING

Apparatus and Materials.—Fine sand, salt, funnel, filter paper, watch glass or glass plate, cup of boiling water, potassium dichromate solution, solution of lead nitrate or of lead acetate (sugar of lead).

a. Mix thoroughly half a teaspoonful of fine sand with the same amount of powdered salt. Put the mixture into a dish, and add to it half a test tube full of hot water.

Make a filter as shown in Fig. 68, § 84, of the text. Fold the

circular filter through the middle, and then fold each half. Press the folded edges between the thumb and forefinger, but not between the nails. Open the filter so that it forms an inverted cone, and fit the cone exactly into the funnel. Hold the filter in the funnel, wet it with water, and press it carefully against the sides of the funnel.

Stir the mixture of sand, salt, and water, and pour the solid and liquid together upon the filter. Catch the part that runs through (the *filtrate*) in a dish, and evaporate some of it on a watch glass or a glass plate over a cup of boiling water (refer to Exercise 29, *c*). What substance do you obtain?

b. To 2 cu. cm. of a solution of potassium dichromate add twice its volume of a solution of lead nitrate or of lead acetate ("sugar of lead"). What happens? Let the solution stand; what settles out?

An insoluble solid that is formed by the mixing of solutions is called a *precipitate*. What color has the precipitate in this case? Filter it off, spread out the filter paper, and let it dry. The powder consists of "chrome yellow," used in the making of certain yellow paints. Evaporate the filtrate; it contains "niter," or "saltpeter."

What is the color of the precipitate formed when carbon dioxide is mixed with lime water? Refer to Exercise 15, *a*.

EXERCISE 32

CRYSTALS

Apparatus and Materials.—Powdered alum, beaker or cup, water, burner.

a. Put 10 cu. cm. (about 2 teaspoonfuls) of powdered alum into a beaker or cup, and add 20 cu. cm. of water to it. Stir the mixture for several minutes. Does some alum dissolve?

Does all dissolve? What evidence is there that you now have a *saturated* solution?

Heat the dish, and stir the alum and water until the solution nearly boils. What happens? Set the solution aside to cool slowly. Examine the crystals that are formed; do they have any regular form? Ask whether you are to save the alum.

What was the shape of the salt crystals formed in Exercise 8, *d*?

EXERCISE 33

DOES THE TEMPERATURE CHANGE DURING SOLUTION?

Apparatus and Materials.—Thermometer, beaker or cup, water, ammonium chloride (sal ammoniac), watch glass or glass plate.

a. Get the temperature of 10 cu. cm. of water in a beaker or cup. Hold the dish by the edge, so that your hand will not warm the water. Then mix with the water a teaspoonful (about 5 cu. cm.) of ammonium chloride (sal ammoniac), and stir the mixture with the thermometer. Have the thermometer bulb immersed, and hold the dish by the edge, as before. What change of temperature is there?

b. Pour a few drops of the sal ammoniac solution on a watch glass or a glass plate, and let it evaporate slowly, without applying heat. What form have the crystals? Draw a sketch of some of them.

Ask what you are to do with the sal ammoniac solution.

EXERCISE 34

HYDROGEN

Apparatus and Materials.—Small, wide-mouth bottle or a test tube, large bottle or fruit jar, a drinking glass, dilute sulphuric acid, granulated zinc, copper sulphate solution, splinter, kettle or pail of cold water, burner.

a. Preparation and Properties.—Prepare hydrogen in a small, wide-mouth bottle, as shown in Fig. 17. The bottle contains about 5 cu. cm. of granulated zinc and about 10 cu. cm. of dilute sulphuric acid. If these substances do not act vigorously, add to them about half a teaspoonful of copper sulphate solution. Over the small bottle invert a larger bottle (pint fruit jar); the hydrogen displaces the air. A test tube may be used instead of the small bottle.

FIG. 17.

After some minutes remove the larger bottle, keeping its mouth downward, and bring to its mouth a long, burning splinter. Does the gas take fire? Where? Push the splinter up into the jar of hydrogen, and hold it steady for a minute or two. Does the splinter burn in the hydrogen? Where does it take fire? Why?

From the method used in collecting hydrogen do you think the gas is heavier, or lighter, than air?

b. Burning of Hydrogen.—Light the hydrogen coming out of the small bottle or test tube. What is the color of its flame? If you cannot see the flame, find out if it is there by holding your hand over it. Invert a cold glass or bottle over the flame. What is deposited?

Set a tin cup or beaker of cold water over a gas burner. What is deposited on the bottom and sides? Where does it come from? What substance must be present in illuminating gas? Why does the liquid cease to be deposited after a while?

EXERCISE 35

HYDROCHLORIC ACID AND AMMONIA WATER

Apparatus and Materials.—Wide-mouth bottle or drinking glass, glass plate, concentrated hydrochloric acid and ammonia water, red and blue litmus paper, filter paper or blotting paper.

a. Open a bottle of concentrated hydrochloric acid, and blow your breath over it; your mouth should be wide open. What happens? The cloud or fog is composed of the moisture of your breath and the gas that comes from the hydrochloric acid of the bottle. Hold a piece of moist blue litmus paper over the mouth of the bottle, and state the result.

b. Open a bottle of concentrated ammonia water, and get its odor. Hold a piece of moist red litmus paper in the gas (ammonia) that comes out of the bottle; result?

c. Wet a small strip of paper, such as blotting paper or filter paper, with ammonia water, and hold it over the mouth of a wide-mouth bottle into which you have poured a few drops of concentrated hydrochloric acid. Result? The product is a solid (ammonium chloride or sal ammoniac).

Wet one side of a plate of glass with ammonia water, and lay the glass, wet side down, over the bottle containing the few drops of hydrochloric acid. Let the apparatus stand for some time, and state the result.

EXERCISE 36

CHLORINE

Apparatus and Materials.—Wide-mouth bottle, glass plate, manganese dioxide, concentrated hydrochloric acid, litmus paper, colored cloth, paper with ink writing, green leaves.

NOTE: Chlorine is a **dangerous** gas to inhale in any considerable amount, and should be made only under a fume chamber or by an open window with an outgoing draft. The window does very well. Probably it will be best for the teacher or a few students to make a bottle of the gas and to show it to the class. If you have breathed too much chlorine, smell cautiously of the bottle of ammonia water.

a. Into a wide-mouth bottle (Fig. 18) put about half a

teaspoonful of powdered manganese dioxide and about 2 teaspoonfuls of concentrated hydrochloric acid. Usually the gas is formed at once; if it should come off slowly, set the bottle in a pail of warm water. What is the color of the gas? Wave a little toward your nose, and smell of it cautiously.

FIG. 18.

What is its odor?

b. Hang in the bottle of the gas a piece of moist litmus paper (either color), a piece of moist colored cloth (such as cheap, red cheesecloth), a piece of paper with ink writing upon it, and a small bundle of green leaves, such as grass or parsley. What happens to them? Leave them some time if the changes are slow.

Remove the cover of the bottle for a moment, and put a burning match into the gas. Does the gas burn? Does the splinter continue to burn?

EXERCISE 37

SULPHUR

Apparatus and Materials.—Wide-mouth bottle, or fruit jar, with cardboard cover; evaporating dish or watch glass, test tube holder; combustion spoon and test tube (for a way of making these out of tin, see Introduction); sulphur, powdered iron, dilute hydrochloric acid, red litmus paper, grass, red rose or carnation petal.

a. **Sulphur Dioxide.**—In a wide-mouth bottle or fruit jar burn some sulphur. You will need a long-handled spoon (combustion spoon) and a cardboard cover with a hole for the spoon handle. Light the sulphur in a flame before putting it into the bottle of air. Let the sulphur burn as long as it will. Why does it finally stop burning?

Wave a little of the gas toward the nose, and learn its odor. Into the bottle (or jar) of gas put a piece of moist red litmus and

a small bundle of green leaves, such as grass. If you have it, put in also a petal from a red rose or a red carnation. What is the effect on each of these?

b. **Iron and Sulphur.**—On a clean paper mix thoroughly a teaspoonful of powdered sulphur and half as much powdered iron or fine iron filings. Put the mixture into a test tube, hold the test tube by a wire holder, if possible, and heat the bottom of the test tube red hot. The heating should start a brilliant *glow*, and this should travel through the mixture as the iron and sulphur unite to form *iron sulphide*. Note the appearance of the substance when it is cool; you will need to break the test tube.

c. **Hydrogen Sulphide.**—Put a very small lump of the iron sulphide into an evaporating dish or watch glass, and add to it 1 or 2 cu. cm. of dilute hydrochloric acid. Note what happens, and learn the odor of the gas (hydrogen sulphide) that is given off. What is it like?

EXERCISE 38

CHARRING OF CARBON COMPOUNDS

Apparatus and Materials.—Small iron dish (cake or muffin tin), “tin” cover to fit into it (Fig. 19), ring stand, burner or stove; pieces of wood, coal, and starch; sugar.

a. In a small iron dish (Fig. 19) put some small pieces of wood (pine is best), and push the cover tightly into the dish. The cover should be circular; it may be cut out of a sheet of “tin,” or the tin of a can. It should fit into the iron dish about half way from top to bottom. In the center of the cover have a hole of about the diameter of a small pencil.

Heat the iron dish over a flame or on a hot stove, lighting the gas that escapes

FIG. 19.

through the hole in the cover. When no more gas comes off, remove the dish from the flame, and let it cool. Then take off the cover, and examine what remains in the dish. What is it? Save it for the present.

b. Repeat experiment *a*, using soft coal instead of wood.

c. Repeat it again, using half a teaspoonful of sugar.

d. Repeat it again, using a lump of starch. What is the residue called in each case?

EXERCISE 39

HOW ORES ARE REDUCED TO METALS

Apparatus and Materials.—Small iron dish of Exercise 38, piece of wire, powdered charcoal, lead oxide, burner or stove, limewater.

a. Powder some of your charcoal, or get some powdered charcoal from the bottle, and mix half a teaspoonful of it very thoroughly with the same volume of powdered lead oxide (it is called *litharge*). Put the mixture in a heap in your iron dish (Fig. 19), push in the cover, and heat the dish very hot for about 10 minutes. While the heating is going on, hold over the hole in the cover a drop of limewater. You can hold the limewater in a loop made at the end of a piece of wire.

What happens to the limewater? What gas must be formed from lead oxide and charcoal? From what substance does the carbon of the charcoal get the oxygen?

Let the dish remain covered until it is cool; then examine its contents. What change has occurred? Do you get any evidence of a metal? If necessary, wash away any unused charcoal in a stream of water. What is the metal? Try to cut it with a knife.

EXERCISE 40

CARBON DIOXIDE AND FERMENTATION

Apparatus and Materials.— Bottle with glass-plate cover, drinking glass, fruit jar, marble, dilute hydrochloric acid, candle, splinter, lime-water, baking soda, washing soda, sour milk, vinegar, cream of tartar, baking powder, limestone, shells, old mortar, molasses or brown sugar, yeast.

a. Carbon Dioxide from Carbonates.— In a bottle like that of Fig. 18, Exercise 36, put some marble and dilute hydrochloric acid. What happens? Put a burning splinter into the bottle; does it continue to burn? Does the gas burn?

Put a very short candle into the bottom of a bottle or drinking glass, light it, and pour upon it the gas formed from the marble and acid (see Exercise 15). Do not pour out any of the liquid. What is the effect of the gas upon the burning candle?

b. Treat half a teaspoonful of baking soda with some sour milk, and prove that carbon dioxide is formed. Try washing soda and vinegar.

c. In a water glass or beaker mix about $\frac{1}{4}$ of a teaspoonful of baking soda with twice its volume of cream of tartar, and then add water to the mixture. Prove that carbon dioxide is formed. In the same way treat a teaspoonful of baking powder with water, and find what gas is given off.

d. Treat small lumps of limestone with dilute hydrochloric acid, and prove that carbon dioxide is formed. Do the same with some broken oyster, clam, or snail shells. Try some old mortar in the same way; what gas is given off, and what is the residue that does not dissolve?

e. Fermentation.— In a bottle or fruit jar put 50 cu. cm. of warm (not hot) water and 10 cu. cm. of molasses or brown sugar. Add about 1 cu. cm. of yeast, cover the bottle loosely, and set it where it will remain warm. Watch the contents of

the bottle, and note what happens. After the action has become vigorous, prove that carbon dioxide is being formed. After the action has ceased (it may be after several days), bring the fermented solution to the instructor, so that he may distill it, and may show that it contains alcohol.

EXERCISE 41

LIME

Apparatus and Materials.—Small iron dish, test tube, bottle with stopper, glass tube, lump of lime, sand, water.

a. Put a lump of fresh lime, about the size of a walnut, into your small iron dish, and add water, a few drops at a time, as the lime absorbs it. Do not use an excess of water. If you can see no sign of a reaction at first, try warming the dish gently. Note how the “slaking” of lime takes place, and describe the process. Watch the process of making mortar for some building in your neighborhood, and see how lime is slaked on a large scale.

When your lime has ceased to react with water, mix it with enough water to form a thick paste. Mix half of this paste with clean sand, and lay it aside for a week or two. What happens to it?

Mix the remainder of the paste with more water, stir the mixture (we call it “milk of lime”), and pour it into a bottle which can be stoppered tightly. Let it stand until it settles, or filter some of the milky solution. Prove that the clear solution behaves like limewater. You can do this best by putting some in a test tube, and blowing your breath slowly through a tube reaching into the liquid.

EXERCISE 42

MAGNETS

Apparatus and Materials.—Bar magnet and horseshoe magnet, small iron nails or tacks, iron filings, sewing needles, cork, dish of water (glass or porcelain), iron “cut” nail or a wire nail, sheet of paper or a pane of glass.

a. Bring one end of a bar magnet or horseshoe magnet near some iron nails or tacks; near a needle, a pin, a piece of “tin-ware,” a piece of copper (a cent). Are all attracted? Try the other “pole” of the magnet with the same materials; what are the results?

b. Magnetize a needle by stroking it, from the middle to the point, with one end of a magnet. Magnetize a second needle by stroking it with the other end of the magnet, also from the center to the point.

Cut two thin, circular slices of cork from a small cork stopper, and push each needle through one of the slices, so that the cork will make the needle float in a horizontal position. Float the two magnetized needles on some water in a porcelain or glass dish (not an iron one).

Find out whether the points of the two needles attract or repel each other. The eye ends. The eye end of one and the point of another.

Float a third needle, one that has not been magnetized at all, near one of your floating magnets. Does it show repulsion for either end of the magnetized needle?

c. Hold one end of your large magnet over the floating magnet, and account for the movements that take place. From the position which the floating magnet takes, and from the way in which it acts toward your large magnet, decide which end of the large magnet is north-seeking.

d. Hold a nail near one end of a magnet, as in Fig. 113 of the

text. Use an iron "cut" nail if possible; if you use a wire nail, you may need to heat it red hot and then to let it cool slowly. While the nail is near the magnet, bring it near small tacks or iron filings. What is the result? Now hold the magnet farther away from the nail, and note what happens.

e. Place a horseshoe magnet under the middle of a smooth piece of writing paper (or a pane of glass) and sprinkle some iron filings over the paper. Tap the paper gently, and see how the filings arrange themselves. Draw a sketch showing this arrangement. Compare it with the arrangement in the case of a bar magnet, as shown in the text, Fig. 114, § 138. Is the influence of a magnet cut off by paper or glass?

EXERCISE 43

ELECTRIC CHARGES

Apparatus and Materials.—Glass rod or a slender bottle, silk pad, silk thread, cork or pith, sealing wax, rubber ruler or comb, flannel pad or fur muff.

a. Hold a clean, dry glass rod (or a slender bottle) by one end, and rub the other end vigorously with a pad of silk cloth. Bring your knuckle near the rubbed part of the glass, but do not let it touch the glass. What occurs? Do the same with the rubbed part of the silk pad, and tell what happens.

b. Make an "electric pendulum" by attaching a silk thread to a piece of dry cork about 5 mm. in diameter. Instead of cork you can use the pith found inside the stem of a burdock.

Suspend the pendulum from a ring stand, a shelf, or a bracket; then rub the glass and silk together, and hold the glass near the pendulum. What happens at first? What further change takes place? Now hold your hand near the charged pendulum; what happens?

Hold the pendulum in your hand for a second or two, to discharge it; then hold near the uncharged pendulum the rubbed silk pad. Give all the results.

c. Rub a stick of sealing wax, or a rubber ruler or comb, with a piece of woollen goods, such as flannel. Bring the sealing wax (or rubber) near an uncharged pendulum, and compare the results with those that took place when glass was used. Also try the action between the rubbed part of the flannel and the uncharged cork. Give all the results.

d. Charge two electric pendulums from a rubbed glass rod, and hold them near each other, as in Fig. 119, § 143, of the text. What happens?

e. On a cold, dry evening put on some heelless slippers, and shuffle your feet vigorously, several times, across a rug or carpet. In this way your body becomes charged; so does the rug or carpet. Now hold your finger near a metallic object, such as a door knob or a chandelier. Describe what takes place.

On the same kind of a night comb your hair vigorously with a rubber comb, and prove that the comb becomes charged. Do the combed hairs show any sign of repelling one another? Why should they?

f. With a silk handkerchief, a flannel cloth, or a fur muff, rub a sheet of smooth paper, and hold the paper near the wall. Tell what happens, and why?

EXERCISE 44

A SIMPLE ELECTRIC CELL

Apparatus and Materials.—Strips of sheet zinc and sheet copper, pieces of copper wire, block of wood, tacks, drinking glass or jelly glass, compass or floating magnet, dilute sulphuric acid, saturated solution of potassium dichromate.

a. Prepare a strip of sheet zinc and one of sheet copper, each about 3 x 10 cm., and make a small hole near one end of each strip. Through each hole put one end of a piece of copper wire about 20 cm. (8 in.) long, bend the part that is through the hole, and with a hammer flatten the wire tightly against the strip. Then tack the strips of metal on opposite sides of a block of wood (Fig. 20) long enough to reach across the glass.

FIG. 20.

b. Half fill the glass with dilute sulphuric acid, and put the free ends of the two metal strips into it. Note what happens. From which metal do bubbles appear to rise? Touch the tips of the copper wires, held a little distance apart, to the tip of the tongue. What evidence do you get that a current is traveling through the wires?

c. Join the free ends of the two wires, and place them over a compass or a floating magnetized needle (*cf.* Exercise 42). What is the result?

d. If your simple cell is too weak to give good results, put into the dilute sulphuric acid about 10 cu. cm. of a saturated solution of potassium dichromate, and try the experiments again. What are the results now?

EXERCISE 45

THE SAL AMMONIAC CELL

Apparatus and Materials.—A sal ammoniac cell, ready to set up, wooden paddle, battery that operates house doorbells.

a. Examine the construction of a “sal ammoniac” cell. The common form is also called a “carbon cylinder” cell. If the cell is not ready to use, set it up according to the directions on the jar. Usually about 150 g. (5 ounces) of solid ammonium chloride are used. This is mixed with water, and

the water is stirred until the solid is dissolved. A clean wooden stick, whittled into the form of a paddle, makes a good stirring rod. The upper level of the solution should be at least 5 cm. (2 in.) below the top of the jar before the zinc and carbon are put in.

b. Find out where in your house the battery for the electric bell is placed, and get help, if necessary, to take it out, so that you can examine it. Describe it in your notes, giving the commercial name, the name of the manufacturer, etc.

How much did your house battery cost per cell? Find out how long the stick of zinc lasts, and how much a new one costs. What is the "life" of the sal ammoniac solution, and how much does a new charge of sal ammoniac cost?

c. If your doorbell is operated by "dry" cells, get all the data regarding them, and write the data in your notes.

d. If your doorbell is operated by a battery of two or more cells, notice how they are connected. If the carbon of one cell is connected with the zinc of the next cell, as in Fig. 134, § 159, of the text, the cells are said to be connected *in series*.

If all the carbons are connected with one wire, and all the zincs with the other wire, as in Fig. 21, the cells are said to be connected *in parallel*, or *abreast*.

FIG. 21.
Three Cells Connected "In Parallel"

EXERCISE 46

ELECTROMAGNETS

Apparatus and Materials.—Sal ammoniac cell, insulated wires, magnetized needle or compass, soft iron bar or wire nail, for a core; iron filings, tacks, and nails.

a. We have already tested the effect of a wire carrying a current upon the magnetized needle or compass. Try it again with the sal ammoniac cell, but use covered ("insulated") wire.

b. Coil the insulated wire around a thick pencil, giving it about 10 turns. Hold the coil of wire, with a current flowing through it, in some iron filings or small tacks. Do any cling to the coil?

c. Into the coil of wire put a bar of soft iron. A large wire nail will do, if you first heat it red hot, and then let it cool slowly. Bring the soft iron "core" of this "electromagnet" near some iron filings or tacks. Are more, or less, picked up than when the coil alone was used? Now "break the circuit" by disconnecting one of the wires from the cell, or by separating the wires that connect the zinc and the carbon. What takes place?

d. Again coil the insulated connecting wire around a pencil, winding it in about 50 turns, or as many as the length of the wire permits. Instead of doing this you can use a coil, already prepared and having a large number of turns. Into the coil put the soft iron core, and let the current flow. How does the ability of the electromagnet to pick up iron nails, etc., compare with its strength when the coil is small?

What, then, is the advantage gained by the use of a coil of many turns?

EXERCISE 47

SHADOWS

Apparatus and Materials.— Ordinary candle and "birthday" candle, each about 8 cm. (3 in.) high, two cardboard squares, upright object, such as two spools; kerosene or electric lamp.

a. Take an ordinary candle and a small "birthday" candle, each about 8 cm. (3 in.) high, and fasten them to cardboard

squares about 6 cm. on a side. You can do this by heating the bottom of the candle with a burning match until a little of the wax has melted and dropped upon the middle of the cardboard. Then press the candle against the cardboard until the wax has hardened.

In a room that is dark, light the larger candle, and place near it some opaque, upright object, such as two spools of thread one on top of the other. Have both the candle and the spools on a piece of white paper. Examine the shadow behind the spools, and see that it has two parts, one (the *umbra*) much darker than the other (the *penumbra*). Draw a sketch of the shadow, labeling each part, but not shading it.

b. Carry out the same test with the small candle; then try a larger source of light, such as a kerosene or electric lamp. The lamp must be reasonably near the spools. Draw the shape and size of the umbra and penumbra in each case, and compare them.

c. Now put the two candles as close together as possible, and place the spools near them.

Note how the shadows, and their parts, cross one another. Draw these parts, labeling them. Then slowly move the candles apart, noting the effect upon the umbra and penumbra. What is the effect of a large flame, or of separate flames, upon the size of the penumbra?

EXERCISE 48

BRIGHTNESS CHANGES WITH DISTANCE

Apparatus and Materials.—Cardboard square 4 cm. on a side, sheet of paper, metric rule, checkerboard, “birthday” candle.

a. Out of cardboard cut a square piece 4 cm. on a side; then draw on a piece of white paper a large square divided into 16

squares each 4 cm. on a side. Darken the room, and use a small "birthday" candle as the source of light.

Hold the small square upright, 10 cm. from the candle flame, and hold the ruled paper beyond it, and at such a distance that the shadow of the small square just covers 4 of the squares on the ruled paper. Measure the distance of the ruled paper from the flame, and compare it with the distance of the small square from the flame. Give the results.

b. Hold the cardboard square as before, 10 cm. from the flame, and hold the ruled paper so that the shadow of the small square covers 9 squares on the ruled paper. Compare the distances as before.

Again change the position of the ruled paper so that all 16 of the squares are covered by the shadow of the small square. What is the distance between the ruled paper and the candle now?

c. How many squares are there on a checkerboard? If you were to cut a cardboard square having the size of one of the checkerboard squares, and were to hold it upright, 10 cm. from the candle flame, how far from the candle would the checkerboard need to be so that the shadow of the single square could cover all the squares of the board?

EXERCISE 49

CANDLE POWER

Apparatus and Materials.—Large and small candles of Exercise 47, two spools of thread, white paper, lamp or electric bulb, metric rule.

a. In a dark room use again the two candles, the spools of thread, and the white paper of Exercise 47. Place the spools (one upon the other) between the two candles, and note whether the two shadows are equally dark. If not, shift the spools until this is the case. Then measure the distance from the spools to

each flame, and *square* this distance; that is, multiply it by itself. Now divide the square of the distance of the larger candle by the square of the distance of the smaller candle. Suppose the result is 3.5. This would mean that the larger candle has 3.5 times as great an illuminating power as the smaller candle. What result do you get?

b. Now compare the illuminating power of a lamp, or of an electric bulb, with that of the large candle. Instead of the spools, you can use an upright pencil, and instead of putting it between the two sources of light, you can put it to one side, as in Fig. 145, § 171, of the text. What is the "candle power" of the lamp or bulb?

EXERCISE 50

MIRRORS

Apparatus and Materials.—Mirror (vertical), two hand mirrors, pencil, plate glass or thick window glass, bottle of water, small candle, silver spoon.

a. Before a vertical mirror hold an open book, with the pages toward the mirror. How are the letters apparently altered by the reflection?

b. Lay a mirror, such as a hand glass, on the table before you, and set an open, upright book behind the mirror. How does the image of the letters differ from the letters themselves?

c. With a mirror lying flat on the table before you, take a second mirror in both your hands and revolve the mirror slowly, so that first its face and then its back are turned toward you. By changing your distance from the mirror you will find a position in which you can see images of yourself, at one time upright, at another, upside down. Objects behind the mirror will also form images in both upright and inverted positions. You can also get a large number of images of yourself at one

time, because not only the object (yourself) is reflected, but your image in one mirror is reflected by the other mirror.

What phenomenon do you see when you stand in a room that has vertical mirrors on opposite walls?

d. On a mirror put a speck of soap or ink, and look at the spot from one side. How many specks appear? Why? How can you use the distance between the speck and its image to get an idea as to the thickness of the glass of the mirror?

e. Hold an object, such as a pencil, near, but not touching, a mirror, and look at it from one side. The mirror should not be in too bright a light. You should see 3 images of the object. Remembering that the glass has thickness, and that the front, as well as the back, can reflect light, tell why there are so many images.

f. With a piece of plate glass or thick window glass carry out the experiment shown in Fig. 149, § 175, of the text.

g. **Curved Mirrors.**— Use a bright silver spoon (a circular one, if you can get it) as a curved mirror. The bowl will be a *concave* mirror; the back of the bowl, a *convex* mirror. Darken the room, and hold a small candle flame between the bowl of the spoon and your eyes. The image of the flame will be in front of the spoon, and inverted. If you turn the convex side of the spoon bowl toward you, and hold the flame between your eyes and the spoon, the image of the flame will appear back of the spoon, and right side up.

EXERCISE 51

REFRACTION OF LIGHT

Apparatus and Materials.— Thick glass, cup, coin, water, glass lens, paper, match.

a. Lay a piece of thick window glass, or of plate glass, over a straight pencil mark, so that the mark projects beyond the

edge of the glass. Note that if you look vertically through the glass, the line appears unchanged, but if you look at the line obliquely, it appears to be broken at the edge of the glass. Explain the phenomenon.

b. In a cup place a coin. Raise the cup so that the coin just disappears from view, behind the side of the cup. Now hold both the cup and your eyes steady, and pour water slowly into the cup. Note how the coin comes into view, and explain why.

c. **Refraction by a Lens.**—Get a glass lens with two convex faces, or with one plane and one convex face. You can use a magnifying glass, a reading glass, or the lens from a discarded bicycle lamp or “flashlight.” Look through the lens at print, cloth, etc., holding the glass near the object. Note that the object seems enlarged. Is the image reversed in any way?

Now move the lens farther from the object, and the parts of the object will appear reversed. What must have happened to the rays of light when the image is a reversed one? See Fig. 141, § 168, of the text.

d. **Burning Glass.**—Let sunlight pass through your lens, and hold the lens at such a distance from the back of your hand that the rays are brought together in one tiny, bright spot (a focus). Do you get any evidence that the sunlight brought together contains or produces heat? See if you can ignite paper, or a match, by holding it at the focus of your burning lens.

EXERCISE 52

OF WHAT IS WHITE LIGHT COMPOSED?

Apparatus and Materials.—A glass prism or a substitute, color top (see below), colored, glazed paper such as is used for covering boxes, tacks or thumb tacks.

a. **Decomposing White Light into its Colors.**—Get some thick, transparent glass object with glass surfaces that are not

parallel. A 3-sided prism is the best thing to use, but other objects, such as a chandelier pendant, a cut-glass bowl, or a many-sided perfume bottle made of thick glass, will do. On a sunny day darken a room almost completely; then let a beam of sunshine enter through a crack around the window shade. Place the prism, or its substitute, in the path of the sunbeam, so

Fig. 22.

that the *spectrum* of "rainbow" colors will be thrown upon a sheet of white paper placed on the wall, the floor, or on a table. Give the names of the colors in their order.

b. Mixing of Colored Light.—

In this experiment you will need a "color top." You can buy one at a toy store, or you can make one as follows (Fig. 22):

Out of stiff cardboard cut a circle 8 cm. in diameter (3 in.), and in the center make a square hole about 4 mm. on a side. Make a peg and handle for the top out of a soft-wood stick about 5 cm. long and 6 mm. thick. Let the "peg" end remain as thick as the original stick, but cut down the rest of the stick slightly, so that the cardboard can slip down to a "stop" 1.5 cm. from the peg, but no closer. Have the peg smoothly rounded, so that the top will spin evenly. The part that is to hold the cardboard circle should be *square* in cross section, so that the circle cannot turn on the stick. Round off the upper part of the stick (the handle). The circle should be slipped over the handle until it comes to the "stop," above the peg. By twisting the handle between your thumb and second finger you can spin the top.

c. Out of sheets of colored paper cut circles having the size of the cardboard one. Use violet, blue, green, yellow, red, and black paper. Make a round hole in the center of each circle, and cut a slit from circumference to center. Take first a yellow

circle and a blue one. By slipping one circle through the slit of the other you can get portions of each color to show. Move the two circles over each other so that $\frac{2}{3}$ of the circle is blue and $\frac{1}{3}$ is yellow. Slip the combination circle on the top, and fasten it to the cardboard by means of tiny tacks or thumb tacks. Instead of tacks you can use a drop or two of paste. Then spin the top. What color do you get? Remember that *gray* is poorly illuminated *white*.

d. Try a combination yellow-red circle; what is its color? A red-blue circle.

Make a circle out of the 3 colors: red, green, and blue, each of them $\frac{1}{3}$ of the circle. What color do they give?

e. Try a black disk with a yellow one, using several different proportions of the colors. Try black and red and black and green, giving the results.

EXERCISE 53

HOW COLOR IS AFFECTED BY THE KIND OF LIGHT

Apparatus and Materials.—Strip of blotting paper or asbestos paper, saturated salt solution, Bunsen or alcohol burner, colored papers of Exercise 52, lamp with a red globe (or paper soaked in strontium chloride solution).

a. Soak a strip of blotting paper or asbestos paper in a saturated salt solution, and dry it on a radiator. Have the room dark, and hold the prepared paper in a Bunsen or alcohol flame. What is the color of the light given by the flame? Examine the colored papers of Exercise 52 in this "sodium" light. What color has each one?

b. Examine the colored papers in a red light. Get this light from a lamp or lantern with a red globe, or cover a globe with red crêpe paper. What is the apparent color of each paper?

You can get a crimson light from a piece of blotting or asbestos paper that has been soaked in a solution of *strontium chloride* and then dried.

c. In order that a color may appear red, what kind of rays must be in the light that illuminates it? What rays must a light contain if we are to see an object as yellow? Why do objects have these colors in sunlight? Why do colors appear unnatural by electric light?

EXERCISE 54

HOW SOUND IS MADE AND CARRIED

Apparatus and Materials.—Table bell or doorbell, tuning fork or table fork, newspaper, watch, pillow, room with steam pipes or water pipes, wooden board.

a. While a table bell or doorbell is ringing, touch the bell lightly with your finger. What proof have you that the bell is vibrating?

b. Strike a tuning fork lightly against the edge of a table, and hold your finger against the fork. Account for the result. A table fork can be used in the same way. Hold the fork lightly by the handle while you strike the back of the prongs against a table or chair, and then bring the vibrating fork near the top of some loose paper, such as a partly folded newspaper. What is the result, and why?

c. Lay a watch upon a pillow, at some distance from you, say, at the farther end of a table. Note whether you can hear the watch, and how loud the ticking is. Then lay the watch, at the same distance, upon the bare table, and compare results.

d. Have some one scratch with a pin, or tap with a pencil, at one end of a steam or water pipe, and put your ear close to the other end of the pipe. Can you hear the sound? Can you

hear it as well when your ear is away from the pipe? What conclusion can you draw from this fact?

Try the same experiment with a long, wooden board.

EXERCISE 55

HOW SOUNDS ARE STRENGTHENED

Apparatus and Materials.—Wide-mouth bottle, tuning fork or table fork, metric rule, water.

a. Into a wide-mouth bottle, such as a milk bottle or fruit jar, pour a little water, and hold over the mouth of the bottle (near it, but not touching) the prongs of a vibrating tuning fork or table fork. If the sound produced by the fork does not increase in loudness, add more water, so that the depth of the water will be increased about 1 cm., and set the fork in vibration once more. Do this again and again until the sound is reinforced, or strengthened, so that you can hear it very plainly. For a common, Rogers Brothers', plated table fork the reinforcement was found to be loudest when the water was 9 cm. from the top of the bottle. That is to say, the vibrating air column was 9 cm. high. What is the length for your fork?

b. Try another tuning fork or table fork. Strike it, and note whether its pitch is higher or lower than that of the first fork. If it is lower, make the air column longer; that is, take out some of the water. If the pitch is higher, make the air column shorter. Get the length of the air column in this case also.

The reinforcement of sound by means of a second vibrating material (here it is air) is called *resonance*.

EXERCISE 56

LEVERS

Apparatus and Materials.—Strip of wood for lever, fulcrum, books, a weight, such as a flat stone.

a. For this exercise you need a strip of dry wood about 5 cm. (2 in.) wide and 45 cm. (18 in.) long. Make a triangular block for a *fulcrum* (a spool laid on its side will do), and lay

FIG. 23.

the strip of wood (the *lever*) over the fulcrum, as in Fig. 23, A. Put a book near one end of the lever, and push downward at the opposite end. Change the fulcrum so that its positions vary from almost under the book to almost under your hand.

When is it easiest to lift the book? When is it hardest? Such a lever is of the *first class*. Where is the fulcrum placed as regards the weight (the book) and the place where the power (your hand) is applied?

b. Vary the experiment by hanging the book in a sling of stout twine (Fig. 24) and putting the loop of the string over the lever, near one end. Use the back of a chair as the fulcrum. Hang another book of the same weight at the opposite end of the lever.

Where must the fulcrum be placed so that the two arms of the lever, with their loads, will balance each other?

Now put two books at one end and one at the other. About how far from the end having one book must you place the fulcrum? From

FIG. 24.

the end having two books? Compare the lengths of these two *arms* of the lever.

Finally put three books at one end and one at the other, and compare the lengths of the two arms of the lever.

Is it true in the *first* case that the weight arm multiplied by its load is equal to the power arm multiplied by its load; that is, that the weight arm multiplied by its number of books is equal to the power arm multiplied by its number of books?

Is it true in the *second* case? In the *third*?

c. Make a *second-class* lever as in Fig. 23, *B*. Put the book near the fulcrum, and lift upward at the end having the arrow. Move the book toward the hand, and note how much effort you need to put forth to lift the power arm. Where is the book when the lifting is most easy? When it is most hard? What is the greatest force you must exert in lifting a weight with a second-class lever?

d. Make a *third-class* lever as in Fig. 23, *C*, using your left hand as a loose fulcrum to keep the fulcrum end from slipping out of place. Put the book on the other end of the lever, and with your right hand lift upward at the left of the book. Try lifting upward at several places, each one a little nearer the fulcrum. What are the results? At which part of the lever is the lifting most easy? What is the smallest weight you must lift in raising a book by means of a *third-class* lever?

e. Use a book cover as a lever, placing a weight upon it. Find where the weight is when the greatest effort is needed to lift it. Where is the weight when the least effort is needed? To what class of levers does the book cover belong?

EXERCISE 57

TOOLS BASED ON THE LEVER

Apparatus.—Jackknife, scissors or shears, can openers, hammer, board, nail, nail extractor.

a. Open the blade of a jackknife and show that the blade itself is a lever. What is the force to be overcome in opening the knife? If the springs were equally strong, and the distances from the rivets (fulcrums) to the springs were equal, which blade could be opened more easily, a long one or a short one?

b. With a pair of scissors or shears try to cut a match stick. Where must you place the stick in order to cut it most easily? Why?

c. Examine several of the "openers" used for opening "tin" cans, and find one that is a lever of the first class. Describe it. Find one that is of the second class. Describe it.

What kind of a lever is a full suit case when you are trying to close it?

d. Suppose that you stand on the outside of a closed door, and that your brother is on the inside trying to hold it shut. If you push against the knob, and he against the middle of the door, what kind of a lever is the door, so far as you are concerned? What kind of a one is it so far as he is concerned? Suppose he pushes against the knob, where ought you to push to get the greatest advantage?

e. Find out from a carpenter how to drive a nail into a board. How should the hammer be held? Why? How should the nail be held? Why? Drive the nail partly into the board, then draw it out. Find out how to do this properly.

f. Ask to see the construction and operation of the nail extractor used in opening large packing boxes, such as those of a dry goods store. Describe it.

EXERCISE 58

PULLEYS

Apparatus and Materials.—Pulleys or casters, string or tape, books for weights.

a. Support a pulley as in Fig. 175, § 201, of the text, and fasten a weight, such as a book, to one string.

How much force must you exert, pulling downward, to lift the book? Prove this by fastening a second book, of the same weight as the first, to the free end of the string. Do the books balance each other? What is the use of such a pulley?

b. Now try two pulleys, as in Fig. 176 of the text. Do you need to exert more, or less, force than the weight of the book? Note carefully how far down you must pull the free cord, and how far the weight rises. How do the distances compare?

Put two books for the weight, and one on the free end of the string. Can the one be made to balance the two? Why?

c. Finally, support two pulleys as shown in Fig. 25, this manual. Can one book be made to balance two?

FIG. 25.

d. If you can get no pulleys for this exercise, use casters, such as are put under bureaus and tables. In this case use tape for your pulley cord, as this will not slip off so easily as string.

EXERCISE 59

THE INCLINED PLANE

Apparatus and Materials.—A board about 3 ft. long (a drawing board, moulding board, or ironing board will do for *b*), spool, nail to fit it, two-pointed tacks, cord or tape, round dowels or spools or a cart, books for weights.

a. Make an inclined plane out of a board about 3 ft. long (Fig. 26). To make the friction small at the edge of the board

a spool is fastened to the board. The axle of the spool may be a wire nail that is nearly as large as the hole in the spool. It may be fastened to the edge of the board by means of two-pointed tacks.

For the weight (Fig. 27) use a book in a sling, and a cord or tape long enough to go over the edge. Under the book place

FIG. 26.

FIG. 27.

two round dowels about 8 cm. (3 in.) long, or use spools. Best of all, use a small cart with spools for wheels.

Make the plane half as high as it is long, and see if one book will support two. Then make it $\frac{1}{3}$ as high as it is long, and see if one book can support three. If you use a cart, you must make allowance for the weight of the cart.

b. Simpler Form.—Use a drawing board, moulding board, or ironing board for the inclined plane. Up the plane roll an unopened tin fruit can, such as a can of tomatoes or peaches. If the plane is vertical, how much force must you exert? If it is half as high as long? If it is $\frac{1}{3}$ as high as long? If it is horizontal?

Find out where you can see an inclined plane in actual use, watch the operation, and describe it.

EXERCISE 60

THE SCREW

Apparatus and Materials.—Steel screw, metric rule, board of soft wood, hammer, screw driver, carpenter's brace, screw-driver bit. For examination: copying press, jackscrew, carpenter's wood screws.

a. Examine an ordinary steel screw, measure accurately the threaded part, and count the number of threads. What is the distance between two successive threads?

b. Force a screw into a piece of soft wood. To do this, first give the head of the screw a tap or two with a hammer, so as to "start" the screw. Then use a screw driver, giving it a few turns. Can you turn the screw with the fingers alone? Why?

c. Find out how far it is around the screw-driver handle (circumference) at its thickest part. If the screw driver has flat sides, get its greatest thickness (diameter) and multiply this by $3\frac{1}{4}$. Compare the circumference of the handle with the distance between threads. How far must the hand be turned in order to make the screw advance the distance between two successive threads? If you exert a force of 1 kg. on the circumference of the screw driver, how much do you exert on the threads?

d. Go to a hardware store, and ask to see the different varieties of screws. Ask for what each kind is used. How are the sizes of screws stated? Ask to see a copying press, a jackscrew, and carpenters' wood screws, and have their uses explained to you.

e. Examine a carpenter's *brace*, and put into it the screw-driver bit. Use this to drive the screw farther into the wood. Can you drive the screw more, or less, easily than with the screw driver? Why?

Find out how large a circle your hand goes through in turning

the brace once. How many times as great as the distance between threads is the circle "described" by your hand? If you exert a force of 1 kg. on the brace, how much do you exert on the screw threads?

EXERCISE 61

WHEEL AND AXLE

Apparatus and Materials.— Wheel and axle (usual form) or a wheelbarrow, cord, tape, books or weights.

a. Set up a wheel and axle as shown in Fig. 178, § 202, of the text. Wind the cord about the wheel so that it will unwind at the same time that the cord on the axle is wound up. What is the diameter of the wheel? Of the axle? How many grams tied to the cord that is attached to the wheel will just balance 100 g. on the cord attached to the axle? If you attach one book to the wheel, how many books of the same weight will it support on the axle?

b. Another form of the apparatus can be made out of a wheelbarrow. Turn the wheelbarrow upside down, over a box or some saw horses if possible, so that the wheel will be at least 45 cm. (about 18 in.) from the floor.

A stout cord tied to the inner end of one of the wheel spokes is to be wound upon the "hub." The hub serves as the "axle" of the apparatus. A tape may be tied to the rim of the wheel, so that the free end of the tape is wound up at the same time that the cord on the hub is unwound.

What is the diameter of the wheel? What is the diameter of the hub at the place where the cord is attached to it? How great a weight, tied to the hub cord, can be supported by 1 kg. tied to the wheel tape? Try the experiment, using several books of equal weight if you have no metal weights.

EXERCISE 62

FRICTION

Apparatus and Materials.—Book, flatirons, spools or dowels, wheelbarrow or cart, machine oil, bicycle.

a. Lay a book upon the table, and push it over the table. What force must be overcome? Does the degree of smoothness of the book cover and the table have anything to do with the force required? Now put some flatirons or other heavy weights on the book, and try the experiment again. What is the result? Put under the book and its weights four spools, or two round dowels (*cf.* Exercise 59), and try moving the book. Suggest why “rolling” friction is less for a given weight than “sliding” friction.

b. Try spinning, as hard as you can, the wheel of a wheelbarrow or cart that has not been oiled recently. Count the time during which it continues to turn. Now lubricate (“oil”) the bearings with machine oil, and find for how long the wheel continues to turn. Give the cause of any difference that you notice.

c. Why is oil put on “oil stones” that are used for the sharpening of cutting tools? Have some one take off a bicycle pedal for you, and examine the “ball bearings.” Why are they used?

EXERCISE 63

APPLIED FORMS OF SIMPLE MACHINES

Apparatus.—For examination: bread mixer, egg beater, self-sealing fruit jar, ordinary fruit jar, skates, sewing machine, bicycle, typewriter, clothes wringer, washing machine, screw eye, “crosscut” and “rip” saws.

a. Examine a *bread mixer*. How many simple machines can you find about it?

b. Count the number of cogs in the large wheel of an *egg beater*. In the small wheel to which the beating apparatus is attached. How many times does the small wheel revolve while the large wheel is turned one revolution?

c. What kind of a machine is there in the "self-sealing" *fruit jar*? In the ordinary form? In modern *ice skates*? In a *door catch*? In a window having *window weights*? In a *window fastener*? In a *key*?

d. Examine carefully a *sewing machine*, a *bicycle*, a *type-writing machine*, a *clothes wringer*, and a *washing machine*, and write down all the simple machines you find in each.

e. What tool is a *screw driver* when you use it to take a tack out of the floor? To force a *screw eye* into a board?

f. Examine a "crosscut" saw, and describe it. Do the same for a "rip" saw. What kind of a simple machine is a saw?

EXERCISE 64

ACIDS

Apparatus and Materials.—Glass or porcelain dishes, test tubes, dilute sulphuric, nitric, hydrochloric, and acetic acids; crystals of tartaric and citric acids; lemons, grapefruit, oranges, tomatoes, sour milk, vinegar, dill pickles, rhubarb; blue litmus paper, ammonia water, tea leaves, apple, dry oak leaves, zinc, copper (wire or cent), iron (filings or tacks).

a. **Taste of Acids**.—What is the characteristic taste of lemons, grapefruit, oranges, and tomatoes? Of sour milk, vinegar, dill pickles, and rhubarb?

To 5 cu. cm. of water add a few drops of ordinary, dilute sulphuric acid, and taste the solution; then spit it out. Save the remainder for b. Do the same with a few drops of dilute hydrochloric acid; with dilute nitric acid; with acetic acid. Give the results.

Taste a crystal of tartaric acid; one of citric acid. What taste have they? What is meant by an *acid* taste?

b. Acids and Litmus.—Test each of the fruit juices (at home?) and acids of *a* with blue litmus paper. One piece of litmus paper will do, if, after the color has been changed, you restore the original color. Do this by dipping the paper into dilute ammonia water; then wash off the ammonia water under the faucet. If you wish to dry the litmus paper, lay it on a blotter or a piece of newspaper. Write down all the results.

Boil some tea leaves with water, and test the solution with blue litmus. Do the same with a piece of an apple; with some dry oak leaves. Give the results.

c. Acids and Metals.—We have already tried the action of zinc with dilute sulphuric acid (*cf.* Exercise 34). What gas was formed? Try zinc, in a test tube, with dilute hydrochloric acid; also iron filings or small tacks with either dilute sulphuric or hydrochloric acid. Is the same gas formed?

To a piece of copper wire, or to a cent, add about 5 cu. cm. of dilute nitric acid. Does any reaction take place? Warm the acid if necessary. What kind of a gas is formed this time? What happens to the copper? What is the color of the solution? After a few minutes pour the liquid into another dish, and rinse all the acid from the copper.

d. Acids and Carbonates.—The reactions of acids with carbonates have already been studied (*cf.* Exercise 40). What happens when soda or marble is treated with a dilute acid?

Name four ways in which we have tested for an acid.

EXERCISE 65

BASES, OR ALKALIES

Apparatus and Materials.—Glass or porcelain dishes, solid potassium hydroxide or sodium hydroxide, red litmus paper, dilute acetic

acid, ammonia water, limewater, washing soda, laundry soap, "Gold Dust," wood ashes, dilute hydrochloric acid.

a. Examine some solid potassium hydroxide or sodium hydroxide; then dissolve a piece the size of a bean in about 3 cu. cm. of water. Rub a little of this solution between your fingers. How does it feel? Dilute the solution with more water, and test it with red litmus paper. You can use the piece of blue litmus of the last exercise, if you will first dip it into dilute acetic acid. Wash off the excess of acid with running water. How does the alkali affect red litmus?

b. Test the following with red litmus: ammonia water (*cf.* Exercise 64), limewater, solution of washing soda. Also test a piece of some laundry soap, or its solution, and some wet "Gold Dust." What takes place?

c. Get some wood ashes (or burn some wood to ashes), treat them with water, and filter the solution. Test the filtrate with red litmus. What is the result?

d. Put upon a small piece of potassium hydroxide or sodium hydroxide a drop of dilute hydrochloric acid. Is there much effervescence? Let a similar piece stand in the air for a day; then add a drop of acid. What is the result? What has the hydroxide probably taken up from the air? What happens to lime that is exposed to the air? Why does mortar become hard? See § 132, text.

EXERCISE 66

NEUTRALIZING A BASE BY AN ACID

Apparatus and Materials.—Glass or porcelain dish, solid sodium hydroxide, litmus paper, dilute and concentrated hydrochloric acid, lemon, limewater, filter paper and funnel, black or blue woolen cloth, ammonia water, baking soda.

a. In a glass or porcelain dish dissolve a lump of sodium hydroxide the size of a bean in about 10 cu. cm. of water.

Save a few drops of it. Into the greater portion put a small piece of litmus paper (either color; why?); then add dilute hydrochloric acid drop by drop, stirring the solution after every drop, until the litmus is just barely pink (lavender). If you get too much acid, add a drop more of sodium hydroxide solution. The base and the acid are said to *neutralize* each other.

b. Remove the litmus, and evaporate the solution over a flame until crystals begin to appear. Then let the solution evaporate further by itself. What is the shape of the crystals? Taste the crystals and the solution. What substance is formed by the neutralization of sodium hydroxide by hydrochloric acid?

c. Take about 5 cu. cm. of filtered lemon juice, add a small piece of litmus paper, and neutralize the solution with lime-water. Remove the litmus, and boil the solution vigorously. You should get a white precipitate of *calcium citrate*. Give your results.

d. On a piece of black or blue woolen cloth put a drop of concentrated hydrochloric acid, and let it remain for a few minutes. What happens? Now treat the acid spot with dilute ammonia water. What is the result? How could you remove an acid spot from cloth?

Make another spot on the cloth; then apply a thin paste of baking soda (sodium bicarbonate). Will this do as well as ammonia water?

EXERCISE 67

SOAP AND SOAP MAKING

Apparatus and Materials.—Olive oil, sodium hydroxide solution, solid sodium hydroxide, "tin" can, lard, salt, blotting paper or newspaper, red litmus paper, linseed oil, limewater, test tubes.

a. In a test tube put about 2 cu. cm. of sodium hydroxide solution and 1 or 2 drops of olive oil. Close the test tube with

your thumb or a cork, and shake it vigorously. What becomes of the oil? Half fill the test tube with water, and shake it again. Do you get a good suds? The oil and the alkali react to give a *soap*.

b. Dissolve 5 g. of sodium hydroxide in 35 g. of water, and put the solution in a clean "tin" can. Add 2 g. of lard; then carefully heat the mixture to boiling. Place a loose cover over the can, and do not allow the alkali to be spattered into your eyes.

Boil the mixture for about 20 minutes; then add to it 10 g. of salt in 3 portions. Stir the contents of the can, but do not look into it! After the salt is all in, boil the mixture for 10 minutes more; then let it cool thoroughly. The soap should separate out as a solid cake that floats upon the solution. Take it out, rinse it with water, and lay it on blotting paper or newspaper to dry.

c. Put a small piece of the soap you have made into a test tube, and shake it with some water. Does it make a good suds? Review Exercise 30, b.

Test the soap solution with red litmus paper. Is there a strong alkaline reaction, or not?

d. Shake together in a closed test tube about $\frac{1}{6}$ of a test tube full of linseed oil and half a test tube full of limewater. What is the appearance of the mixture? Do the materials separate easily when allowed to stand? What is an *emulsion*? See § 91, text.

EXERCISE 68

TESTING OF COTTON AND WOOL

Apparatus and Materials.—Glass or porcelain dishes, 10 per cent sodium hydroxide solution, white cotton cloth and thread, white woolen yarn, dilute sulphuric acid, mixed cloth, burner, beaker or "tin" can.

a. Soak a piece of new, white cotton cloth for 5 minutes in a 10 per cent solution of sodium hydroxide. Then take out the cotton, wash it free from the alkali, and dry it. Has the cotton been changed in any way? Treat a piece of white cotton thread in the same way; is the thread noticeably weaker, or not? What is the *mercerizing* process? See § 227, text.

b. Test the strength required to break a piece of white woolen yarn. Now soak it for 5 minutes in a 10 per cent sodium hydroxide solution, rinse out the alkali, and again test the strength of the yarn. Result? Do you think that a "strong" soap, that is, one containing much alkali, would be good for woolens?

c. Soak a piece of white cotton cloth in dilute sulphuric acid for 5 minutes. Dry it without rinsing; then rub it between your hands. What becomes of it? Do the same to a piece of white wool (flannel or yarn). Is it affected like the cotton?

d. Get a piece of *mixed* cloth, that is, one consisting of both cotton and wool. Soak it in dilute sulphuric acid, and dry it without rinsing. Rub it between the hands; what falls out? Which material is this?

e. Take another piece of the mixed cloth, and boil it for 5 minutes (Care! Do not let the alkali spatter into your eyes!) in a beaker or "tin" can with 10 cu. cm. of 10 per cent sodium hydroxide. This takes out the wool. What happens to the cloth's appearance? Rinse out the alkali, and dry the cotton. If you wished to get the exact proportion, by weight, of cotton and wool in a cloth, how would you proceed?

EXERCISE 69

DYEING

Apparatus and Materials.—Bottle or flask; beakers or dishes of porcelain or enameled ware; solutions of alum, lead acetate ("sugar of

lead"), and potassium dichromate; new, unbleached cotton cloth; white woolen yarn; cochineal (powdered) and picric acid. If the dyes are furnished in solution, less material will be wasted.

a. Into a bottle or flask put about half a teaspoonful of powdered cochineal and 100 cu. cm. of water. Shake the mixture from time to time during 10 minutes; then let it settle.

Prepare a **mordant** of *aluminum acetate* as follows:

To half a test tube full of lead acetate solution in a beaker or bottle add about 10 cu. cm. of alum solution. A white precipitate of *lead sulphate* is formed at once. Let this settle, and add more of the alum solution (about 1 cu. cm. at a time) until no more precipitate is formed. Let the precipitate settle completely; then pour the clear solution of aluminum acetate into another dish. Throw away the white precipitate.

b. From a piece of new, unbleached cotton cloth cut off 5 strips about 2.5 cm. (1 in.) wide and 10 cm. (4 in.) long. Wash the strips with soap and water, and rinse them.

Put 50 cu. cm. of the cochineal solution into a beaker or porcelain dish, heat it to gentle boiling, and leave a strip of the cotton cloth in it for 2 minutes. Remove the cloth, rinse it thoroughly, and let it dry. Is the color fast?

c. Soak the second piece of cloth in the aluminum acetate solution for 2 minutes, remove it, and let it dry for 5 minutes. Then boil it in the cochineal solution for 2 minutes. Remove the dyed cloth, rinse it thoroughly, and dry it. Is the color fast now, or not? Paste the cloth in your note book, and label it. Save the mordant for e.

d. Dissolve about 2 grams of picric acid in 20 cu. cm. of hot water; add 3 drops of dilute sulphuric acid. Put into the hot solution a piece of white woolen yarn and a strip of the cotton cloth. Heat the solution to boiling for 2 minutes; then remove the cloth and the yarn, and rinse them thoroughly. Which one is dyed permanently? Its color?

e. Soak a piece of the cotton cloth in the mordant of *a*; let it dry for 5 minutes; then boil it in the picric acid solution for 2 minutes. Rinse the cloth, and let it dry. Is the color fast now? Which material is dyed *directly* by picric acid? Which *indirectly*?

f. Boil a piece of the washed cotton cloth in a solution of sugar of lead (5 cu. cm.); then leave it for 2 minutes in a boiling solution of potassium dichromate. Rinse the cloth, and let it dry. What is the result?

Paste all the dyed materials in your note book, giving them the proper labels.

EXERCISE 70

BLEACHING

Apparatus and Materials.—Bleaching powder, hydrochloric acid, colored cheesecloth or mosquito netting, unbleached muslin, ink, glass or porcelain dishes (beakers or cups).

a. Make a bleaching solution out of about 5 cu. cm. (a teaspoonful) of bleaching powder (chloride of lime) and 100 cu. cm. of water. Stir this for 5 minutes; then either filter it or pour off the clear solution. Note the odor of bleaching powder and of its solution.

Get ready also some rather dilute hydrochloric acid (5 cu. cm. of concentrated acid and 50 cu. cm. of water).

b. Into the bleaching powder solution put a small piece of cheap, colored cheesecloth or mosquito netting (use pink, green, or blue, if possible). Let it remain in the solution for 2 minutes, and note whether the color is altered. Now take the colored material out of the bleaching powder solution and dip it into the dilute hydrochloric acid. How does this affect the color? If the color is still unchanged, try dipping the cloth once more into the first solution and leaving it a longer time before you put it into the dilute hydrochloric acid. Give the results.

c. Get a piece of new, unbleached muslin. What is its color? Why has it a color? Try to remove the color by means of bleaching powder solution and dilute hydrochloric acid, as you used these in *b*. Finally rinse the muslin thoroughly, and let it dry. What is the result?

d. Make an ink spot on a piece of white muslin. Try to remove the spot by soaking it first in bleaching powder solution and then in dilute hydrochloric acid. What are "ink eradicators"?

Would it be a good plan to try to remove ink from a *colored* fabric by means of bleaching powder solution and dilute hydrochloric acid? Tell why.

EXERCISE 71

HOW TO REMOVE STAINS

Apparatus and Materials.— Piece of black cloth, candle or lard, benzine or gasoline, blotting paper, white cloth, rusty iron, hydrochloric acid, white paint, grass or leaf, alcohol.

a. Make a spot, with candle grease or lard, on a piece of black goods. Remove it by putting a few drops of benzine or gasoline on the spot and rubbing it with a black cloth. A piece of clean blotting paper or a pad of cloth may be placed under the spot to absorb the liquid and the grease it has dissolved. Try the operation more than once, if necessary.

b. Rub a white cloth with a rusty can or nail until you get a decided stain. You can get a still deeper stain by putting a drop of ferrous sulphate (copperas) solution on the cloth and letting it dry. Soak the stain in dilute hydrochloric acid (5 cu. cm. of concentrated acid to 50 cu. cm. of water) for about 5 minutes; then rinse it thoroughly with water. If the stain is not removed, try a second time.

In the household, lemon juice and salt are used to remove rust stains. This mixture acts like dilute hydrochloric acid.

c. With white paint make a small spot on some black goods. To remove the paint spot soak it in a teaspoonful of gasoline or benzine. These liquids dissolve the linseed oil of the paint (*cf.* § 229, text). Let the cloth dry; then brush off the white powder that remains. What is the powder?

d. With grass or some other green plant make a stain on white muslin. Soak the stain in a little alcohol, and rub the spot with a clean white cloth. Result?

EXERCISE 72

PLUMBING

Apparatus and Materials.—Sample or demonstration faucets, plumbing trap, piece of old lead pipe or trap.

a. Examine Fig. 28. If you were closing the “compression” faucet, would the water pressure in the pipe help to close the

FIG. 28

The faucet on the left is a **Compression** faucet, the one on the right, a **Fuller** faucet. Both are cut open so that we can see how they work. Courtesy of the Central Scientific Company, Chicago.

faucet, or would you have to overcome the water pressure? Which would be the case with the “Fuller” faucet? What simple machines are used in the opening and closing of these two faucets?

If there is no sample faucet at school, get some one at home, or a plumber, to take a faucet apart for you and to show you how it works. Which of the two in the figure does it resemble? When a faucet leaks, so that you cannot cut off the water, what part is usually out of order? Which is the more likely to get out of order, the cold-water faucet or the hot-water one? Why?

b. Examine a "trap." Make a drawing showing how the trap would look if cut lengthwise. Is the trap like that shown in Fig. 200, § 236, of the text? If not, how does it differ?

If a trap is stopped up, how should you clean it? How does a trap form a "water seal"? Why is a water seal necessary? Suppose that strings and hair collect in a trap, so that they extend over the bend shown on the right of Fig. 200 (the text), would they be likely, or not, to carry away the water of the trap? See Fig. 25, § 32, text. Why should such materials not be allowed to accumulate in a trap?

c. Examine an old piece of lead pipe, such as an old trap. Is there any evidence of its having been worn thin? What wore it thin? If grease is deposited in a trap attached to a kitchen sink, what could be used to "cut" the grease? Why should the cutting substance not be left standing in a lead trap for a long time?

EXERCISE 73

FLAMES

Apparatus and Materials.—Iron spoon, burner, candle, glass tube about 10 cm. long, kerosene lamp, matches; materials for an alcohol lamp, if needed (see e).

a. Hold an iron spoon in the luminous flame of a burner or candle. What happens? Where does the soot come from? What is soot?

Hold the sooty spoon in a colorless Bunsen flame. What happens? Why? What substance is present in excess in the luminous flame? In the non-luminous Bunsen flame?

b. Take a piece of glass tubing about 10 cm. (4 in.) long, and hold it at an angle of about 45 degrees, with the lower end of the tube in the central part of a large candle flame. Apply a lighted match at the upper end of the tube. Can you get a gas to burn there? Try the same experiment with a luminous gas flame. Are the gases in the central part of the candle and gas flames burning?

c. After a candle has been burning for some time, blow out the flame. At once apply a lighted match above the wick but not touching it. Can you relight the candle? Try the experiment again to find out how far from the wick you can hold the match and still relight the flame. How does this experiment show that a candle flame is really a burning gas?

If possible, try the same experiment with a kerosene lamp. Results? Why does a kerosene lamp give off such a strong odor after you have blown out the flame?

d. In the center of a luminous gas flame hold the head of a match. Does the head take fire? What does this show as to the interior of the gas flame? Try the same experiment with a large candle flame.

e. An alcohol lamp can be made, if you need one, out of an empty library-paste jar (Fig. 29). You can buy a round wick, or you can make one out of calking twine or darning cotton.

FIG. 29

EXERCISE 74

GAS AND ELECTRIC METERS

Apparatus.— Home meters for gas and electricity, fuse box.

a. On the left half of a page of your note book make 5 neat pencil copies of the gas meter shown in Fig. 212, § 256, of the text. Do not, however, put in the “hands” of the meters until they are called for. On your first drawing put in the hands just as you find them on your home meter. If the upper circle of your meter is intended to read only to 2 cu. ft., change your drawings accordingly. On the right half of the page, opposite the first meter, write down in figures the reading of the meter and the date on which the reading was made.

b. Exactly one week after the first reading take a second one, putting in the hands of your second drawing. Opposite the drawing put in the date, the reading, and the difference between the first and second readings. Continue making the readings for 4 weeks.

What was the total gas consumption for the 4 weeks? What was the average for a week? What was the cost of the gas for the 4 weeks?

c. Find the key or lever by which the gas supply can be cut off so that it cannot go through the meter. How could you prevent gas from escaping if a pipe should burst somewhere in the house?

d. In the same way as in *a*, but on another page, draw 5 copies of the kilowatt-hour meter. See Fig. 215, § 259, of the text. Take 5 readings, just a week apart, and mark the positions of the hands on the dials. Date each drawing, write down the readings in figures, and give the differences between successive readings.

How much electric energy did your family use each week? What was the total? The average for a week? What was the total cost?

e. Examine the fuse box in your house, and tell how it is constructed. Find out how you could cut off the current entirely if you wished to.

EXERCISE 75

HOW HEATING THE AIR CHANGES ITS DENSITY

Apparatus and Materials.—Balances, flask holding about 100 to 200 cu. cm., string, weights or shot, Bunsen burner.

a. By means of a string having a loop at one end suspend a clean, dry flask from one arm of a balance. Into the pan attached to the other arm put weights or shot, enough to balance the flask. Now remove the flask and heat it by turning it rapidly in a Bunsen flame; then put it back in its place on the balance. What is the result?

Let the flask hang until it becomes cool; what happens? What evidence have you that hot air is lighter, that is, has a lower density, than cool air?

EXERCISE 76

THE DEW POINT

Apparatus and Materials.—Metal beaker or bright metal (aluminum or tin) cup, thermometer, large bottle with small mouth, bits of ice.

a. Use a simple dew-point apparatus, such as is shown in Fig. 217, § 267, of the text. The metal beaker may be a bright aluminum or tin cup. Have the cup $\frac{3}{4}$ full of water at the room temperature; then add bits of ice or snow, stirring vigorously with the thermometer until the first drops of dew are deposited on the cup. Now get the thermometer reading at once, and record it. To repeat the trial take out any ice that remains, and let the water become just warm enough to permit the dew to evaporate. Then add another bit of ice, and stir with the

thermometer until dew is deposited. Get the thermometer reading; is it the same as before?

b. If air is saturated with water vapor, and we lower its temperature, even slightly, we cause a fog to be formed. One way by which we can cool air is to cause it to expand. The experiment is carried out by pouring water in spurts (*cf.* Exercise 1) from a large bottle that has a small mouth. Half fill such a bottle with water, and invert it over a pail or sink. Notice that as a spurt of water falls out, and the air inside is slightly expanded, a cloud or fog is formed, but that as soon as an air bubble enters, and the air in the bottle is again at the ordinary pressure, the fog disappears.

How does this experiment explain the formation of clouds in rising currents of air?

EXERCISE 77

WEATHER RECORDS

Apparatus and Materials.—Weather reports, or thermometer, barometer, rain gauge, and weather vane; if possible, an anemometer.

a. Keep a weather record for at least two weeks, putting down your observations under the heads given below. For the temperature you can use your home thermometer or the one at school. For the barometer height inquire each day at school, or get it from the daily weather report in your local newspaper. You will need to depend on some one with a rain gauge, or on the weather report, for the amount of precipitation; you yourself can tell whether it is rain or snow.

You can also tell the direction of the wind. Judge of its velocity according to the table given in § 274 of the text. Describe the clouds as in § 269 of the text. Make your own readings, twice a day if possible: first in the forenoon, and again in the afternoon.

Date	Hour	Temperature	Barometer Height	Direction of Wind	Velocity of Wind	Kind of Clouds	Amt. of Precipitation	Rain or Snow

EXERCISE 78

WEATHER MAPS

Material.— Weather map.

a. Get a weather map from the Weather Bureau. Paste it in your note book. What is the lowest pressure shown on the map? The highest? Where are the “lows” of the map, that is, in what states? The “highs”?

b. What is the difference in pressure, in inches, between two successive *isobars* (lines of equal pressure)? What happens when the isobars are close together? See § 274 of the text.

Are there any lines of equal temperature (isotherms) on the map? For what temperatures are they given? Why are they so irregular?

EXERCISE 79

KINDS OF ROCKS

Apparatus and Materials.— Pocket knife, cent, triangular steel file; the substances named in *a*; hydrochloric acid.

a. Examine a piece of each of the following materials: sandstone, marble, limestone, rock salt, soft coal, hard coal, shale, conglomerate, quartz, feldspar, granite, glass, soapstone, slate, brick, pumice, concrete, gypsum.

What is the color of each? Is the material all of one color, or of different colors? Which substances are crystalline? See § 69 of text. "Heft" each substance to determine whether it is dense or light.

b. Try to *scratch* each substance, with—

1. Your finger nail.
2. A cent piece.
3. A knife blade.
4. A triangular steel file.

Which of the substances scratch glass?

c. On the surface of each piece put a drop of hydrochloric acid (1 cu. cm. of the concentrated acid to 3 cu. cm. of water). Do any of them *effervesce*; that is, get *frothy* and give off tiny bubbles of gas?

How can you distinguish rock salt from all the others?

d. Classify your results under the following heads:

Material	Color	Crystalline or not	Dense or Light	Hard or Soft	Does it React with Acid?

EXERCISE 80

CONCRETE

Apparatus and Materials.— Tin can (tomato can), measuring cup, wooden paddle or iron spoon, block for "tamp," pasteboard box (small), cement, sand, and gravel.

a. Measure out $\frac{1}{4}$ of a cupful of fresh, powdered cement, $\frac{1}{2}$ of a cupful of fine, sharp sand, and a cupful of rather fine gravel (stones about $\frac{1}{2}$ the size of a coffee bean). Do the mixing in a quart tin can (tomato can); for the stirring use a wooden paddle or an iron spoon. First put in the sand; then add the cement, and stir the two together. Wet the gravel, and mix it with the sand and cement, adding water little by little, so as to form a thick, "mushy" mixture. Finally pack the mixture (use a block for a "tamp") into a small pasteboard box; have the top of the mixture just below the top of the box.

b. Make a finishing coat for the concrete out of about $\frac{1}{6}$ of a cupful of cement and $\frac{1}{4}$ of a cupful of fine sand. Put these into the empty can, mix them with enough water to form a paste, and spread the paste evenly over the concrete. Use a flat block or a kitchen knife for a trowel.

Cover the concrete loosely with paper, and set it aside for 3 or 4 days to harden. Note its appearance from day to day. What is its color when hard? Finally remove the cover, expose the concrete to the light, and wet its surface once or twice a day. What is the effect of this treatment upon the color of the concrete?

c. What advantage has concrete over flagstones for use in sidewalks? Over bricks? What is reinforced concrete?

The mixture described in *a* is called a 1, 2, 4 mixture; why?

EXERCISE 81

ORE TESTS

Apparatus and Materials.— Pieces of pyrite (iron pyrites), hematite, galena, and copper ore; magnet or magnetized knife blade; piece of charcoal or of soft earthenware, such as a piece of a flower pot; mouth blowpipe; Bunsen burner or alcohol lamp.

NOTE.—Dr. J. C. Foye, in his "Handbook of Mineralogy," tells how to make a home-made mouth blowpipe out of a clay pipe (Fig. 30, this manual).

FIG. 30
A Home-Made Mouth
Blowpipe.

His method is given in modified form. A piece of pipe stem about 5 cm. (2 in.) long is broken off, and the hole in the smaller end is filled for a distance of about 1 cm. with putty. A fine needle is pushed through the putty. The closed end of the pipe stem is heated in a Bunsen flame until the putty is hard; the needle is then pulled out. There remains a small, smooth hole.

The piece of pipe stem is fastened to the bowl of the pipe by means of plaster of Paris. Cut out of cardboard a circle that will just go into the bowl of the pipe, make a hole in the center, and push the piece of pipe stem through the hole. Push the cardboard into the bowl, having the prepared "tip" outward, and fill the bowl, above the cardboard, with a thick paste of plaster of Paris and water. When the plaster of Paris has "set," the blowpipe is ready for use.

a. Test the pieces of pyrite and hematite with a magnet. Are they attracted?

b. Break a small piece of pyrite into powder, and heat it on charcoal, or on a piece of soft earthenware, in a blowpipe flame. The method is as follows:

With a pocket knife hollow out a depression near one end of the piece of charcoal, and put the powdered pyrite into it. To make the blowpipe flame we use a luminous gas flame about 4 cm. (1.5 in.) high. Hold the charcoal in your left hand, and the blowpipe in your right. Place the tip of the blowpipe just at the outer edge of the flame at its middle part, and blow a steady stream of air against the flame. Have the tip turned slightly downward, so that the flame produced will be forced down upon the pyrite. Hold the pyrite so that it will be at about the middle of the long blowpipe flame. In using the blowpipe, breathe regularly through your nostrils; your puffed-out cheeks should

serve as bellows. Do not blow in jerky breaths. With a little practice you will be able to produce a steady, hot flame.

You can use the blowpipe with an alcohol lamp, if you have no gas. Put into the alcohol $\frac{1}{10}$ of its volume of turpentine.

c. After you have heated the pyrite for a minute, smell of it. Can you perceive the odor of burning sulphur? What element must pyrite contain?

Continue heating the pyrite for several minutes in the blowpipe flame; then let it cool, and test it with a magnet. Is it attracted? What element, besides sulphur, is present in pyrite? Read § 137, text.

d. Rub some hematite on white paper; what color has its "streak"?

Heat powdered hematite in the blowpipe flame, as you did pyrite. Is any odor of burning sulphur given off? Is the material that remains magnetic? What metal is present in hematite?

e. Examine a piece of galena and describe it. Break off some pieces; what shape do they seem to have?

Heat powdered galena on charcoal in the blowpipe flame, as you did pyrite. Do you get the odor of burning sulphur? Heat the galena steadily for some minutes; what happens? Let the product cool and try to cut it with a pocket knife. What substance is it? What elements are present in galena?

f. What is the color of the copper ore? Break off a little, powder it, and mix it with an equal volume of dry washing soda. Heat the mixture in the blowpipe flame. Cut out the mass on the charcoal, break it up finely, and put it into a white dish. With water wash away the excess of soda, charcoal, and unchanged ore. Do you find any heavy material that looks like copper?

EXERCISE 82

KINDS OF SOIL

Apparatus and Materials.— Drinking glasses or bottles, teaspoon, gravel, sand, clay, and black loam.

a. Get samples of 4 kinds of soil: gravel, sand, clay, and loam. Get as dark a loam as possible.

Crush each sample of soil with your hands, and rub it between the tips of your fingers. Which is made up of the largest particles? Which of the smallest?

b. Wet a teaspoonful of each kind of soil; then work it between the fingers. Which soil sticks together best? Which crumbles most easily?

c. Put a heaping teaspoonful of the gravel into a drinking glass half-full of water. Stir the water thoroughly, let it settle one minute, then pour off the liquid into another dish. To the gravel that remains in the glass add as much water as you poured off, and stir the water again. Let the liquid settle for one minute; then pour off the water. Write down your results.

d. Treat each of the other kinds of soil with water, as you did the gravel, and record all the results.

Does much or little material settle out from the water that is poured off? Which soil settles least in the minute given it? Which most? Describe the materials left after the second stirring with water.

EXERCISE 83

SOIL TESTS

Apparatus and Materials.— Black loam, white sand, filter paper, funnel, porcelain or "tin" evaporating dish, burner, beaker or flask, test tube, dilute hydrochloric acid, 2 saucers, thermometer.

a. Soluble Matter in Soil.— Get a filter paper and a funnel ready for use (see § 84, text). Nearly fill the filter paper with black loam, packing the soil in as tightly as you can. Pour through the soil 100 cu. cm. of boiling water, about 5 cu. cm. (a teaspoonful) at a time. Catch the filtrate, and evaporate it in a clean porcelain or tin dish over a can of boiling water. Describe the material that remains after evaporation.

b. Organic Matter in Soil.— Put into your iron dish the soil that is left in the funnel, and heat the dish. Heat gently at first, so as to dry the soil; finally heat it as hot as you can. Note how the color of the soil is changed by the heating. What caused the dark color? Why does it disappear?

c. Put a teaspoonful of fresh loam into a beaker or flask, shake or stir it up with about 50 cu. cm. of water, and pour off the turbid liquid. Do this twice more. To the soil that remains add a test tube full of dilute hydrochloric acid. Boil the mixture gently for about 10 minutes.

What is the appearance of the substance that is left? What is the advantage of having this substance in soil? Can you suggest what materials may have been taken out of the soil by means of the hydrochloric acid? See § 217, text.

d. Soil Absorbs Heat.— Fill one saucer with dark, black loam and another with white sand. Make sure that the two have the same temperature; then expose them both to bright sunlight. After 10 minutes take the temperature of each. Is one warmer than the other? Which one? Why?

EXERCISE 84

HOW SOILS TAKE UP THE RAIN

Apparatus and Materials.— Vinegar or ketchup bottle with bottom removed, fruit jar, measuring cup, Bunsen burner, piece of muslin, string, gravel, sand, loam, and clay; watch or clock.

a. Prepare a bottle and a fruit jar as shown in Fig. 31, this manual. One way to break off the bottom of the bottle is to drop a metal rod, such as a solid metal curtain rod or a straight

FIG. 31

poker, through the mouth of the bottle. Another way is to hold the bottle horizontal and rotate it over a small, but hot, Bunsen flame, so that it will be heated in a circle parallel to the bottom. Then plunge the bottle into cold water; the bottom will usually break off. Close the mouth of the bottle by tying a piece of muslin over it.

b. Tie a string tightly around the bottle, about 5 cm. (2 in.) from the broken end. This serves as a mark. Fill the bottle to the mark with small gravel. Shake the material, and press it down, but do not make it too compact. Then set the bottle in the fruit jar.

Pour upon the gravel just a cupful of water. Do not add the water all at once, but pour it upon the upper surface just as fast as the gravel can absorb it. Note the time when you add the first water; then find out just how long it takes for the water to begin to drip from the mouth of the bottle.

c. Empty out the gravel, and fill the bottle to the same mark with fine sand. Add the cupful of water as before, and take the time.

d. Repeat the experiment of *b* with loam; then with clay. Give all the results? What causes the difference in results?

Which soil allows water to pass through it most rapidly? Which least rapidly? Which soil would be the most likely to have water standing on it after a rain? Which would be the least likely?

EXERCISE 85

CONTENTS OF A FERTILE SOIL

Apparatus and Materials.— Three one-quart flower pots, clay, sand, garden soil (loam), ammonium nitrate, potassium chloride, powdered rock phosphate or bone meal, 3 glass covers, oats.

a. Into each of 3 one-quart flower pots put a layer of clay 2.5 cm. (1 in.) deep. Fill the first pot with good garden soil, the second with clean sand; for the third make the following mixture: a scant pot full of clean sand, half a teaspoonful of ammonium nitrate, $\frac{1}{4}$ of a teaspoonful of potassium chloride, a tablespoonful of powdered rock phosphate or bone meal. Mix these materials thoroughly, and fill the third pot with the mixture. Label the third pot.

b. Provide each flower pot with a glass cover. Soak some oats over night (not longer) in water; then plant 16 of the soaked seeds in each pot, about $\frac{3}{4}$ of an inch below the surface. Put down the date of planting.

Cover the pots with the glass covers, and set them in diffused light (not direct sunlight) in a warm room. Keep the soil moist but not soggy. Note how long it takes for the seeds to sprout (record the date); then remove the covers, set the young plants in the sunlight, and watch their growth from day to day for several weeks.

c. Do all the seeds sprout? In which pot do the seedlings grow most rapidly? What necessary plant food is supplied by each of the 3 materials mixed with the sand of the third pot? Does garden soil contain these plant foods?

EXERCISE 86

HOW MOISTURE IS TAKEN UP BY PLANTS

Apparatus and Materials.— Egg, napkin ring or wide-mouth bottle, glass tubing 7 cm. long, candle, iron wire (thick hair pin), hat pin, egg

cup or small glass, small potted plant (see *e*), glass tube, rubber tube or adhesive tape.

a. In this exercise we are to study the phenomenon called *osmosis*, or the passing (diffusion) of water and dilute solutions through thin membranes. In this way the dilute soil solution enters the root hairs of the plant. We can study osmosis most easily by the use of an egg (Fig. 32).

FIG. 32

Tap the large end of an egg so as to crack the shell; then pick off the shell, bit by bit, from an area about as large as a cent. Be very careful not to break the thin membrane ("skin") inside the shell. Crack the small end also, but do not remove the shell from an area more than 1 or 2 mm. in diameter. Stand the egg in a napkin ring, or in the mouth of a bottle, so that the smaller end is upright.

b. Select a piece of glass tubing about 7 cm. (3 in.) long. From one end of a candle cut off, by means of a hot piece of iron wire (a thick hair pin will do), a round piece about 6 mm. ($\frac{1}{4}$ of an inch) thick. Take out the wick, and with the heated wire enlarge the wick hole so that the glass tubing can just be pushed in. Use the iron wire (reheat it when necessary) as a "soldering iron" to fasten the edge of the wax securely to the glass. See that the opening of the glass tube is not closed with wax.

Now hold the glass tube so that the piece of wax is against the small end of the egg, and so that the hole in the glass tube is just over the opening in the shell. With the heated wire melt some of the wax, and fasten the lower edge of the wax securely against the egg shell.

c. Push a hat pin through the glass tube, and thus break the skin in the small end of the egg. Put the egg in an egg cup or

small glass (Fig. 32), adding water enough to rise a third of the height of the egg. Then set the apparatus aside, and examine it from time to time. Observe it after an hour or two, if possible.

d. What do you observe in the glass tube? How does this show that water passes through the skin at the larger end of the egg? If water were free to enter through ordinary holes in the skin of the egg, would anything rise into the glass tube?

e. A small potted plant, such as a geranium, or some plant out of doors, may be cut off about 5 cm. above the ground, and a glass tube may be fastened to it by means of a rubber tube or by adhesive tape (Fig. 33, this manual). The glass tube should be filled with water to the top of the tape or rubber. If the plant is kept watered, sap will rise into the glass tube.

FIG. 33

If possible, try the experiment, and note how high the liquid will go.

FIG. 34

EXERCISE 87

PLANTS GIVE OFF MOISTURE

Apparatus and Materials.—Plant, cardboard, knife or shears, paraffin (white wax), cloth or brush, large tumbler or fruit jar.

a. Select a thrifty plant, such as a geranium, growing in a pot, and water it thoroughly (Fig. 34). Cut out a piece of cardboard larger than the top of the pot; in it make a round hole that will just fit the stem of the

plant. Also cut a slit from the edge of the cardboard to the central hole.

Use a piece of cloth, or a small brush, to "paint" the cardboard with melted paraffin, so that it will be water-tight; then slip the cardboard around the stem of the plant and over the pot. Close the slit in the cardboard with melted wax, and pack some of the soft, but not hot, wax around the stem.

b. Over the plant put a large tumbler or a glass fruit jar, and set the plant in bright sunlight. Look at the jar from time to time. Can you see a deposit of water inside it? What part of the plant gives off the water? Why does a potted plant need to be watered frequently?

EXERCISE 88

SEEDS AND THEIR GERMINATION

Apparatus and Materials.— Germination box, or "flat," good soil, pocket knife, garden beans, lima beans, scarlet runner beans, castor

FIG. 35

beans, squash seeds, peas, corn, radish seeds, red clover seeds, some other seeds.

a. Make a germination box like that shown in Fig. 35. The box should be about 10 cm. (4 in.) deep, 50 cm. (20 in.) wide, and 60 cm. (24 in.) long, all inside measure. The squares will then be 5 cm. (2 in.) on a side.

The squares are marked off by thread held in place by tacks that are driven into the sides of the box. The figures may be

made, in ink, on the edges of the box. In the figure, square No. 1 is in the lower right-hand corner; No. 10 is in the upper, right-hand corner; No. 120 is in the upper, left-hand corner. Fill the box with good garden soil (loam); pack it down gently.

b. Soak in water over night (not longer) 14 garden beans, 14 lima beans, 14 scarlet runner beans, 14 castor beans, 14 squash seeds, 14 peas, and 14 grains of corn. Plant one seed in each square, in a hole made with a small stick (pencil), and about 1 in. deep. Put 12 beans in the first (lower) row of holes, 12 lima beans in the second row, and so on. Save the 2 remaining soaked seeds of each kind for *e*. Label each row of seeds carefully, giving the date of planting.

In row 8 from the bottom plant 12 radish seeds; in row 9, 12 red clover seeds; in row 10 any seeds you wish.

Water the soil moderately, but do not soak it. Keep the box in a sunny window of a warm room. Now proceed with *e*.

c. After 2 or 3 days, begin to excavate carefully around the seeds in squares 1 to 10 (the first vertical row on the right-hand side). If any of the seeds have germinated, take them out and examine them carefully. Study §§ 307 and 308, text.

You will need to keep a careful record. For this purpose rule two opposite pages of your note book, together, into 120 squares like those of the germination box. In each square make note of the time when you examined the seed in the square, and the condition of each seed part; that is, the testa, cotyledons, plumule, and hypocotyl.

d. After the seeds of each kind begin to germinate, remove one each day for 6 days, or until each seedling has grown definitely out of the ground. Leave the remaining seedlings to grow more fully. Observe them every day, and save them for further study in Exercises 90, 91, and 93.

In which of the plants that have 2 large cotyledons do the cotyledons come above ground? In which do they become

green? In which do they remain attached? Describe all the changes that the cotyledons undergo. Why do they change?

e. Examine the soaked seeds of *b* that were not planted. How is the testa of each affected by the soaking? Look for the scar (hilum) showing the place at which the seed was attached. With a knife cut through the testa; do it carefully, so as not to mutilate the plumule or the hypocotyl. In the beans you can cut on the curved edge. Pick off the testa, and spread the cotyledons apart. Describe what you find in each case.

In the corn look for the single cotyledon. After removing the testa cut through the kernel lengthwise, at right angles with the flat surfaces. Describe all you find.

EXERCISE 89

MATERIALS PRESENT IN PLANTS

Apparatus and Materials.—Scissors or a knife, bottle, saucer or evaporating dish, iron dish, glass cover, burner, test tube, white writing paper, grass or other green leaves, alcohol, slaked lime or soda-lime, flour, starch, iodine solution, corn meal, potato, radish, lard or linseed oil, benzine, ground flax seed.

a. Chlorophyll.—With scissors or a knife cut up very finely a handful of grass, spinach, parsley, or other green leaves. If you have a mortar and pestle, you can crush the material also. Put the material into a bottle, and cover it with alcohol. Let the bottle stand, stoppered, for an hour or two, and note the colored solution that is produced.

Pour out a few cubic centimeters of the solution into a saucer, and let the alcohol evaporate without heating it. Note the green chlorophyll that remains. If you wished to prepare a green “ice,” how could you get a harmless coloring material?

b. Nitrogen.—Thoroughly mix about a test tube full of fine grass cuttings with half a test tube full of slaked lime. Soda-lime is still better; use it if you can. Put the mixture into your iron dish. Cover the dish with a clean piece of glass on the under side of which you have pasted a piece of wet, red litmus paper. Heat the dish carefully; does the litmus change color? If so, ammonia is being given off. Can you get its odor? If ammonia is given off, the grass must contain *nitrogen* (*cf.* § 112, text).

Try the same test with flour instead of with grass. Use equal volumes of flour and lime (or soda-lime). What are the results? Does flour contain nitrogen?

c. Starch.—Cook a pinch of laundry starch with half a test tube full of water. Pour the liquid out into a white saucer or evaporating dish to cool; then add a drop of iodine solution (a small crystal of iodine dissolved in 5 cu. cm. of a dilute solution of potassium iodide). What happens? This is a *test* for starch.

Try the experiment with a pinch of flour instead of starch. Try it again with corn meal; also with scrapings from the freshly cut surface of a potato. Try it with the scrapings from a radish, parsnip, or sweet potato. Give all the results.

d. Fat.—Put a speck of lard or linseed oil on a piece of clean, white writing paper; then wipe off the lard or oil, and hold the paper between you and the light. What do you see?

Put a drop of benzine on the paper, and hold the paper to the light. Does benzine produce a permanent stain on the paper?

Put a small heap of corn meal on the paper and wet the meal with benzine. After 3 or 4 minutes remove the meal, and let the benzine evaporate. Is there a stain? Do the same with ground flax seed. Result? Is fat present in the seeds of corn and of flax?

EXERCISE 90

STUDY OF LEAVES

Apparatus and Materials.— Different kinds of leaves, 2-quart and 1-quart glass fruit jars, bottle, marble, dilute hydrochloric acid, pan and pail of water, parsley or spinach, test tube, pine splinter.

a. Get together at least 15 kinds of leaves in addition to those on the seedlings of Exercise 88. Get leaves of trees and weeds as well as of garden plants; be sure to know the name of the plant to which each leaf belongs. Include in your list, if possible, the leaf of the apple tree, of red and white clover, of the maple, and of the black locust.

Study § 309, of the text, for some of the differences between leaves. Do any of the leaves you have brought have stipules? Have all of them petioles? Which leaves are deeply indented? Which ones are compound, that is, broken into *leaflets*? What is the kind of veining in each leaf?

Have you found any plants with tendrils? If possible, get a leaf of Boston ivy and some of the suckers by which it clings.

b. Classify the facts learned in *a* under the following heads:

Name of Leaf	Simple or Compound	How Indented	Has It Stipules?	Petiole?	Color and Shade	Veining	Shape

c. The Work of Leaves.— Half fill a 2-quart fruit jar with water, and hold over the mouth of it a bottle in which you are generating carbon dioxide from marble and dilute hydro-

chloric acid (see Exercise 40). Pour the gas into the fruit jar, but do not pour over any of the liquid (see Exercise 15). From time to time close the mouth of the fruit jar with your hand, or with the cover belonging to the jar, and shake the jar vigorously, so as to make the gas dissolve in the water.

Fill a quart fruit jar (see Fig. 235, § 310, text) loosely with parsley or spinach; then add the carbon dioxide water to overflowing. Invert the jar (do not let any air bubbles enter) in a pan of the carbon dioxide water. Let the bottle stand in bright sunlight for two days, if possible. Do gas bubbles collect over the water?

Transfer the gas, under water (see Fig. 78, § 102, of text), to a test tube filled with water and inverted in the water. If the gas does not fill the test tube, close the mouth of the test tube, under water, with your thumb; then remove the test tube and invert it. Test the gas with a glowing splinter. What is the gas? What change did the leaves bring about?

EXERCISE 91

STEMS

Apparatus and Materials.—Pocket knife, pocket magnifier; young twig and older stem of lilac, box elder, oak, poplar, cherry, elm; corn-stalk, handle of palm leaf fan or a palm leaf; a potato, also one that has sprouted in the dark; rhubarb stalk; red ink.

a. Read §§ 312, 313, 314, and 315, text. Examine the young twig and an older stem of a lilac. Describe the color and appearance of the bark. Look for marks of any kind. Where are the *nodes*? Can you find the scars of leaves of other years? How are they arranged? How are the buds related to the leaf scars? Do the buds go singly, or in pairs? How is one set of buds arranged with respect to the next set? Is it directly above it?

Cut across a bud, and describe what you see. Has your twig a growing tip? Describe it.

b. Make a smooth cut across the young twig and the older stem. If you need to saw the stem, polish the sawed surface with fine sandpaper, so that you can see the markings plainly. Also cut a small piece of the lilac twig lengthwise.

Examine the cut surfaces carefully; if possible, use a magnifier (*cf.* Exercise 51, c). Compare the cross section of the lilac stem with Fig. 238, *a*, of the text. Are the two exactly alike? Identify the *epidermis*, *cortex*, *woody bundles*, and *pith*. Also find the *pith rays* and *annual rings*.

c. Study a young twig and an older branch of the box elder as you did the lilac. What resemblances? What differences?

Do the same with one of the following: oak, poplar, cherry, or elm.

d. Examine a piece of a last year's cornstalk; it should contain a node. Cut off the end smoothly, and examine the cross section. Does the cornstalk have its materials arranged in concentric circles, as the other stems have? Note that the interior is pith, with woody (fibro-vascular) bundles scattered through it. Draw a cross-sectional view of it.

Cut the cornstalk lengthwise, so that you can follow the course of some of these bundles.

If possible, cut or saw across the handle of a palm leaf fan, or of a palm leaf itself. Does the cross section resemble the corn, or the lilac?

e. Examine a potato that is sprouting, or ready to sprout. Find the "eyes." What evidence is there that the scales are imperfect leaves? Do the potato buds arise in the axils of the leaves? How much of the potato must be planted in order that a new potato plant may be formed?

Note the color of the leaves of a potato that has sprouted in the dark; why are they so? Bring the potato into bright sunlight for a few hours; what change takes place?

f. Cut off a small slice from one end of a potato, and set the potato with its cut end in a shallow dish (saucer) containing water. After an hour color the water with red ink, and allow the potato to remain in the dish for 3 or 4 hours. Finally cut the potato open lengthwise. How high has the red color risen? Has it risen through the whole of the potato, or along certain lines? What are these lines?

Cut off slices (cross sections) from the potato, beginning at the end that was farthest from the colored water. What evidence do you get that the water rose into the potato?

g. Carry out the same experiment as in *f*, using a stalk of rhubarb with the leaf attached. First cut off a piece from the lower edge of the stalk. Can you see the ends of the woody bundles? Now put the stalk, first, into water, then into colored water, and leave it some hours, or over night. Cut off slices from the stalk at various places. What is the appearance of the ends of the woody bundles? See if the colored water has gone into the leaf. Is the rhubarb a monocotyl or a dicotyl?

You can use the weeds plantain, burdock, and lamb's-quarters as well as rhubarb for this experiment.

EXERCISE 92

WOOD

Apparatus and Materials.—Sandpaper, carpenter's plane (?), "tin" can; several kinds of wood, wire nail, hammer, paint, shellac, burnt umber, linseed oil, turpentine, a cloth, and a paint brush.

a. With sandpaper smooth the surfaces of blocks or boards of oak (plain-sawed and quarter-sawed), whitewood, white pine, Georgia pine, and hemlock. If the ends are rough, smooth them first with a plane (or have a carpenter do it); then use the sandpaper.

Describe the appearance of the ends, faces, and edges of each block or board. How do the two kinds of oak differ in appearance?

Try to drive a wire nail into each of the boards, about 1 cm. (half an inch) from the end; which kinds split most easily? Suggest why.

b. Get a smooth piece of Georgia pine, or of yellow pine, that has a knot passing through it. Describe the appearance of the knot and of the wood around it. What is a knot?

Paint one side of the board, both the knot and the wood around it. Cover the knot on the other side of the board with shellac; after a few minutes paint over both the knot and the wood. Let the paint dry thoroughly for a day or two; then examine the two sides of the board. What is the difference in their appearance? Is there any good reason why knots in a board should be covered with shellac before painting it?

c. Put a piece of knotty yellow pine or hemlock in hot sunlight or near a hot radiator or stove. What happens to the knots? Describe the odor produced; what causes it?

d. Make some brown stain by mixing $\frac{1}{4}$ of a teaspoonful of burnt umber with 2 teaspoonfuls of linseed oil, and then adding about $\frac{1}{6}$ of a cupful of turpentine. The materials may be mixed in a "tin" can; the stain should be kept in a stoppered bottle.

Apply the stain with a cloth or brush to one face and the smoothed end of each of your blocks of wood. Let the stain remain on the wood for 5 minutes; then wipe it off with a cloth. After the stain has entirely dried, examine the blocks. Which were stained most deeply, the ends, or the faces, of the blocks? Tell why. Which kind of wood "took" the stain best? Why?

N. B.—Be sure to burn the oily cloths, or to put them into a covered metal can, so that they cannot set the building afire.

EXERCISE 93

ROOTS

Apparatus and Materials.—Garden trowel, the germination box of Exercise 88, glasses of water, dandelion, sweet potato, dahlia roots, turnip, parsnip, carrot, onion.

a. Read § 316 of the text. Carefully loosen the soil around a young radish in the germination box, and take out the plant without injuring its roots. Note how the root hairs cling to the particles of soil. Why do they?

Put the root into a glass of water, and note the multitude of root hairs. Make a drawing of the entire plant.

b. To which of the two classes of primary roots do the roots of radishes belong? Carefully dig up a grass plant, place the roots in water, and wash off the soil. To which class do the roots of grass belong? Make a sketch of them.

In the same way examine, describe, and sketch the roots of the bean, pea, squash, clover, and corn seedlings.

c. Dig up a dandelion; to which class does its root belong? Examine the root of a dahlia; to which class does it belong? How does it differ from the root of the grass?

d. How do you know that a sweet potato is a root, while an ordinary potato is a modified stem?

If possible, examine the roots of the turnip, parsnip, and carrot. To what class of roots do they belong? Is an onion a root? Prove your answer.

e. Give 3 important uses of roots.

EXERCISE 94

THE FLOWER

Materials.—A simple flower, also clover and dandelions. The kind of simple flower will depend somewhat on the season and the location of the school. Among wild flowers the trillium, spring beauty,

hepatica, dog tooth violet, anemone, and wild rose are excellent material. The blossoms of the apple, cherry, pear, plum, and strawberry may be used. The Easter lily is excellent because of its size. The clover illustrates flowers that grow in a "head"; the dandelion is an example of composite flowers.

a. Read carefully §§ 318 and 319 of the text; then examine the flower in hand. Has it a distinct stalk? Is the stalk thick or slender? Rough or smooth? Is it tough, or easily broken?

b. Has the flower a calyx? Its color? Is the calyx made up of separate parts, or are they united? What are these parts called? How many are there?

Examine the receptacle; has it any special shape or color?

c. Describe the corolla, giving its color, markings, number of parts, and the shape of the parts. What are the parts of the corolla called? Are they alike in all respects?

d. Describe the stamens, giving their number, color, shape, and arrangement. Describe the filament; the anther. Is there pollen?

Do the stamens grow directly on the receptacle, or are they attached to the corolla or other plant organ? Are all the stamens of the same length?

e. Examine the pistil of the flower; what is its shape and color? What is the form of the style? How many carpels are there in the pistil? How many stigmas are there?

What is the form of the ovary? Cut across the ovary at the top and at the thickest part. Describe and draw what you see. How many compartments are there in the ovary? Cut lengthwise through the ovary; how are the ovules attached?

f. Is the flower you are studying built on the plan of 3, or of 5 parts? What kind of veining has the leaf of the plant? Compare this flower with others, note resemblances and differences. Can you find any connection between the kind of veining of the leaf and the number of parts of the flower?

g. Examine a "head" of clover, with the magnifying glass if possible; of what is the head composed? Remove an individual blossom by cutting it off at its point of attachment. Take the blossom to pieces, and describe the flower parts in detail. Which part of the clover head matures first, the outer or the inner part?

h. Study the dandelion. Note that it is made up of many flowers growing on the same receptacle. Describe the corolla of each flower. Describe the stamens and pistil.

Examine a dandelion that has gone to seed. Remove the winged seeds (akenes), and describe one of them. Make a drawing of one. Draw the receptacle that remains. Describe the double circle of green "leaves" below the receptacle; are they true leaves? Are they sepals?

EXERCISE 95

THE EARTHWORM

Materials.—Earthworm and leech.

a. Read § 336 of the text. Put an earthworm on a moist sheet of paper (newspaper), or on some moist earth, and find out how it crawls along. Which is the anterior (head) end? Does the worm crawl forward or backward? While it is moving, touch the part that is forward; does the worm reverse its direction?

Count the number of segments in the earthworm. Count the number in several specimens, if possible. Do all have the same number?

b. Look carefully at the worm while it is at rest. Can you see any pulsations, or "beats," that pass through the body? What are these? Is the body wall of the worm thick or thin? Do any of the internal organs show through the body wall?

c. Does the earthworm require air for its respiration? Why are so many worms found on the ground and sidewalks after

a heavy rain? In the morning look for the tracks of earthworms; describe them. Find also the holes leading to the earthworm burrows; account for the heaps of earth about them. How does the earthworm go through the ground? What effect does it have upon the soil?

d. If the laboratory has a leech, examine its movements. Compare the leech with the earthworm.

EXERCISE 96

MOLLUSKS

Materials.—Shell (both halves) of the freshwater clam (mussel), of the saltwater clam, of the oyster; a snail shell; if possible, a living clam and a living snail. An oyster “on the half shell” will also be useful.

a. Study § 337 of the text. Examine the clam shell and the oyster shell; compare the two.

Describe the appearance of the outside of the clam shell. Which part of the shell was the top (*dorsal* part) and which the bottom (*ventral* part) in the living animal? Are the two halves of the clam shell exactly alike?

If you have a living clam, find which is the anterior (head) end; then find which is the right valve and which the left valve of the shell. Draw an outside view of the left valve, showing the markings and the *hinge*. Trace the outside markings all the way around the shell. Label the parts of the drawing.

b. Describe the inside of the clam shell; then draw the inside view of the left half, showing the markings as accurately as possible. Why does the presence of these marks indicate that the shell increases in size? Which part of the shell is the oldest?

c. Examine the insides of both halves of the shell for the spots at which the two muscles (anterior adductor and posterior adductor) were attached (see Fig. 261, text). Can you see any evidence that a spot may not always have been at the same place?

d. Examine the hinge, and note the tough ligament that held the halves of the shell together. Which act required muscular effort on the part of the animal, to close the shell, or to open it? Can you find on the hinge the device by which the shell was thrown open? If the projecting material at the hinge forms the *fulcrum*, if the stretching of the ligament represents the *work* to be done, and if the contraction of the muscles is the *power*, what kind of a lever is the shell when the clam is trying to close it?

If you were trying to pry the shell open, and the clam were trying to keep it shut, to what other class of levers would the shell belong? Where would the power be as regards the fulcrum and the new resistance? To exert the greatest force, ought the muscles to be attached near the hinge or near the ventral edge of the shell? Where are they attached? Why?

e. If you have a clam or oyster identify the cut ends of the muscles, also the mantle, foot, and "siphons."

f. Carefully examine a snail shell; sketch an outside view of it. If possible, get some one to saw lengthwise through an empty shell, from the tip to the widest part. Draw a section of the shell. In what part did the animal live first?

g. Describe the body and movements of a living snail.

EXERCISE 97

INSECTS

Materials.—House fly and horsefly, spider, ant, May beetle; if possible, a butterfly or a moth; also a spider's web, the larva of a May beetle ("white grub"), and a cocoon of the cecropia moth.

A convenient way to catch a butterfly or moth is to use a bag of mosquito netting attached to a ring and pole; for the other insects use a wide mouth bottle. Put this over the insect; then slip a piece of cardboard between the mouth of the bottle and the table or wall on which the insect had alighted.

a. Read § 339 of the text. Answer the following questions for each insect you can study:

1. How many regions has the body? Are they equally distinct in all the insects examined?

2. How many pairs of legs has the insect? To which region of the body are they attached? What ones are put forward at the same time?

3. How many pairs of wings has the insect? Are all of them used for flying? To what body region are they attached? What are the markings of the wings?

4. How many segments are there in the abdomen? Are all the segments of the same shape and size? Are any structures attached to these segments?

5. What is the shape of the head? What parts of the head can you distinguish? What is the shape and size of the parts of the mouth? How are they used? What does the insect eat?

6. Can you find the eyes of the insect? How many are there? What is there remarkable about the eyes of insects such as the fly?

b. By digging in a barnyard or in a strawberry patch, or even in the open field, you can usually find "white grubs," the larvæ of the May beetle. Examine one carefully, and describe it. What is its color? Can you count its body segments? Has it "feet?" To what parts are they attached? Describe the parts of its mouth. What does the grub feed upon?

c. If possible, find a spider's web; study its construction, and draw it. Are the webs of all spiders alike? Out of what do spiders spin webs? Why do they spin webs?

d. Between late fall and early spring you will usually be able to find the large, dense cocoons of the cecropia moth. They are brown, and attached to the branches of such trees and shrubs as the apple, cherry, willow, lilac, maple, and elder. Get several, if possible, and put them into a box with a cover of wire netting.

Often the cocoon is empty. You can tell, by "hefting" the cocoon, whether there is a pupa inside or not. If there is, cut open the cocoon, beginning at the open end. Use slender, sharp scissors, and be very careful not to injure the creature inside. Touch the pupa; result? Sketch it.

When you are through examining the pupa, see that it is placed as it was when you opened the cocoon, and close the slit with a strip of gummed paper; then lay the cocoon in the net covered box. Leave the box where it will be warm, and where the sunlight will shine on the cocoon. You may be rewarded, in the spring, by the appearance of the beautiful *imago*, the adult moth.

e. Look for some ants; you will usually find them on sidewalks or along the road. Follow them, and find out where they live. Carefully open up their "house," and see the galleries they have formed. Tell what they do when disturbed.

EXERCISE 98

BIRDS

Materials.—Skeleton of bird, live chicken, foot and leg bones of a duck, leg bones and wing bones of a chicken and a turkey, feathers of a chicken, duck, pigeon, goose, and turkey; a chicken gizzard.

a. Read § 344 of text. If the school has the skeleton of a bird, study it carefully, and compare its bones with those of Fig. 269.

b. Examine the foot of a domestic fowl ("chicken"), noting the scales. How many toes has the chicken's foot. How many are directed forward? How many backward? Is the chicken a perching or a climbing bird? Find the end of the white tendon that is connected with the chicken's toes, and pull it. What happens?

If possible, examine the foot of a duck. How does it differ from that of a chicken? Has this difference anything to do with the habits of the two birds?

c. What is the scientific name of the chicken bone that we commonly call the "drumstick"? See Fig. 269. What is the bone of the "second joint"? Compare these with the corresponding bones in the human skeleton. See Fig. 275, § 354, text. What bones are in the foot of the bird? If possible, study the leg bones of a duck and a turkey, and compare them with those of a chicken.

Compare the bones of a bird's wing with those of your own arm and hand. What bones of the wing bear the feathers most needed for flight? Do these correspond to the bones of the upper arm, lower arm, or hand?

d. Get a large wing feather, also a small contour feather, or body feather, of the chicken, duck, pigeon, goose, and turkey. Examine the quill of each feather, and describe it. Is it hollow or solid? Is the *axis*, or central part, hollow all the way?

The outspread part of the feather is called the *vane*. The parallel rows that make up the vane are the *barbs*. Which feathers have the barbs joined together? Which ones have them separate? Which class of birds would need to have the barbs joined, flying birds or walking birds? Why?

e. Examine the eye of a living chicken; how many eyelids has it? The extra one is the *nictitating membrane*; in what direction is it moved across the eye?

f. At home or in the meat market have a chicken gizzard cut open for you. What materials do you find inside it? Why does the fowl eat such things? Note the tough, rough, inside covering. What is its use? Note the thick muscular walls; why are they needed? Why does a bird need no teeth?

g. Are any birds harmful to man? Give examples. Do these birds make up in any way for the harm they do? Why is it important that a farmer should know the birds on his farm, and their habits? Send for Farmers' Bulletin No. 630, U. S. Department of Agriculture, Washington.

EXERCISE 99

BONES AND JOINTS

Apparatus and Materials.—Pocket knife or needle mounted in a small stick (dissecting needle), beef or mutton bone containing a joint and sawed lengthwise, an old bone, chicken bones, a slender bone, such as a “wishbone” or the rib of a lamb chop.

a. Read §§ 352, 353, and 354. Examine the bone in a piece of uncooked “round” steak. Ask the butcher to get you a fresh, long, beef (or mutton) bone that contains a joint end. Have him saw the bone lengthwise, for an inch or two, through the joint; then have him cut off one of the lengthwise pieces.

Examine the sides and ends of the bone. What kind of material covers the bone? Name it. Identify the *marrow*. Can you find marrow of two different colors? At what part of the bone is each kind? Do you find cartilaginous material at the joint? What are its uses? Describe the interior of the bone.

b. Compare with the new bone an old bone that has been dried thoroughly, or has lain out of doors for some time.

c. Collect the bones of a fowl (“chicken”) after the flesh has been removed, and clean them thoroughly. Test some of the bones to determine whether they are hard, or easy, to break. Are they at all elastic? Chop, or saw, lengthwise into the leg bone (“drumstick”); is it solid, or hollow?

Find a hinge joint in the chicken; a ball-and-socket joint.

d. Thoroughly clean and dry a slender bone, such as the “wishbone” of a chicken or the rib of a lamb chop. Boil it for a few minutes in water; then let it soak in hydrochloric acid (1 volume of concentrated acid to 4 volumes of water) for 3 or 4 days. Finally rinse off the acid and examine the bone. Is it hard now? What has the acid removed?

e. Burn a small bone in a place where there is a good draught, or on a bed of hot coals. Continue heating it until it is white.

Let the bone cool; then examine it. Is the burnt bone tough, or brittle? What did the burning remove from it?

EXERCISE 100

MUSCLES AND TENDONS

Apparatus and Materials.—Pocket knife or dissecting needle (see Exercise 99); tough, lean beef and tender beef; tendon from a sheep's hoof, a heavy book, magnifying glass (?).

a. Read §§ 355 and 356 of the text. Ask the butcher for a small piece of lean beef that is sure to be tough. From what part of the animal does it come? Ask also for a small piece of tender beef. Cut across the muscle fibers of each, and examine the cut ends. Is there any difference in their appearance? Use a magnifying glass if possible.

Cook the tough piece until the fibers can be picked apart (not cut) with a knife or needle. What is the name of the tissue between them? Why was the piece tough?

b. Recall the appearance of the tendon in the chicken's foot (Exercise 98). Ask the butcher to get for you the tendon in the hoof of a sheep; describe it.

c. Place one forearm on the table, with the elbow on the table and the palm upward. Let the arm and hand be relaxed (limp). With the other hand find the tendon that attaches the biceps muscle to the *radius* of the lower arm (see Fig. 277 of text). Note how it stiffens when you raise the forearm, especially if you have a considerable weight, such as a heavy book, in your hand.

d. Repeat c, but feel of the biceps muscle in your upper arm instead of the tendon. How does it change?

e. To what class of levers does the forearm belong? See Fig. 277. Would you need to exert more, or less, force to lift a flatiron that is in your hand than if it were attached just above your wrist? Why?

EXERCISE 101

FOODS AND FOOD TESTS

Apparatus and Materials.—Potato, kitchen grater, laundry starch, measuring cup, flour, cheesecloth, test tube or beaker, grape sugar, Fehling's solution (see Introduction), raisin, granulated sugar, hydrochloric acid, white of egg, nitric acid, ammonia water, white woolen yarn, white cheese or sour milk, ground peanuts.

a. Starch.—Peel a potato, grate it fine, and stir it with water. The starch will thus be separated from the other material, such as cellulose, and will tend to settle to the bottom. If you then pour off the water and the lighter sediment, the starch will remain. Pour the starch upon a filter paper or a piece of newspaper, and let it dry.

Note the "crunchy" feeling of some laundry starch when you crush it between your fingers.

Boil about $\frac{1}{2}$ of a teaspoonful of powdered starch in your measuring cup with $\frac{1}{4}$ of a cupful of water. Let the mixture cool; it should "set" to a thick paste. Review Exercise 89, c.

b. Gluten.—Out of $\frac{1}{4}$ of a cupful of flour and a little water make a tough dough. Tie the dough in a piece of good cheesecloth, and knead the dough under water. Note that the starch comes through the cloth. When no more starch can be kneaded out of the dough, examine the impure gluten that remains. Give its color. Is it sticky? Elastic?

c. Grape Sugar.—Into a test tube or small beaker put a pinch of grape sugar; dissolve it in the least possible amount of hot water. Add to the solution about 3 cu. cm. of Fehling's solution, and boil the mixture. What is the result? This serves as a *test* for grape sugar. Taste a little of the grape sugar.

Crush a raisin, soak it in water, and boil the solution with Fehling's solution. Is grape sugar present?

Dissolve a pinch of granulated sugar in the least possible amount of water, and boil with Fehling's solution. Result?

To another portion of a solution of granulated sugar add 1 drop (not more) of concentrated hydrochloric acid. Boil the solution for a few minutes; then add Fehling's solution and boil again. Has the granulated sugar been changed to grape sugar?

d. Proteids.—In a beaker boil half a teaspoonful of white of egg with about a test tube full of water. Note how the proteid is *coagulated*. Pour off the water, and heat the white of egg with dilute nitric acid. How is its color changed? Now put the white of egg into ammonia water. Is the color removed, or made more intense?

Boil a piece of white woolen yarn in the nitric acid in which you heated the white of egg; then put the yarn into ammonia water. Results? Do the same with a piece of white cheese, or with the curd of sour milk. Results?

e. Fats.—Review the test for fats in Exercise 89, *d*. Try it with some ground peanuts.

EXERCISE 102

THE MOUTH AND THE THROAT

Apparatus.—A hand mirror, a rubber band.

a. Read §§ 359, 360, and 361 of the text, also § 388. Go through the process of chewing a rubber band, and make a note of all the motions of your tongue, teeth, jaws, cheeks, and the special organs of swallowing. Swallow the saliva and at the same time feel of your throat. What rises in it in the act of swallowing? You can understand these motions better if you stand with your back to a well-lighted window and look into a hand mirror.

b. Open your mouth wide, and examine the inside by the aid of the mirror. Can you move any part of the roof of your mouth? This is the *soft palate*. Is it in the front, or the back, of the mouth?

Describe the tongue; compare its upper and under surface.

Swallow all the saliva you can, so as to get the mouth as free from it as possible; then raise your tongue, and note how the saliva gathers under it. Where does the saliva come from?

c. Hold your tongue in the bottom of your mouth, and identify the *tonsils* at the side of the throat.

d. Count the total number of teeth in each jaw, and the number of each kind. How do the teeth differ? Why?

EXERCISE 103

DIGESTION OF FOOD

Apparatus and Materials.—Bottles or beakers, pan of water, litmus paper, corn starch, white bread, hard-boiled egg, grater, rennet (or junket tablet), milk, thermometer, pancreatin, pepsin (get the ferments at a drug store), olive oil, Fehling's solution.

a. **Saliva.**—Put into your mouth a piece of clean, pink litmus paper; what effect has the saliva upon it? Has saliva an acid, or an alkaline, reaction?

Put on the tongue a pinch of powdered cornstarch; let it soak in the saliva, and note if it becomes sweet. How does saliva affect starch?

Chew a piece of white bread; does it become sweet?

b. **Gastric Juice.**—Grate finely a part of the white of a hard-boiled egg; put a teaspoonful of it into a bottle containing about 100 cu. cm. of water, a teaspoonful of dilute hydrochloric acid, and a good-sized pinch of pepsin. Also add a piece of the ungrated white of egg.

Put the bottle in a warm place for several hours, or overnight. What is the result in the case of the grated material? The larger piece? What is the reason for keeping the materials warm? What is the advantage of the chewing of food?

c. **Rennet.**— Into a bottle put about 50 cu. cm. of milk, and set the bottle in a dish of water at 37° to 38° C. (about 100° F.). Add some commercial rennet, or a “junket” tablet. Keep the milk warm for about 10 minutes; then set it aside. What happens? Which part is curd? Whey? What does each contain?

d. **Pancreatic Juice.**— Dissolve a little commercial *pancreatin*, or pancreas extract, in warm (not hot) water; divide the solution into two parts. Add half of the pancreatin solution to a tablespoonful of olive oil and the same volume of warm water. Set the mixture in a warm place. Shake up the mixture from time to time for 2 or 3 days. Note what happens.

Make a smooth starch paste by mixing a teaspoonful of starch with 3 or 4 teaspoonfuls of cold water. Set the paste in a pan of warm water, and add to it the other half of the pancreatin solution. Let it stand for at least a day, and note what happens. If possible, test the product with Fehling's solution? Has the starch been changed to sugar?

EXERCISE 104

THE BLOOD VESSELS

Apparatus and Materials.— String, stethoscope (get it from a physician), heart of sheep or calf, with the connecting organs.

a. Press with three fingers upon the artery in the wrist, and count your pulse beats. How many are there each minute? In the same way “take the pulse” of an old person, and of a young child. Compare the number of beats.

Take some vigorous exercise, or breathe very deeply a number of times; what is the effect upon your pulse?

b. Find the large veins on the back of your hand. Press the blood out of one of them by pushing down hard with a finger of your other hand and at the same time moving the finger from the wrist toward the knuckle. Notice that blood does not

enter the vein from either direction; the finger prevents its flow *toward* the heart, while the valves in the vein prevent the flow in the opposite direction. Remove the finger; result?

c. Wind a string tightly about a finger, and note what takes place. What vessels carry blood *into* the finger? What ones carry it out? Which of these is closed by the string? Why is it important that arteries should not be near the surface?

d. Ask a physician to show you a *stethoscope* and the way it "works." With it study the heart-beat of some member of your family. What sounds does the heart make?

e. From a butcher get the heart of a sheep or calf, with the lungs and trachea attached if possible. Examine the blood vessels connected with the heart. Study their position by the aid of Fig. 284, § 375, of the text. Distinguish the arteries from the veins by the differences in thickness, strength, and elasticity. Distinguish the ventricles from the auricles. In what part of the heart are the ventricles? Why are their walls so thick?

f. If your specimen of the heart has the lungs attached, examine them. Are they heavy or light? Are they of exactly the same shape? What is their color? What is the shape and structure of the trachea? What keeps it in shape?

EXERCISE 105

RESPIRATION

Apparatus and Materials.—Watch, measuring tape, 2-qt. fruit jar, deep pan of water, glass tube, graduated cylinder, small-mouth bottle with bottom removed (Ex. 84), touch paper.

a. Read §§ 381 to 391, inclusive, of the text. For the test for the presence of carbon dioxide in exhaled air, recall Exercise 15, b. Test for water in exhaled air by blowing the breath into a cold bottle or against a cold window pane. What happens?

b. When you are breathing quietly and regularly, count the number of inspirations in a minute, and record them. Find out the number for another person of your own age; for a young child. Count your respirations after violent exercise.

c. With a measuring tape get the distance around your chest. To do this, pass the tape across your back and just under your arm-pits; bring it together just over your breast bone. Now breathe very deeply, and get the chest measure. Finally exhale all the air you possibly can, and get your chest measure. What is the difference between the last two results? This represents your chest expansion.

d. Find how many cubic centimeters of air you can expel: (1) from lungs that are normally full of air; (2) from lungs that are as full as you can make them. The apparatus needed is a 2-quart glass fruit-jar, a pan of water, and a tube, as in Fig. 37, § 45, of the text. You will need to know the capacity of the jar and the volume of water left after each trial. Results?

e. You can show by simple means how the action of the diaphragm aids in bringing air into the lungs and in expelling it from the lungs. You need a small-mouth bottle from which the bottom has been removed (see Exercise 84). This form of the apparatus is suggested in Walters' *Physiology and Hygiene*. Set the bottle, right side up, in water that is about half as deep as the bottle is tall. Let the level of the water represent the diaphragm. As you raise the bottle, the water level falls, and air rushes into the bottle's mouth. This represents an *inspiration*. As you lower the bottle, the water level rises, and air is expelled; this represents an *expiration*. The results are seen better if a piece of smoking "touch paper" is held over the mouth of the bottle. To make touch paper, soak strips of filter paper or blotting paper in a solution of potassium nitrate (saltpeter), and dry them.

EXERCISE 106

THE NERVOUS SYSTEM

Apparatus and Materials.— Model of brain (?), brain of calf or sheep, piece of spinal cord, pair of dividers.

a. Read §§ 399, 400, and 401, of the text. If your school has a model of the human brain, study it, and identify its parts.

Ask your butcher to get for you the brain of a calf or sheep, and study its form and appearance. Have him also get a piece of the spinal cord; describe a cross-sectional view of it.

A section of the spinal cord may be found in the proper cuts of sirloin of beef. Ask the butcher to show you one.

b. With your finger feel for the nerve at the elbow ("crazy bone"); what sensation is produced? When you hit the crazy bone against a hard object, where do you feel the tingling sensation? Why?

c. Cross your middle finger over your first finger, and hold a pencil between the crossed ends of the fingers. How many pencils do there seem to be? Why?

d. Close your eyes, and have some one touch the skin of your neck, hands, finger tips, forehead, and forearm, with a pair of "dividers." The two points of the dividers should be varying distances apart; sometimes one point should be used, sometimes both points. Where do you find the skin very sensitive; that is, where can the two points be distinguished as two, even when they are only a very small distance apart?

EXERCISE 107

THE EYES

Apparatus and Materials.— White paper, light-pink paper, printed letters $\frac{3}{8}$ of an inch high, circle of red paper, model of the eye (?).

a. Read §§ 414 to 418, inclusive, of the text. On a piece of paper make two circles (entirely black) about $\frac{1}{4}$ of an inch in

diameter and 3 inches apart. Hold the paper at arm's length, shut the left eye, and fix the right eye upon the left spot. You should see both spots.

Now bring the paper toward the eye; when it is about 8 inches away, the right-hand spot will disappear, because its image falls on the *blind spot* of the eye. At less than this distance the right-hand spot will reappear.

b. On a piece of paper draw 2 circles each 3 inches in diameter. Have the outlines heavy. On one of the circles draw parallel *vertical* lines, all the same distance apart. On the other circle draw parallel *horizontal* lines. Pin the paper to the wall, and look at it from some distance. Do the circles appear to be true circles? How is each distorted?

Repeat the experiment, using two squares. Results?

If a wall paper contains many vertical stripes, what is the effect upon the apparent height of the room? What is the effect of horizontal stripes?

If a person wishes to appear slender, ought he to wear clothing with vertical or with horizontal stripes?

c. Out of a newspaper or an advertising circular cut several letters $\frac{3}{8}$ of an inch high. Paste them upon a sheet of white paper, and pin the paper to the wall. Find out how far away you can stand and yet see every letter distinctly. Measure this distance and record it.

Ask an elderly person to try this test; get the distance. Ask a near-sighted person to do it. What are the results?

d. Get a sheet of light-pink paper (tissue paper), and hold it before you. Now look steadily at a red circle in bright sunlight; then look quickly at the pink paper. What kind of a circle do you see on the paper? Tell why.

e. If your school has a model of the eye, study it carefully, and make out its parts. Compare them with Fig. 300, text.

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