Fig. 23, will be quite large enough for any experiment you will want to make.

The retort shown in Fig. 24 is made of a kind of glass which has been carefully annealed, so that it can be heated to quite a high temperature without breaking. It is made with a ground-glass stopper, and can be set in a ring-stand directly over a flame. Half a dozen watch glasses, or *crystals*, as they are often called, see Fig. 25, are useful for

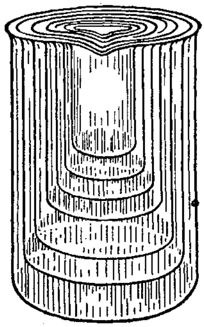

FIG. 14.—A Nest of Beakers.

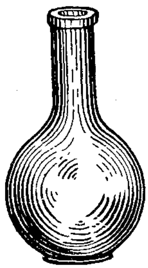

FIG. 15.—An Ordinary Spherical Flask.

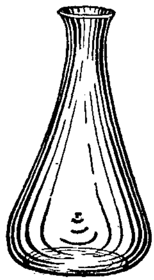

FIG. 16.—An Erlenmeyer Flask.

evaporating small quantities of solutions, and you should also have a 3-inch porcelain evaporating dish, which is shown in Fig. 26. A 5-inch U-tube, pictured in Fig. 27, is a convenient apparatus for purifying and drying gases. When handling phosphorus (*P*), potassium (*K*), and other solids that you do not want to get on your hands, use a pair of forceps, or *tweezers*, as they are commonly called. These are shown in Fig. 28.

Besides the above apparatus you will need several pieces of glass tubing that is sold under the trade name of *German soft glass;* you can easily bend this kind of glass in the flame of your alcohol lamp or Bunsen burner, which process I shall explain to you a little farther along. Get the tubing ⅜ inch (about 8 millimeters)[1] in diameter, outside measurement, and in 2-foot lengths. You can buy glass T-tubes and glass Y-tubes of the same size if you should need them. You must also get two or three feet of rubber tubing, with inside diameter, ¼ inch, for making connections.

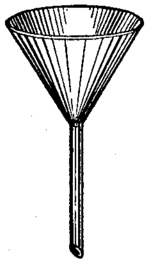

FIG. 17.—A Glass Funnel.

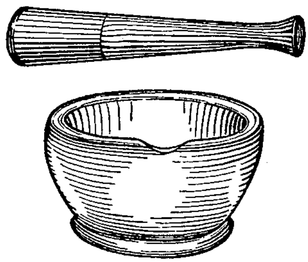

FIG. 18.—A Mortar and Pestle.

While I have given the amounts of chemicals to be used in making the experiments in this book in the way that seemed to me to be the easiest for you to measure out, still, in chemistry as it is taught in schools to-day, the solid kinds of chemicals are most carefully weighed out on a pair of scales, or a balance, and liquids are measured out in a graduated cylinder, and for both of these the *metric system* of measurements is used.

This system of weights and measures runs in multiples

[1] It is listed in the catalogues in the *metric system.*

of ten, and this is, consequently, much more simple than the English system, which is purely an arbitrary one that has come down to us from an unscientific past. You can buy a small pair of hand scales, or a balance, for $1.50 or so, but the weights will cost you considerably more, and you can get a medium-size graduated cylinder for about

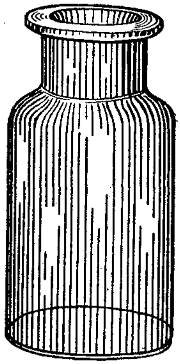

FIG. 19.—An Ordinary Wide-Mouth Bottle.

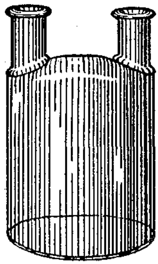

FIG. 20.—A Woulff's Bottle.

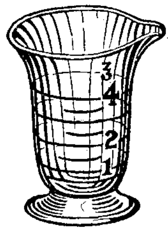

FIG. 21.—A Four-Ounce Graduated Glass.

FIG. 22.—A Tea-spoonful Graduated Glass.

$.75. Both of these you will eventually require in order to do accurate work, but for all the experiments that follow in these pages they will not be needed.

Your Supply of Chemicals. I shall not write out a list of the chemicals you will need, for you can do this better after you have decided what experiments you want to make. But what you should do is to write to the firms I have named below for their price-lists of chemicals.[1] These will include not only all those I have named in this book but many others. Many of the chemicals you will want can be bought of your druggist, and you can often get test tubes and other ordinary pieces of chemical glassware of him.

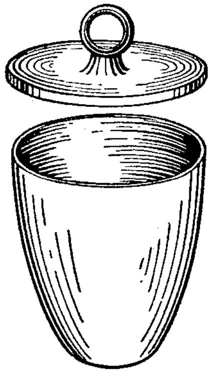

FIG. 23.—A Porcelain Crucible.

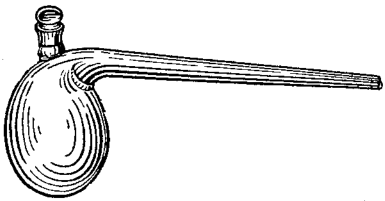

FIG. 24.—A Glass Retort.

While many of the chemicals come in the form of solid substances, it is a good scheme to keep them in tightly corked bottles, while acids and other liquids should be kept in glass-stoppered bottles. Label each bottle carefully and then place all of them in a cabinet where the light cannot reach them, as some compounds decompose under its action.[2] Place them in the cabinet in alpha-

[1] When you have made out the list of the chemicals and chemical apparatus, you should write to the L. E. Knott Apparatus Co., Cambridge, Mass., or to Eimer and Amend, Third Ave. and Eighteenth St., New York City, and either firm will not only quote you prices but will give you other information you want.

[2] See Chapter XII.

betical order so that you will know at a glance just what you have in stock and, what is equally to the point, will be able to find the one you want without having to hunt for it. It is also a good plan to keep all the poisonous chemicals together and to put a red label on each of these, and tie a string around the neck of each one, to the end that you will not mistake them.

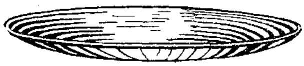

FIG. 25.—A Watch Crystal.

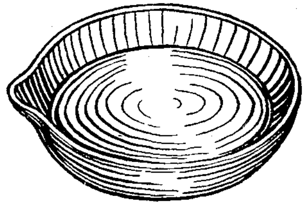

FIG. 26.—A Porcelain Evaporating Dish.

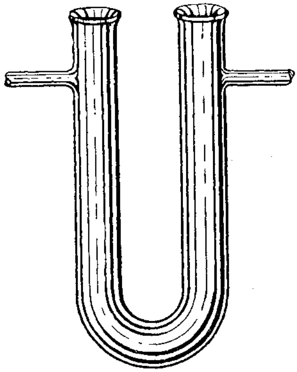

FIG. 27.—A Five-Inch U-Tube.

FIG. 28.—A Pair of Tweezers.

Indicator Papers and Solutions. *Indicators* are papers or liquids that change from one color to another when they are dipped in or mixed with an acid or an alkaline solution. Hence, if you want to know whether a solution is acid, neutral, or alkaline you have only to test it with an indicator.

How Litmus Paper Acts. Litmus is a blue coloring matter that is found in *lichens*, and hence its name. When this is extracted from the plant it is dissolved in hot water (H_2O) and a sheet of absorbent paper, that is, paper without any sizing in it,—like filter paper—is dipped in the solution and then dried, taking on a *blue* color; this, then, is the way that *blue litmus paper is made.* If, now, you dip the paper in a weak acid solution it will turn red, and this gives you *red litmus paper*; finally, if you dip this in an alkaline solution it will turn blue again. Litmus paper is the simplest, though not the most sensitive, of the indicators, but it will serve for all your experiments. You can buy blue and red litmus paper already prepared, as well as the other indicators that follow.

How Phenolphthalein Acts. Phenolphthalein ($C_{20}H_{14}O_4$) —pronounced *fen-ol'-tha-lein*—is a colorless substance that is much used by chemists as an indicator. This is because it is very sensitive to acids, even to those of the weakest kind, but it shows the presence of an alkali only when the latter is strong. It acts the reverse of litmus in that it remains colorless when it is used with acids, but turns red in alkaline solutions.

How Methyl Orange Acts. This indicator is a complex compound with the gentle formula of ($(CH_3)_2 \cdot N \cdot C_6H_4 \cdot N_2 \cdot C_6H_4SO_3H$) and you will come to a full realization of what this means as you get farther along in the book. It is a synthetic dyestuff, and when added to an acid solution it turns *red*, and when added to an alkaline solution it turns *yellow*. Its value lies in the fact that it is a very sensitive indicator of weak alkalis.

How Congo Red Acts. Congo red $(C_{12}H_8(N_2 \cdot C_{10}H_5 \cdot NH_2 \cdot SO_3Na)_2)$ as shown by its formula, is also complex. Congo red paper when dipped in an alkaline solution remains *red*, and when dipped in acid solutions turns *blue*, hence it acts in just the reverse way from litmus paper. Its especial usefulness lies in the fact that it shows

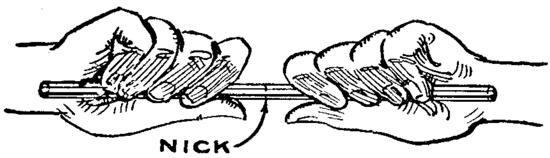

FIG 29.—How to Cut a Glass Tube.

graduation of color, by which is meant that the depth of the blue it turns depends entirely on the strength of the acid which you are testing.

How Sulphide Test Paper Acts. Sulphide test paper is used for testing the presence of sulphur (S) in water (H_2O) and other liquids. If the liquid contains sulphur (S), the test paper will turn brownish-black.

How to Work Glass Tubing. While you can buy glass tubing bent to whatever shape you want it, still in making chemical experiments you will often find it a great convenience to be able to bend it yourself, and as it is an easy and pleasant job, I'll tell you how to do it.

How to Cut a Glass Tube. As I have mentioned under the caption of "The Apparatus You Need," you want to get the kind of glass tubing that goes under the trade name of *German soft glass*, as this kind melts at a comparatively low temperature. This kind of tubing comes in 2-foot lengths, and so the first thing is to know how to cut off a piece of the length you want to use. To do this, you need only to file a nick in it with a three-cornered file, when it will easily break in two. The way you hold it to do this is shown in Fig. 29.

How to Smooth up the Sharp Edges. Hold the end of the tube that you want to smooth up in the flame of your alcohol lamp, or, better because it is hotter, a Bunsen

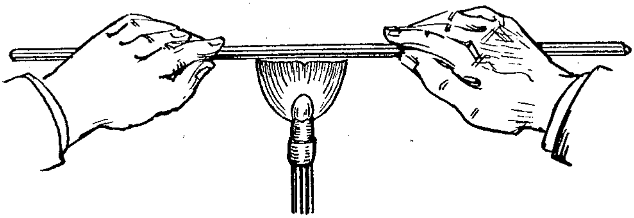

FIG. 30.—How to Bend a Glass Tube.

burner, and turn it rapidly around. As soon as it is hot enough it will begin to melt, and this will round the sharp edges, and you can easily see just how far to carry the process.

How to Bend Glass Tubing. To bend a piece of glass tubing, hold it in the flame of your alcohol lamp or Bunsen burner with a wing-top attachment until it is red-hot an inch or so on either side of the place where you are going to make the bend. Now turn the tube rapidly round in the flame so that it will heat equally all over until it gets soft. This done, take it out of the flame and while it is still at a red heat you can bend it to whatever shape you want. You must not heat it until it is too soft, or you will find that the walls of the tube will collapse and so close up the bore. Figure 30 shows the way it is done.

How to Draw a Glass Nozzle. In many cases where you want a tube with a nozzle on it you can take the rubber

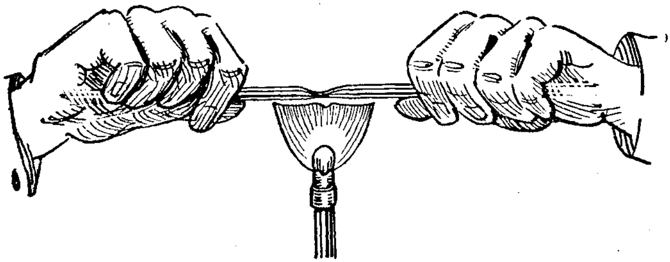

FIG. 31.—How to Draw a Glass Nozzle.

bulb off a pipette, that is, a medicine dropper, and use it, but if you should want a nozzle with a little larger or a little smaller opening in it, the only way to get it quickly is to make one. To do this, cut off a piece of glass tube about 4 inches long, hold both ends of it so that the middle will be in the flame of your lamp or burner, and at the same time keep turning it round so that it will heat evenly.

When it gets red hot it will be quite soft, and you can then draw it out until it is very thin in the middle, as shown in Fig. 31. Now take it out of the flame and make a cut with a file at the place where it will give an opening of the size you want; this done, gently tap it with your file. It will break off and the nozzle is ready to use.

CHAPTER II.

AIR, THE MIRACLE-WORKER

The word *atmosphere* is generally used to mean the whole mass of the air that surrounds the earth, while the word *air* itself is taken to mean some small or large part of it. The atmosphere is really a shell formed of gases, the inside of which has, naturally, the same shape as that of the exterior of the earth, while its outside surface is more like a football than it is like a baseball, since it is flattened out on its opposite sides, as shown in the diagram, Fig. 32.

The Height of the Atmosphere. To just what height the atmosphere extends is not known with any degree of certainty, but it is variously estimated to be from 50 to 200 miles, and it may extend in a highly rarefied state even farther than the last-named figure indicates. Now there are several ways by which its height can be calculated, but all of them give results that are different, as the following will show.

Since the speed of the earth as it turns on its axis is known, its *centrifugal force*, that is, the force by which a rapidly rotating body tends to throw things off from its surface, can be figured out. This action is, of course, opposed by the *force of gravity*, which tends to hold all things down to the surface. But as gravity exerts a constantly decreasing pull on the air the higher up it gets, it