but, of course, in the last analysis there is really only one kind, and this is water (H_2O) — that is the liquid formed by the chemical union of 2 parts of hydrogen (H) and 1 part of oxygen (O) by volume.

Water (H_2O) is classified under two general heads, and these are *soft* water and *hard* water. When water (H_2O) is pure, or nearly so, it is called soft water, and when it contains mineral substances it is called hard water. Of hard water there are also two kinds, namely, those that have *temporary hardness* and those that have *permanent hardness.*

How to Tell if Water Is Soft or Hard. You can easily find out whether water (H_2O) is soft or hard by rubbing up some soap with it. If it lathers well it is soft water, and it follows that if it does not lather well it is hard water.

How to Test For and Get Rid of Temporary Hardness. Half fill a test tube with some of the water (H_2O) to be tested and boil it for several minutes over the flame of your alcohol lamp. If it contains calcium carbonate ($CaCO_3$), or limestone, as it is commonly called, it has temporary hardness, and to get rid of it you need only to boil it, upon which the limestone ($CaCO_3$) will be precipitated, that is, thrown down to the bottom of the tube; in this way boiling the water (H_2O) makes it soft.

How the Experiment Works. When rain falls it absorbs the carbon dioxide (CO_2) in the air, and as the water (H_2O) containing the gas filters through the earth, the carbon dioxide (CO_2) acts on the limestone, or calcium carbonate ($CaCO_3$), and changes it into the more soluble form of calcium bicarbonate ($Ca(HCO_3)_2$), which is dissolved by and remains in the water (H_2O). Now when the water is boiled, the carbon dioxide (CO_2) is driven off and the calcium bicarbonate ($Ca(HCO_3)_2$) again becomes calcium carbonate ($CaCO_3$), and this is precipitated, that is, it is thrown down to the bottom of the vessel.

How to Test For and get Rid of Permanent Hardness. Half fill a test tube with some of the water (H_2O) to be tested and then add ½ teaspoonful of sodium carbonate ($Na_2CO_3+10H_2O$), which is commonly called soda; place your thumb over the mouth of the tube and shake it hard. If, now, the water has permanent hardness, white particles of *gypsum*, that is, calcium sulphate ($CaSO_4$), or *Epsom salts*, which is magnesium sulphate ($MgSO_4$), or both of these salts, will be precipitated, mainly in the form of carbonates. Then run the water through a sheet of filter paper, and the particles will be left behind and the water will be soft.

How the Experiment Works. When sodium carbonate ($Na_2CO_3+10H_2O$) comes in contact with sulphates that cause permanent hardness, the latter are decomposed and form calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$), which then fall to the bottom, thus leaving the water (H_2O) soft. How soap cleans when it is used with water (H_2O) is explained in Chapter XV.

How to Test Water for Odor and Color. Half fill a test tube with some of the water (H_2O) to be tested, shake it well, and then hold it to your nose; if the water (H_2O) contains any living organisms, it will give off an odor, and if there are any decaying organic impurities in it, the odor may be an unpleasant one. Now heat the test tube and again smell of it, when you may find that the odor is even more pronounced.

Half fill a test tube with water (H_2O) and let it stand for a few minutes; now hold if between your eyes and a sheet of white paper against the light, and you can easily see if it is tinted or not and whether it is clear or translucent. This done, shake it well and then examine it again.

How to Test Water for Mineral Substances. Pour a little of the water (H_2O) to be tested into a watch crystal, or, better, a small, porcelain evaporating-dish, and set it in the sun until all the water has evaporated. If you want to evaporate it more quickly, heat it very gently over the flame of your lamp or burner, as shown in Fig. 70. If it contains organic, or mineral matter of any kind, or both, such matter will be left behind as a *residue* on the crystal, or dish. Now heat it to redness, and if the residue is formed of organic matter it will be decomposed and pass off in the form of gases, while if it is formed of mineral matter, it will not be affected by the heat.

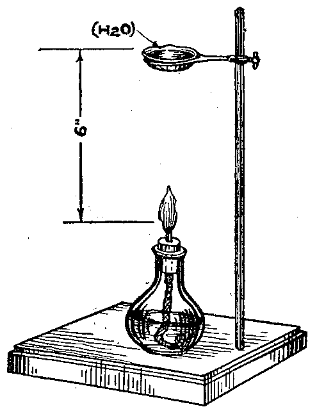

FIG. 70.—How to Test for Mineral Matter in Water.

How to Test Water for Organic Matter. By *organic matter* is meant matter that is living or was once alive. Another and more showy test for organic matter than the one given above is to fill a beaker, or a tumbler, with some water (H_2O); now put 1 teaspoonful of sodium bisulphate ($NaHSO_4$) in a test tube half full of water (H_2O) and shake it until it is dissolved. This done, put 10 or 12 drops of the solution into the water (H_2O) to be tested.

Now dissolve ¼ teaspoonful of potassium permanganate ($KMnO_4$) in a test tube of water (H_2O), and with your medicine dropper, or pipette, as it is more properly called,

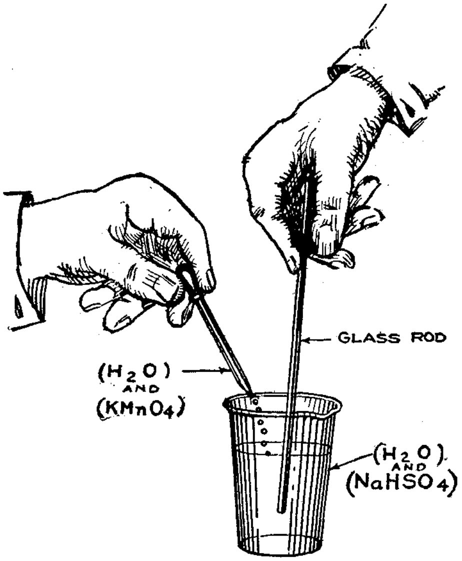

FIG. 71.—How to Test for Organic Matter in Water.

add the solution a drop at a time to the water (H_2O) you are testing, and at the same time stir it with a clean glass rod or tube, as shown in Fig. 71, until it turns a violet color. Let the beaker stand for half an hour or more, and if the color of the water (H_2O) does not change in that time you may safely conclude that there is no organic matter in it.

If, however, the water (H_2O) loses part of its color, it shows that there is organic matter in it.

How to Test Water for Carbon Dioxide. First prepare a little *lime-water*, which is calcium hydroxide ($Ca(OH)_2$), and this you do by half filling a test tube with pure water (H_2O), and then dissolving ¼ teaspoonful of quicklime, which is calcium oxide (CaO) in it. Let it settle and pour off the clear part, which is lime-water ($Ca(OH)_2$). Now fill a test tube nearly full of the water (H_2O) you want to test for carbon dioxide (CO_2) and then put in half a dozen drops of the lime-water ($Ca(OH)_2$). If there is carbon dioxide (CO_2) in the water, it will promptly take on a milky color.

How to Test Water for Alkalis. Take a test tube full of the water (H_2O) you want to test and put in a couple of drops of a solution of phenolphthalein ($C_{20}H_{14}O_4$), and this you can make by dissolving a little of it in pure methyl alcohol (CH_3OH), which goes by the name of *wood-spirit*, or *wood alcohol*. The phenolphthalein ($C_{20}H_{14}O_4$) is a colorless compound, but on coming in contact with an alkali it takes on a red tint and so colors the water.

How to Test Water for Lime. Add ¼ teaspoonful of sodium carbonate (Na_2CO_3) to a test tube of the water (H_2O) you want to test, and let it stand for half an hour. If there is no lime, that is, calcium carbonate ($CaCO_3$), in it, the water (H_2O) will remain clear, but if there is any lime in it, the water (H_2O) will take on a milky color.

How to Test Water for Acids. To make this test all you need to do is to soak a strip of blue litmus paper in the water (H_2O), upon which it will change color if it contains an acid.

How to Test Water for Iron. To a test tube that is half full of the water (H_2O) you are going to test, add ¼ teaspoonful of sodium ferrocyanide ($Na_4Fe(CN)_6+12H_2O$) and shake it well. Let the water (H_2O) stand for a few minutes, and if it takes on a blue color it shows that there is iron (Fe) in it.

How to Test Water for Sulphur. Fill a test tube full of the water to be tested, and then soak a strip of *sulphide test paper* in it. If the water contains sulphur (S), the paper will change its color to a brownish-black. *Sulphur water* is a mineral water (H_2O) that has a gas in it called hydrogen sulphide (H_2S), and it is this gas that makes it smell like rotten eggs.

CHAPTER V.

EXPERIMENTS WITH HYDROGEN

IT was the English chemist, Cavendish, who first showed that hydrogen (*H*) was a gas by itself and, also, that it would produce water (H_2O) when it was burned in air. It was known, however, before he made these experiments that it was the oxygen (*O*) of the air which supports combustion, and this showed that water (H_2O) was formed of oxygen (*O*) and hydrogen (*H*) chemically combined.

Hydrogen (*H*) is the lightest gas known, and it is about 14½ times lighter than air, for which reason it is used for filling balloons. It is a colorless, tasteless, and odorless gas, and does not change blue litmus paper red, which shows that it has no acid properties, and yet it is a necessary element of all acid compounds. Hydrogen (*H*) like nitrogen (*N*) is not a poisonous gas, but it cannot support either combustion or life; unlike the latter gas, it burns with an intense heat in air, or better, in pure oxygen (*O*), and when these two gases are mixed with each other (not chemically combined) they form a very explosive mixture.

How to Analyze Water. After you have made the experiments described in the foregoing chapter your next step is to analyze some water (H_2O), that is, separate it into its two original gases, namely oxygen (*O*) and hydrogen (*H*); and then you want to make some of the latter gas and do the experiments which follow.

You can easily separate the oxygen (O) and hydrogen (H) of which water (H_2O) is formed by a process known as electrolysis—that is, by passing an electric current through it. To do the experiment you will need a pair of test tubes, a couple of pieces of carbon such as is used for arc lights and each of which is about 1½ inches long, a soup-plate, and a battery of 5 or 6 dry cells. Take two pieces of insulated copper wire and scrape the ends clean, then twist one end of each one around each of the pieces of carbon and connect the other ends to the battery of dry cells.

This done, fill the soup-plate nearly full of clean water (H_2O) — it does not have to be distilled — and stir half a dozen drops of sulphuric acid (H_2SO_4) into it. You will remember I told you in the chapter before this that water (H_2O) is not a conductor of electricity, but you can make it so — it is then called an electrolyte — by adding a little common salt, that is, sodium chloride ($NaCl$), or, better, sodium bisulphate ($NaHSO_4$) or, still better, sulphuric acid (H_2SO_4).

Now fill both test tubes full of the electrolyte, which is the water (H_2O) so prepared, then place your finger over the mouth of each one in turn, invert it and set it into the water (H_2O) in the soup-plate over the carbon rod, or electrode, as it is called, as shown in Fig. 72. As soon as you have done this you will see bubbles of gas form on each carbon electrode and rise up through the water (H_2O) to the surface of it.

Now the gas formed in one of the tubes is oxygen (O), and in the other one hydrogen (H); after this action has taken place for a few minutes you will observe that the water (H_2O) is sinking in the tubes, and after a longer interval you will further observe that there is twice as much gas in one of the tubes as there is in the other one; this is easily accounted for, since water (H_2O) is formed of 2 parts of hydrogen (H) and 1 part of oxygen (O) by volume. The gas which takes up the smaller space must, therefore, be the oxygen (O), and the one that takes up the larger space must be the hydrogen (H).

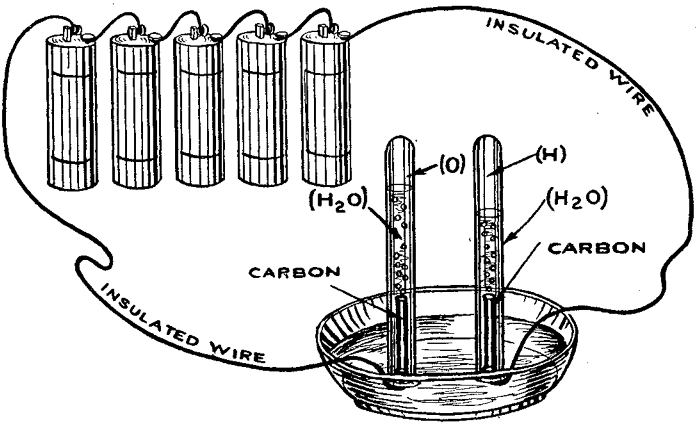

FIG. 72.—Separating Water into Its Original Gases.

To prove that these gases have really been formed in the tubes, lift up the one that has the greater amount of water (H_2O) in it and hold it mouth down, so that the water (H_2O) will run out and the oxygen (O) stay in. Now light a match, and after it gets to blazing well, blow it out and hold it in the tube; instantly it will burst into a flame again, and this shows that the gas is oxygen (O). This done, lift up the other tube and let the water (H_2O) run out of it;

next, light a match and hold it to the mouth of the tube, upon which the gas in it will explode, and this shows that it is hydrogen (H).

How the Experiment Works. The above experiment shows clearly enough that when an electric current acts on water (H_2O) it separates it into the two gases of which it is formed, and this process is called *electrolysis*. The discoveries made by chemists of the action that takes place when water (H_2O) and other substances in solution are

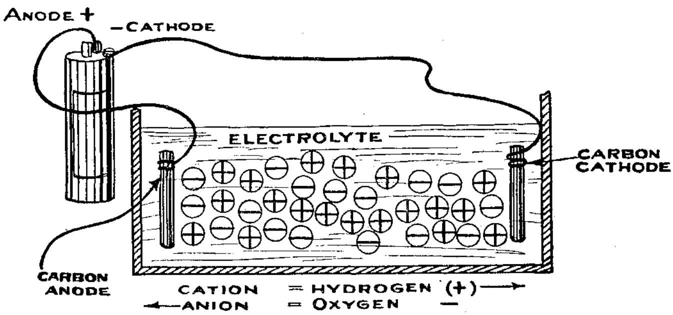

FIG. 73.—Diagram of the Theory of Ionization.

decomposed by an electric current is explained on the basis of what is called *ionization*.

The theory of ionization supposes that the molecules which form the water (H_2O) are made to fall apart, or *dissociate*, as it is called, when an electric current flows through, and the atoms of hydrogen (H) and oxygen (O) are then *ionized* by the electric current, that is, each one takes on a charge of electricity and so they are called *ions*.

The *positively charged* atoms, or *positive* ions, are called *cations*, and the *negatively charged* atoms, or *negative* ions,