affected by it, but in these cases the oxidation is called decay, though the chemical action and the products formed are the same as those produced by burning.

When an animal inhales air, its lungs extract the oxygen ($O$) from it and deliver it to the blood, the red corpuscles of which carry it to all the tissues of its body. On coming in contact with its food that has been eaten, it oxidizes it and forms carbon dioxide ($CO_2$) and water ($H_2O$), with the evolution of considerable heat. The blood returns the carbon dioxide ($CO_2$) to the lungs, whence it is exhaled. The water ($H_2O$) is carried off through the kidneys and the pores, while the heat which is set up is used to warm the body.

The opposite process to oxidation is called *reduction*, and just as oxidation is the result of oxygen ($O$) combining with a substance, so reduction is the result of hydrogen ($H$) combining with a substance. In other words, when oxygen ($O$) combines with a substance, or hydrogen ($H$) is removed from it, it becomes oxidized, and when hydrogen ($H$) combines with a substance or oxygen ($O$) is removed from it, it is reduced.

**What Spontaneous Combustion Is.** It is possible for a slow oxidation to become so accelerated, or quickened, that enough heat will be generated to make a fire, and this kind of an action is called *spontaneous combustion*. The way in which this takes place will be clear when you know that any body that can be oxidized, as for instance iron ($Fe$), will set free exactly the same amount of heat when it combines with oxygen ($O$), no matter how slow or how fast the combining action takes place.

When oxygen (*O*) combines with a substance slowly and the latter has plenty of air around it to conduct away the heat as fast as it is developed, there can be no excess of it stored up. But if the substance contains hydrogen (*H*) and carbon (*C*), that is, if it is inflammable, such as oil-soaked rags, and enough air can reach these rags to set up oxidation, but not enough to carry away the heat as fast as it is generated, then the latter will be stored up until the temperature reaches a high-enough point to cause the rags to burst into a blaze.

**Substances that Oxygen Will Not Affect.** There are some substances that oxygen (*O*) has no effect on and, hence, these cannot burn. While iron (*Fe*) oxidizes rapidly in moist air, it does not oxidize in dry air, and it is therefore largely used for cooking utensils and other purposes.

Gold (*Au*), silver (*Ag*) and platinum (*Pt*) will not oxidize in air, and they are in consequence widely used in the arts, the first two being especially useful for coinage and for jewelry, while the latter, which has a high melting point and is not affected by acids,[1] is useful in certain chemical operations.

**How to Make Ozone.** As early as 1785 Marum observed that wherever the sparks of an electrical machine appeared a fresh, penetrating odor, something like that of very dilute chlorine (*Cl*) was produced. In 1840 Schönbein discovered that the odor was due to a gas, and this is called ozone ($O_3$) from a Greek work which means to smell.

Ozone ($O_3$) is made by adding an extra atom of oxygen (*O*) to a molecule of oxygen (*O*), which is formed of two

[1] Except aqua regia, see Chapter XII.

atoms of oxygen ($O$), and this you will find described and pictured in Chapter X. There are several ways by which oxygen ($O$) can be changed into ozone ($O_3$), but the easiest way to do it on a small scale is to set up an electric spark, and this you can do with either a Leyden jar or a spark coil. Ozone ($O_3$) has powerful oxidizing properties and it is therefore a good bleaching agent and disinfectant.

**How to Test for Ozone.** Put 1 part of pure potassium iodide ($KI$), 10 parts of starch $(C_6H_{10}O_5)_x$, and 200 parts of water ($H_2O$) into a beaker and boil them together for 3 or 4 minutes, and they will form a paste. Spread this on a sheet of writing paper evenly, let it dry, and then cut it into strips, and you will have Schönbein's ozone test paper; place these strips together and wrap them up in waxed paper so that the air cannot act on them. If now you will take out one of the strips and moisten it and then put it in air that contains ozone ($O_3$), even if this is so weak you cannot smell it, the paper will instantly change to a blue color.

## CHAPTER III.

## EXPERIMENTS WITH OXYGEN, NITROGEN, AND CARBON DIOXIDE

KNOWING now something of the nature of air and the chief gases of which it is formed, the next step is to make a small quantity of each one and perform the experiments described in this chapter. Of course you do not really make the gases, but what you do is to separate them, either from the air, which, as you will remember is a mechanical mixture, or else from other substances with which they are chemically combined, and the latter is generally the easier way.

### EXPERIMENTS WITH OXYGEN.

**A Simple Way to Make Oxygen.** With this simple apparatus you can make enough oxygen ($O$) to do some pretty experiments with, but, naturally, the effects are not so striking as where larger quantities of the gas are used. Put ½ teaspoonful of potassium chlorate ($KClO_3$) and the same amount of manganese dioxide ($MnO_2$) into your largest test tube and hold it with your test-tube holder over the flame of your alcohol lamp or Bunsen burner, as shown in Fig. 39, and very soon oxygen ($O$) will be set free. Now slowly sprinkle a little finely powdered charcoal ($C$), sulphur ($S$) and other substances, in turn, into the tube by means of a tin trough and you will get some very pretty effects.

**A Way to Make More Oxygen.** To make a larger quantity of oxygen (*O*) than is possible with the apparatus described above, you will need a small flask with a tightly fitting cork in it; a ring stand, and an alcohol lamp or a Bunsen burner. Now take a piece of glass tubing about a foot long, heat it in the flame of your lamp, and bend it

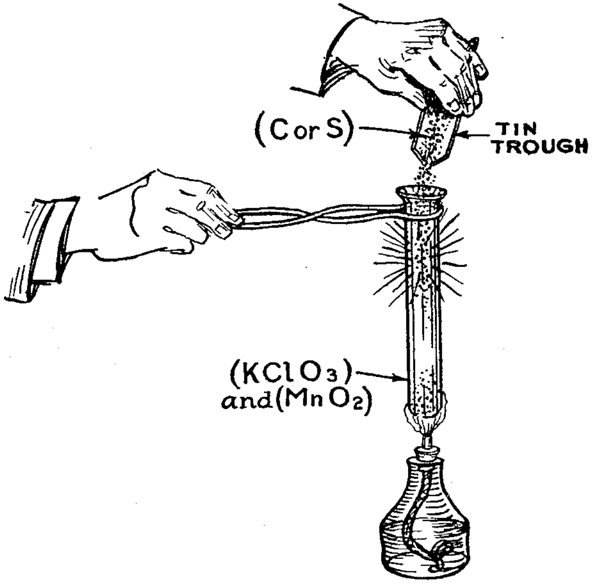


FIG. 39.—How to Make and Experiment with a Little Oxygen.

to the shape shown in Fig. 40. This done, make a hole in the cork and push the short end of the tube into it.

Next take a large cork and bore a ½-inch hole half-way through it from top to bottom, and bore a ⅜-inch hole through the side of it until it meets the first one, as shown by the broken line in Fig. 41. Push the free end of the tube into this latter hole and set the cork in a glass finger-bowl or other dish. Fill the bowl with water ($H_2O$) so that it covers the top of the cork, then fill a large test tube with water ($H_2O$), invert it, and set it on the cork over the hole.

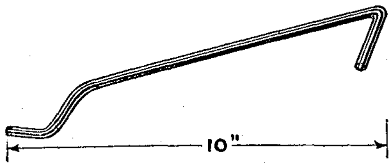


FIG. 40.—How the Delivery Tube is Bent.

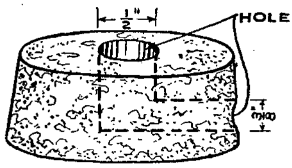


FIG. 41.—The Hole in the Cork.

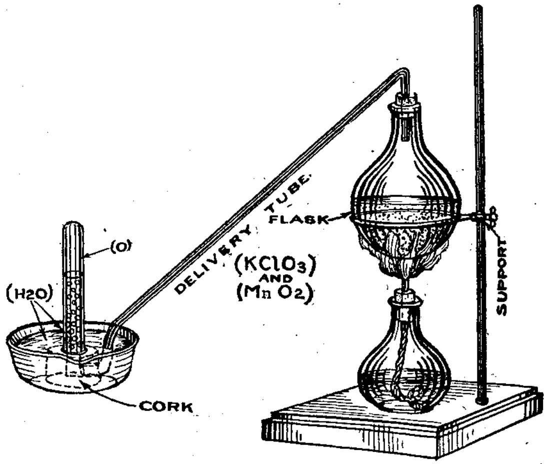


FIG. 42.—The Oxygen Apparatus Complete.

Finally, put 1 ounce of potassium chlorate ($KClO_3$) and 1 ounce of manganese dioxide ($MnO_2$) into the flask, then fit the cork in tight and set it in the ring of the stand with your lamp or burner under it, as shown in Fig. 42. Light the lamp and the heat will soon act on the mixture, setting the oxygen (*O*) of it free, so that it will pass through the delivery tube and up through the water to the top of the test tube. As it gathers there, it will push the water down, and in this way you will know how much oxygen there is in the tube.

**How the Experiment Works.** When the mixture is heated, the potassium chlorate ($KClO_3$), which contains 39 per cent of oxygen (*O*), gives up the latter and no action whatever takes place in the manganese dioxide ($MnO_2$). But if you heat the potassium chlorate ($KClO_3$) without having the manganese dioxide ($MnO_2$) in contact with it, you will have to bring it to a very much higher temperature before it will be decomposed and liberate its oxygen (*O*).

Whenever the addition of a substance causes a chemical reaction to take place more rapidly, yet the substance is found at the end of the reaction apparently unchanged, the substance is called a *catalytic agent* and the process is called *catalysis*.

**The Self-Lighting Match.** Place a large test tube over the delivery tube of your oxygen (*O*) generator and when it is full of oxygen (*O*) remove it and hold it with its mouth down. Light a match around which a wire has been twisted, as shown in Fig. 43, and blow it out, leaving only a glowing spark. Now, if you insert the smoldering match by aid of the wire into the tube of oxygen (*O*), the match will at once ignite again and blaze with more brilliancy than before, as in Fig. 44.

**How the Experiment Works.** The air, as we know, is oxygen ($O$) diluted with about three times its volume of nitrogen ($N$). The number of particles of oxygen ($O$) in a given volume of air is, therefore, much less than in the same volume of pure oxygen ($O$). When combustion takes

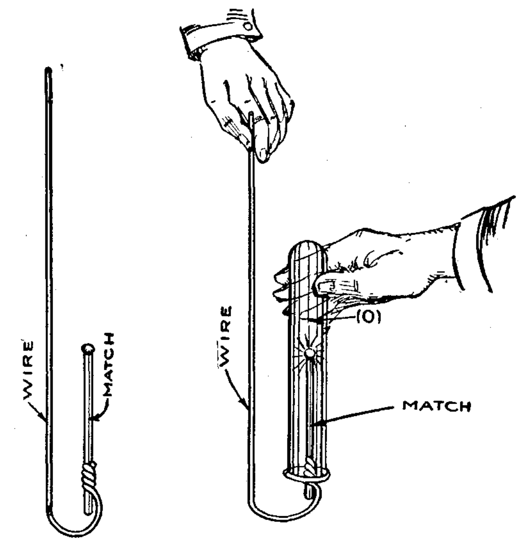


FIG. 43.—
The Wire on the Match.

FIG. 44.—
The Self-Lighting Match.

place in pure oxygen ($O$), the heat that is liberated is expended in raising the temperature of the oxygen ($O$) alone, and the rapidity of the combustion depends chiefly on the temperature of the oxygen ($O$).

**The Flashing Charcoal Pill.** For this and the following experiments use a beaker, or a glass tumbler will do, instead of the test tube, so that you can have a larger quantity of oxygen ($O$) to work with. Take a bit of charcoal, which is practically pure carbon ($C$), made of bark, or very soft wood, about the size of a pea and fasten the end of a bent wire to it to form a handle.

Soak a bit of cotton in alcohol ($C_2H_5OH$) and wrap this around the charcoal pellet. Now light the cotton and hold it in the beaker or tumbler of oxygen ($O$), and the cotton will quickly burn away and the incandescent charcoal ($C$) will throw out flashes like an arc light.

**How the Experiment Works.** When carbon ($C$) burns in more oxygen ($O$) than it needs to support combustion, carbon dioxide ($CO_2$) is formed. You can prove this by moistening a piece of blue litmus paper and, after the charcoal pellet has burned out, pressing this paper against the inside of the beaker, or tumbler. It will turn red. This is because when carbon dioxide ($CO_2$) is dissolved in water it makes carbonic acid ($H_2CO_3$), though neither carbon dioxide ($CO_2$) nor water ($H_2O$) has any acid property in itself.

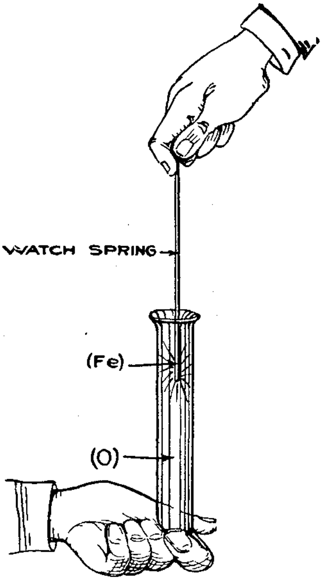


FIG. 45.—The Scintillating Watch-Spring.

**The Scintillating Watch-Spring.** Take a piece of watch spring ($Fe$) about 6 inches long and straighten it out by running it between your fingers. Wrap a bit of cotton which you have moistened in alcohol ($C_2H_5OH$) around one end and light it. Then hold the steel spring in a test tube or a beaker of oxygen (*O*) and it will ignite and, once started, will burn with great brilliance, scintillating beautifully, as shown in Fig. 45. At the same time incandescent drops of dross will fall and a reddish vapor will condense on the surface of the test tube or beaker.

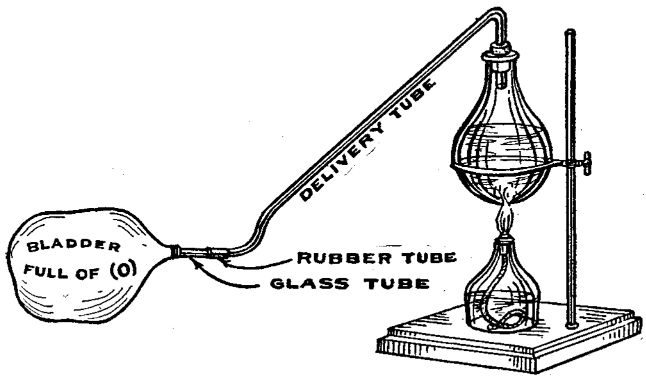


FIG. 46.—Filling the Bladder with Oxygen.

**How the Experiment Works.** When iron (*Fe*) burns in oxygen (*O*) they combine and form ferrous oxide or *oxide of iron* (*FeO*) as it is called. This substance is a neutral compound, that is, not acid nor yet alkaline, and this you can easily prove with a piece of litmus paper.

**The Strange Action of Oxygen on Phosphorus.** Connect the free end of the delivery tube of your oxygen-making apparatus, see Fig. 46, with the tube in a toy rubber balloon, or a bladder, then generate enough oxygen (*O*) to inflate it,