extend just inside the jar and the latter will reach nearly to the bottom of it, as shown in Fig. 134.

Now put a lighted candle inside of the jar and you will observe that as it burns, vapor of water (H_2O) and carbon dioxide (CO_2) escape through the short tube. As they do so, fresh, cool air from the outside flows through the long tube into the jar and provides the necessary oxygen (O) to support the burning process. This experiment done, put your finger over the end of the long tube so that the fresh air is cut off, and the flame will soon begin to grow smaller, and finally it will go out altogether.

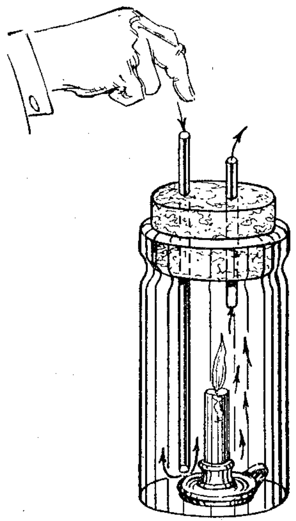

FIG. 134.—How Ventilation Affects Combustion.

How the Davy Safety-Lamp Works. Sir Humphrey Davy invented a safety-lamp, so that when miners who carried it entered a shaft where there was methane (CH_4), or *fire-damp*, as it is generally called, and which when mixed with air is very explosive, it would not ignite. His safety-lamp consists of a common oil lamp, the flame of which is surrounded by a wire gauze cover, as shown in Fig. 135. Now while enough oxygen (O) will reach the flame to keep it burning, the flame cannot get outside of the gauze to ignite the explosive gases.

To make an experiment which shows the principle of the safety-lamp, take a piece of fine wire gauze about 8 inches on the sides and which has about 10 meshes to the running inch and hold it in the flame of a candle with a pair of pliers, as shown in Fig. 136, and you will see that the flame remains beneath it. The reason it does not go through the gauze is because the wire of which it is made cools down the flame to such an extent that it puts it out, but the smoke and other gases of combustion pass through it readily enough.

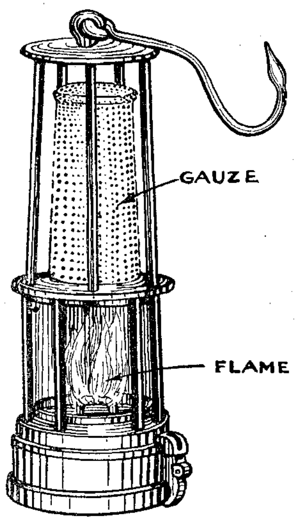

FIG. 135.—The Davy Safety-Lamp in Operation.

Now hold a lighted match above the gauze and the gases will ignite and will make another separate flame. The fact that a flame cannot pass through a piece of gauze is the principle, then, upon which the Davy safety-lamp is based.

How an Alcohol Lamp Burns. It often happens that a flame does not give out any useful light, and usually this kind of a flame is very hot. This is the case when pure hydrogen (H) burns in oxygen (O), generally obtained from the air. Now methyl alcohol (CH_4O) contains, as its formula shows, 4 times as much hydrogen (H) as it does carbon (C).

To produce a flame that has no useful lighting power, you must have not only a certain amount of oxygen (O) present, but it must be mixed with the hydrogen (H). When hydrogen (H) is mixed with oxygen (O), it gives a very hot flame, and this condition is fulfilled in a very simple manner in a lamp that burns alcohol (CH_4O).

How Oil and Gas Lamps Burn. When we want a bright light we must burn compounds that contain hydrogen (H) and carbon (C), and certain vegetable and mineral oils have them in the right proportions. Generally speaking, an oil to burn with a bright light must have a large amount of carbon (C) compared with the hydrogen (H) in it, and,

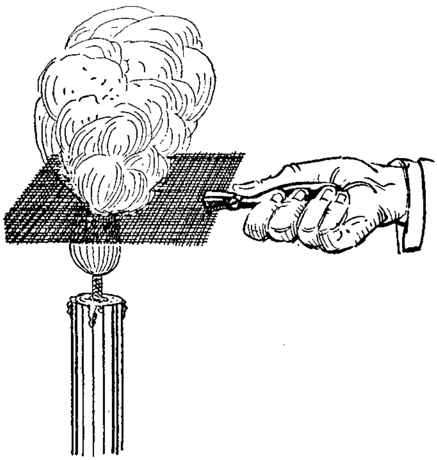

FIG. 136.—The Principle on Which the Davy Safety-Lamp Works.

further, its illuminating power also depends on the amount of oxygen (O) in which it burns, and this must be supplied gradually and from the outside.

Illuminating oils, like kerosene ($C_{10}H_{22}$ to $C_{16}H_{34}$) and gases such as coal-gas (C_2H_4) do not contain oxygen (O), and these burn, therefore, with the brightest light. A tallow candle ($3\ C_{18}H_{35}, C_3H_5O$) contains a little oxygen

(O),and it burns with a less bright flame than oil or gas, while alcohol (CH_4O) contains considerable oxygen (O) in proportion to its hydrogen (H), and so it burns without any brightness whatever.

How a Bunsen Burner Works. While coal gas burns with a bright flame and with little heat in an ordinary burner, it can be made to burn with a flame that is hot, gives no light, and which does not smoke, by using what is called a *Bunsen burner*. It is so-called because it was invented by Bunsen, a German scientist who lived from 1791 to 1860.

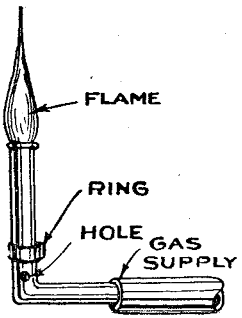

FIG. 137.—The Bunsen Burner.

A Bunsen burner in its simplest form consists of a brass tube ⅜ inch or ½ inch in diameter with a couple of air holes drilled through it near one end. A ring is slipped over the tube so that the amount of air which enters the holes can be controlled, and it is then connected with the pipe that supplies the coal gas, all of which is shown in Fig. 137. The purpose of the air-holes is to supply enough oxygen (O) to burn up the carbon (C) in the gas, and this makes the flame not only non-luminous but at the same time very much hotter.

EXPERIMENTS WITH A BUNSEN BURNER.

How to Light the Burner. The right way to light a Bunsen burner is to turn on the gas and then hold a match to one side of the top of it, upon which the gas will catch fire. If you hold the match over the top of the tube, the pressure of the gas may blow it out before the gas ignites.

The Luminous Flame of the Burner. Slip the ring over the holes in the burner so that it will cut off the air supply and, hence, the oxygen (O), and you will see that the flame gives out light, and if you hold a sheet of glass, or card-board, over it, a film of carbon (C), which is ordinarily called *soot*, will be deposited on it.

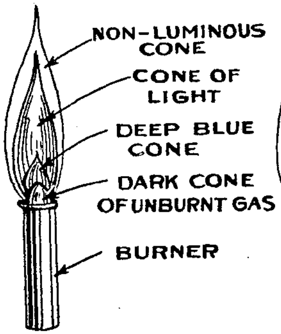

FIG. 138.—A Luminous Gas Flame.

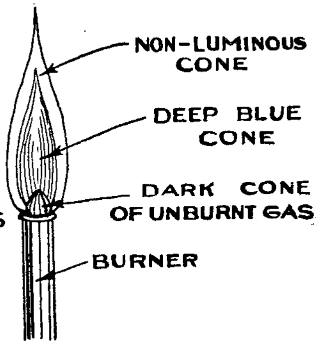

FIG. 139.—A Non-Luminous Gas Flame.

Now examine the flame and you will see that it is formed of four parts, as shown in Fig. 138; named, these are a dark blue cone next to the burner, next, a deep blue cone, then, a luminous cone containing glowing particles of carbon (C), and, finally, a colorless cone, or sheath, on the outside.

The Non-Luminous Flame of the Burner. After you have made the above experiment, slip the ring up and away from the air-holes, and as you do so you will see that the characteristics of the flame are changed. First of all, the glowing carbon (C) disappears and with it the light of the flame; at the same time the deep blue cone, which is the one that gives the heat, expands and takes its place, as shown in Fig. 139.

A closer examination of the flame will reveal the fact that the extreme tip is the hottest part of it, the next, or middle cone is not so hot, while the dark cone at the bottom is quite cool; this means that the gas is not burning at this point, and if you will put a small glass tube into it the gas will flow through it, and you can light it, as shown in Fig. 140.

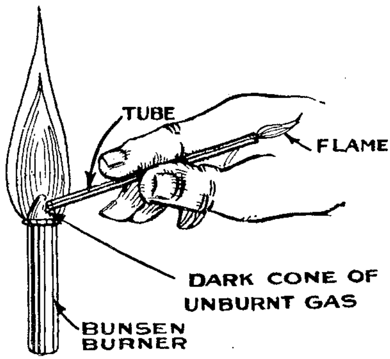

FIG. 140.—Proving the Dark Cone to be Unburnt Gas.

How to Make Colored Flames. To produce beautiful colored flames, get a piece of *pumice stone*, which is very porous and non-combustible, and fashion it into a ball about 1 inch in diameter; now fasten an iron wire around it, then dip it into any one of the following solutions and hold in the flame of an alcohol lamp or, better, a Bunsen burner, and the salt of which the solution is formed will give a characteristic color.

The solutions are made by dissolving the salts in water (H_2O), and these should be quite strong. Strontium chloride ($SrCl_2,6H_2O$) will give a bright red flame; calcium chloride ($CaCl_2$) will give a reddish-orange flame; copper chloride ($CuCl_2$) will give a bluish-green flame, and sodium chloride ($NaCl$) will give a brilliant yellow flame.

To see the colored flames to the best advantage, you must burn the salts in a dark room. A most curious effect is produced by burning sodium chloride ($NaCl$) so that the light from it will shine in the faces of the spectators, giving them a ghastly appearance. To prevent the solutions from dripping into the tube of the burner and so stopping it up, it is a good plan to lay it on its side, as shown in Fig. 141.

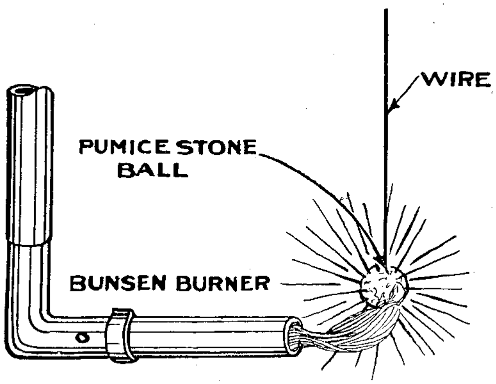

FIG. 141.—Production of Colored Flames.

How to Make Charcoal. Our sun is the original source of all the light, heat, and power we have here on earth, as well as everything else, and hence the energy stored up in all our fuels has come from it. For instance, the light and heat of the sun make plants grow, and these when large enough form trees, and are composed of wood.

In turn, wood is largely made of carbon (C), and by heating it in an enclosed space so that little or no air can get to it the gases are forced out of it and nearly pure carbon (C) is left behind. Now when carbon (C) is made to burn in oxygen (O), and the air supplies the latter, a very hot, flameless fire results.

To make a little charcoal (C), drive three sticks, each about 18 inches long into the ground, about 2 inches apart, then build up a conical pile of wood around them and leave

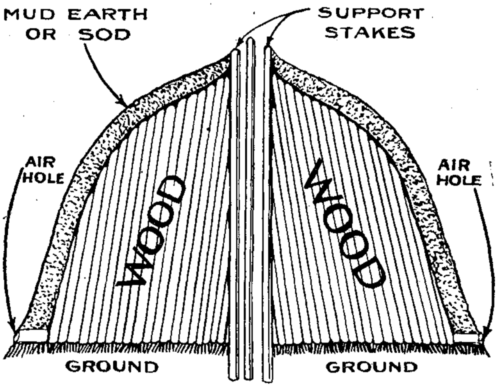

FIG. 142.—Cross-Section of a Charcoal Kiln.

a little space between the sticks, as shown in Fig. 142. This done, plaster it all over with mud so that the air cannot get through it to the sticks and then make a dozen holes, about 1 inch in diameter, through the mud covering, around the base, and also let the top remain open. This is so that when you light the wood the gases will slowly burn out of it and yet not burn the carbon (C) there is in it.

How Charcoal is Made. When the wood begins to burn, the used gases pass out of the kiln and you will see them as a thick black smoke. After 24 hours or so, all the gases in the wood will be burnt out and only charcoal (*C*), which is an impure kind of carbon (*C*), is left behind. The substances in the wood that will not burn are left behind as ash.

What Coal is. When trees and other plant matter are covered over with sand or clay, as the great forests were in the pre-historic ages, so that the air cannot reach them,

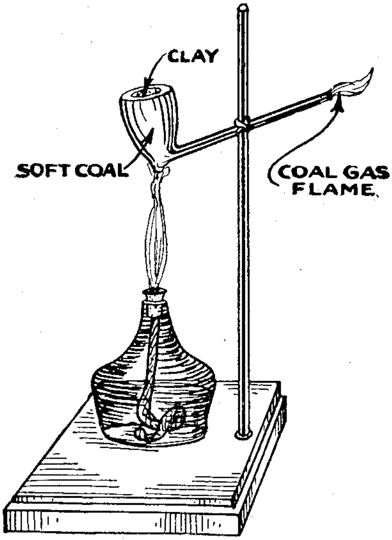

FIG. 143.—A Miniature Gas Works.

they decompose, that is, they *oxidize*, and the water (H_2O) and gases and oils that are in them are set free, and the matter that is left behind is called *coal* (*C*).

Now there are two kinds of coal (*C*), and these are *bituminous*, or *soft*, coal, and *anthracite*, or *hard*, coal. Bituminous coal is coal that still contains large amounts of hydrogen

(H) and oils of various kinds, and, hence, this kind is used for making illuminating gas. The coal is put into closed retorts, and after the gases and oils have been driven out of it by heat, there remain behind *coke* and *coal-tar*, and from the latter, dyes, perfumes, and medicines are made. Anthracite coal is nearly pure carbon (C), and it burns without flame, makes very little smoke, and leaves but a small amount of ash behind; it is, therefore, the most suitable kind of coal for heating purposes.

How to Make Coal Gas. Take a clay pipe and fill it with powdered soft coal and then close up the mouth of it with a piece of clay. Now heat the pipe in the flame of your alcohol lamp, or, better, because it is hotter, your Bunsen burner, and the hydrogen (H) will be driven out, and this you can light at the end of the stem, as shown in Fig. 143. When all the gas has passed out, you will find a little lump of hard, black porous matter in the pipe bowl, and this is coke, while the sticky substance that remains is coal-tar.