can be shown that the upper limit of it is only about 50 miles.

Another way to find the approximate height of the upper limit of the atmosphere is with a *barometer*. This is an instrument that really measures the weight, or pressure, of the air, and as this decreases with its height it is easy to

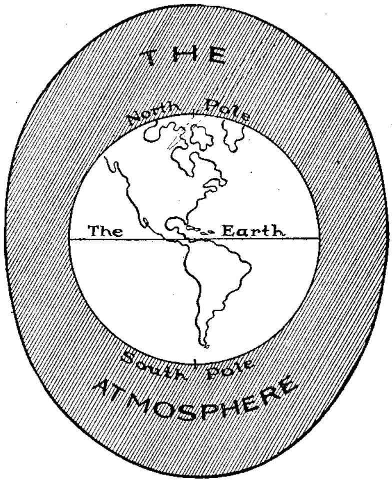

FIG. 32.—The Earth's Atmosphere is Shaped Like a Football.

calculate its upward limit by taking several readings of the barometer at different levels near the surface of the earth. This method shows that the height of the atmosphere is about 100 miles.

A third and very interesting way to find the height of the air, is by the *length of twilight*. If the earth were not surrounded with an atmosphere, there would be no twilight and the day would suddenly change into night the moment the sun sank below the horizon. But if the earth's atmosphere reached a height of a thousand instead of a hundred miles or so, then we should have daylight all the time, for the light of the sun is refracted, that is, it is bent out of its course, and diffused, or spread out by the gases of which the former is composed, and so some of the light from it would reach us whatever the relative positions of the earth and sun might be. Hence, it is the height of the atmosphere that determines the length of our twilight.

Thus while the sun is yet below the horizon in the morning, its rays are bent up and we get some of its light when we have dawn, and again when the sun drops below the horizon in the evening, and then we have twilight.

In the extreme northern and southern regions where the days are the longest, twilight is always present, so that there is enough light to see by throughout the whole night. Oppositely, at the equator twilight is very short, and on top of the Andes it lasts for only about half an hour. By figuring the height of the atmosphere on the basis of the length of twilight, the results show that the limit of the atmosphere is reached in the neighborhood of 200 miles above the earth's surface.

The Weight or Pressure of the Air. The atmosphere must have weight or else it would not cling so tightly to the earth's surface, and since it has weight it must exert a pressure on the surface of the earth. It must be clear, too, that having weight the atmosphere is denser directly on the surface of the earth than it is at the upper levels, in fact a cubic foot of it weighs 1¼ ounces at sea level, while its pressure at sea level is, roughly, 15 pounds to the square inch.

Experiment to Show that the Air has Weight. Here is an experiment that not only shows that the atmosphere has weight but also that it has pressure, and that this is equal in all directions. Take a tumbler that has a flat rim and fill it full of water (H_2O). Then lay a piece of cardboard on top of it and then invert it, that is, turn it upside

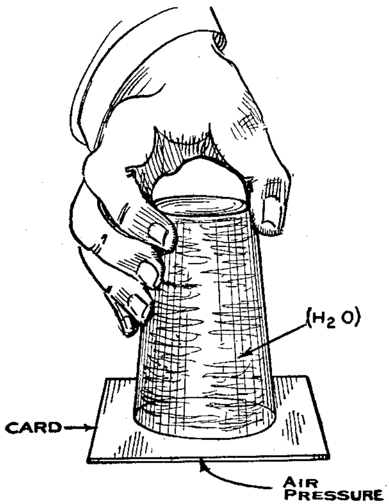

FIG. 33.—An Experiment which shows that the Air has Pressure.

down, as shown in Fig. 33. While the water (H_2O) weighs so much more than a like volume of air, the pull of gravity on the water (H_2O) will not make it run out, because the force is less than that of the pressure of the air on the surface of the cardboard.

What an Element Is. An *element* in chemistry is a form of matter that cannot be changed into any simpler form.[1] A *substance* is a mass of matter that is made up of one or more elements. Some substances are made up by *merely mixing* two or more elements together *mechanically*, and others are made up by *combining* two or more elements *chemically*.

Experiments to Show what a Mechanical Mixture Is. The two following experiments will give you a very good

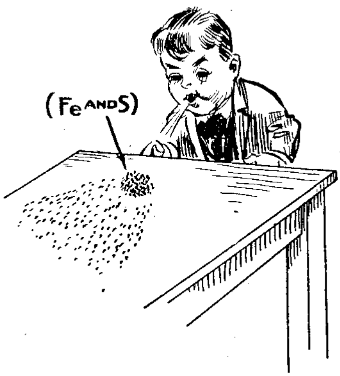

FIG. 34.—Separating Iron Filings from Sulphur by a Stream of Air.

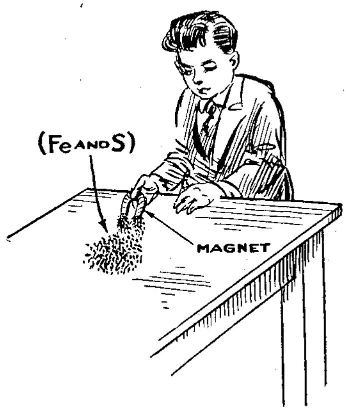

FIG. 35.—Separating Iron Filings from Sulphur with a Magnet.

idea of what a mechanical mixture is and why. Take some *very fine* iron filings (*Fe*) and an equal amount of *pulverized sulphur* (*S*) and stir them well together, as though you were going to make a pie. The mass will then take on a greyish color. There has been no chemical action between the two elements, and to prove that they are simply mixed together you have only to pour them out on a sheet of paper

[1] The splitting up of the atoms of various elements by Rutherford modifies this statement somewhat, but it still holds good for all ordinary purposes.

and then blow gently on them, as shown in Fig. 34, when the sulphur (*S*), which is very much lighter than the filings, will be carried away, and the iron (*Fe*) only will remain.

A somewhat more scientific test is to hold a magnet close to the mixture, as in Fig. 35, when the iron (*Fe*) filings will be attracted to the poles of it and the sulphur (*S*) will be

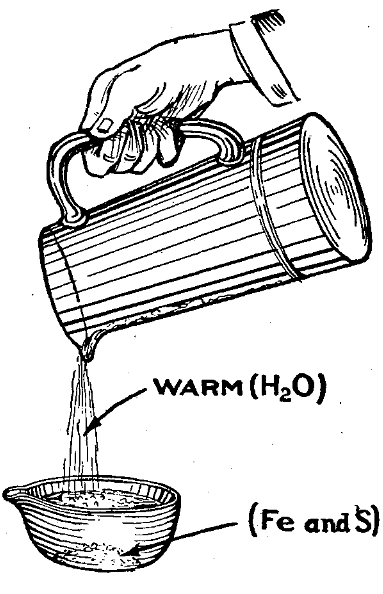

FIG. 36.—Making a Chemical Compound.

left behind. The above experiments show clearly enough that the mixture is a purely mechanical one.

Experiments to Show what a Chemical Compound Is. The following experiment will demonstrate in a striking manner what a chemical compound is. Put the iron (*Fe*) filings and the powdered sulphur (S) in an earthenware dish and then pour a little warm water (H_2O) over them, as shown in Fig. 36. In a short time you will see that a change is taking place in the mass, that it gets very hot, swells up, and takes on a black metallic-looking color. The resultant mass has none of the characteristics of iron (Fe) or of sulphur (S), but is a different substance entirely from either one of them, for they have combined chemically and now form ferrous [1] sulphide (FeS).

Now gases behave like solids in that they can either be merely mixed or they can be combined chemically, in which case they will form a new substance. Air is formed chiefly of two gases, which are *oxygen* (O) and *nitrogen* (N), and these are *mechanically mixed* in about the proportion of 23 parts of the former to 77 parts of the latter by bulk, or volume, as it is called, and mixed with these are several rare gases which include argon (A), neon (Ne), krypton (Kr), and xenon (Xe)[2]. These elements of the air are called its fixed constituents, because they are always present in it in exactly the same proportions.

Then the air contains certain other elements and substances, the foremost of which is carbon dioxide (CO_2) or carbonic acid gas, as it used to be called, though incorrectly, for it has no acid properties, water vapor (H_2O) and ammonia (NH_3), and these are known as its variable constituents. Besides these elements and substances of and

[1] The Latin name for iron is *ferrum*, and from this we get the words ferric and ferrous. The word ferrous is used to show that the combining power or valance as it is called is lowest, and ferric is used to show that it is highest.

[2] Pronounced ze'-non.

in the air there are dust, bacteria,[1] and yeast spores floating around in it.

Carbon dioxide (CO_2) is a colorless, odorless compound that is heavier than the air and is formed by the chemical combination of carbon (C) and oxygen (O), and it is this gas that is used to make soda water fizz and sparkle and to cause bread dough to rise. The water vapor (H_2O) consists of oxygen (O) and hydrogen (H) chemically combined, as you will see in Chapter V, while ammonia (NH_3) is nitrogen (N) combined with hydrogen (H).

What the Air Is Good For. Air as a *physical* substance is used at *atmospheric pressure*, that is, just as it is, as a medium for flight by both the winged animals and man, it is also used in the form of *compressed air* and in a *rarefied state* for various industrial as well as experimental purposes. Its first and chief use as a *chemical* substance is in supporting animal life, and the second in supporting combustion, but in both of these cases it is only the oxygen (O) it contains that is used, the nitrogen (N) merely serving to dilute and to spread it. Air can also be liquefied by extracting the heat of it, and liquid air is largely used for experimental purposes.

About Burning and Combustion. When any element or compound combines violently with oxygen (O) it generates heat and often gives off light, and we call this action *burning*, and the process is known as *combustion*. Oxygen (O)

[1] Bacteria, which is the plural of bacterium, or microbes, as they are popularly called, are vegetable organisms so small that they can only be seen with a high-power microscope. Nearly all of them are harmless, but a few of them are the cause of various diseases.

then, supports combustion, but while it will combine with other elements to make them burn it will not, strange as it may seem, burn itself, and it is well it will not, for otherwise the world would have been consumed in the making.

The reason, then, that you have to supply air in large quantities to make fuel burn is to give the hydrogen (*H*) and carbon (*C*) in it plenty of oxygen (*O*) to combine with, and this is why you blow on or fan a freshly started fire to make it burn, and have a chimney to give the stove, fireplace, or furnace, a draft.

What Rusting, or Oxidation Is. When an element or a substance *unites slowly* with oxygen (*O*), the action is called *rusting*, or *oxidation*. Here are some simple experiments which show how iron (*Fe*) and other metals rust.

Experiment to Show how Iron Rusts. Take a piece of iron (*Fe*) and clean it well, so that there will be no grease on it, or you can file it so that it will expose a clean surface, and then lay it on a damp cloth in the open air. Let it remain over night, and you will then find that the surface of it will be covered with a reddish powder. The iron (*Fe*) has combined with the oxygen (*O*) of the air and formed what we ordinarily call rust, but the chemical name of which is *ferric oxide* (Fe_2O_3), and this is sold as *rouge* and *Venetian red*.

Experiment to Show that other Metals Rust. Nearly all the other metals will rust when they are exposed to oxygen (*O*), but not nearly so quickly as iron (*Fe*), and so instead of saying that they rust we say that they tarnish. Lead (*Pb*) and zinc (*Zn*) will rust in air at ordinary temperatures, but the change is very slow.

Put a small piece of lead (*Pb*) into a porcelain crucible, set it on a stand and place a lighted alcohol lamp, or a Bunsen burner, under it, as shown in Fig. 37; when the lead is melted, stir it with an iron wire and you will soon see a murky yellowish powder appear on top of it; and as you continue to stir in the oxygen (*O*)—for this is what you are really doing—more of the lead is changed into rust, which

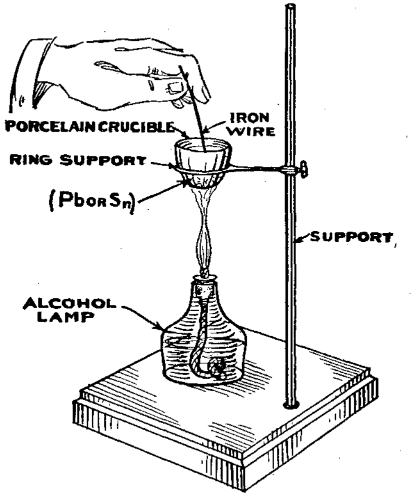

FIG. 37.— Apparatus for Making Lead and Tin Rust.

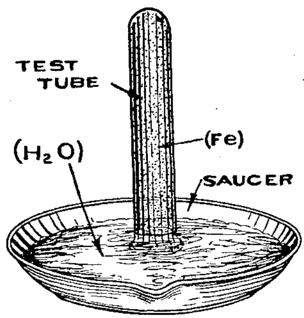

FIG. 38.—Apparatus to Show that Air is Used when Iron Rusts.

is chemically called *lead oxide* (*PbO*). Now melt a piece of tin (*Sn*) and stir it in the same way, and a white power, which is *tin oxide* (*SnO*), will be formed.

Experiment to Show that Air is Used Up when Iron Rusts. This experiment shows that air, or rather the oxygen (*O*) of the air, is used up when iron (*Fe*) rusts.

Take a test tube and dampen the inside surface of it; now put some very fine iron (*Fe*) filings into it and turn the tube over and over until the filings stick to the damp surface; this done, invert the tube, that is, turn it with the open end down, and set it in a saucer of water, as shown in Fig. 38.

The first thing that takes place is that the weight of the atmosphere, or outside air, on the surface of the water (H_2O) in the saucer presses down on it and this forces it up in the tube a little and presses the air that is in the tube into closer contact with the particles of iron (*Fe*). The oxygen (*O*) of the air in the tube makes the damp particles rust and it is thus used up; this leaves more space in the tube so that the weight of the outside air on the water (H_2O) in the saucer presses it still farther up the tube.

In the course of an hour or two, so much of the oxygen (*O*) in the tube will be used up that the water (H_2O) will have reached a height of about $\frac{1}{5}$ of the length of the tube. If, now, you will examine the tube, you will see that some of the particles of iron have taken on a brick-colored hue, and this is due to the rust that has formed on the surface of them.

All the particles would rust away if enough air could be supplied to the tube to supply the necessary oxygen (*O*) to them. The reason that only $\frac{1}{5}$ of the tube is taken up by the oxygen (*O*) is, obviously, because the other $\frac{4}{5}$ is taken up by the nitrogen (*N*), which is not a very active gas.

How Slow Oxidation Causes Decay. Metals are by no means the only elements and substances that are rusted by oxygen (*O*); vegetable and animal matter are likewise