form of a *mass*. A mass of any kind is built up of *molecules*, which in turn are built up of *atoms*, and, finally, the latter are built up of *electrons*. The way in which atoms form molecules and the latter form masses is shown in the diagram in Fig. 129, and the way an atom is built up of electrons is shown in Fig. 130.

The center of an atom is built up of a number of compact *positive* charges of electricity called *electrons*, which are represented by the black dots, and these are surrounded by less compact charges of *negative* electricity, also called *electrons*, which are shown by the white circles. It is the number of positive charges of electricity an atom has that determines whether it is iron (*Fe*), or sulphur (*S*), or oxygen (*O*), etc.

Now the main things for you to remember in chemistry, until you get into that part of it in which electric currents are used, is that an atom is the smallest particle into which matter can be divided without changing its nature, and two or more atoms bound together by chemical affinity form a molecule.

The molecules of a solid are held together by a much stronger attractive force than they are in a liquid and while they are constantly vibrating, that is, moving to and fro, still they cannot move freely about, and so the body keeps its shape. In a liquid they move about quite freely, but still they are held together by an attractive force. It is, however, the force of gravity that pulls them down, and so makes the liquid take on the shape of the vessel that holds it.

The action of a gas is quite different, for all the molecules repel each other exactly as if they were charged with the same sign[1] of electricity, and, hence, they shoot out in every direction. This is the reason why a gas when it is compressed exerts a force against all of the inside surface of a tank, or a gas-bag, that holds it.

What the Elements Are. An *element* is a mass of matter that is built up of molecules, which are, in turn, formed of atoms all of which are of a single kind. Two or more of these atoms may be linked together to make up a molecule, as shown in Fig. 131; this is the way that the molecules which form oxygen (*O*) are linked together. Sometimes the element itself is changed when an extra atom of the same kind is added to those that form the original molecule; thus if 3 atoms of oxygen (*O*) are linked together, as shown in Fig. 132, then the molecule becomes ozone (O_3).

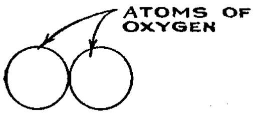

FIG. 131.—Two Atoms of Oxygen Make a Molecule of Oxygen.

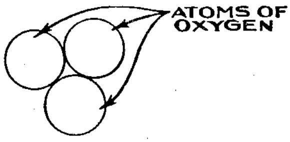

FIG. 132.—Three Atoms of Oxygen Make a Molecule of Ozone.

There are 92 elements theoretically possible, of which 90 are now reasonably well established. See "Table of the Known Chemical Elements and Their Symbols," page 282 of this book.

How the Elements Got Their Names. The names of the elements are interesting, but it is not at all easy to trace

[1] That is, either with + electricity or — electricity, for like signs repel each other.

the older ones. Thus iron (*Fe*) and gold (*Au*) are so old that their names are shrouded in obscruity. Many of the elements that have been discovered in recent times get their names from various Greek and Latin words.

Thus chlorine (*Cl*) comes from the Greek word which means *yellowish-green*, as this is the color of the gas. Bromine (*Br*) gets its name from the Greek word which means *stench*, and it is very aptly named, too, for it is a very smelly gas. Hydrogen (*H*) comes from two Greek words which mean *water*, and *to produce*, for water (H_2O) is produced by burning hydrogen (*H*) in air. In the same way, nitrogen (*N*) gets its name from the Greek word which means *nitre*.[1]

The recently discovered gases, helium (*He*), argon (*A*), neon (*Ne*), krypton (*Kr*), and xenon (pronounced ze-non); (*Xe*) are all named from Greek words meaning respectively: the *sun*, *inactive*, *new*, *hidden*, and *stranger*. Finally, some of the other elements are named from their properties, such as radium (*Ra*), and some are named in honor of the countries the chemists were natives of who discovered them, as for instance, scandium (*Sc*), etc.

What the Symbols Mean. In order that the name of each element would not have to be written out every time it was used, or where several of them are used together, as in *equations*, the names of them have been abbreviated and only the first letter or two — usually the first two where more than one is needed — are used to indicate an element; thus *O* stands for oxygen, *H* for hydrogen, *C* for carbon, and so on.

[1] The common name of potassium nitrate (KNO_3) is *nitre*.

Where there are two or more elements that begin with the same letter (there are 10 that start with *C*), the second or third letter of the name is also used as, for instance, *Cl* stands for chlorine, *Ca* for calcium, etc. Then again some of the symbols are formed of the first and second letters of the Latin names of the elements as *Fe* for iron, since *ferrum* means iron, *Cu* for copper, since *cuprum* means copper, etc.

What the Symbols Show. Now whenever you come to a symbol, which let us suppose is *H*, you instantly know that it stands for hydrogen; if it is *O*, you know that it means oxygen, and the same with all the other symbols. Further, when you see two symbols linked together, thus, *HO*, you know that it means a compound is formed of the elements hydrogen (*H*) and oxygen (*O*). When two or more symbols are so linked together to indicate a compound, they make what is called a *formula.*

Wherever you see a formula, you will almost invariably find a number marked in little figures after one or the other, or both, or all, of the symbols thus, H_2O. This number gives you a great deal of information in a very small space — in fact it is the chemists' system of short-hand — for it tells you at a glance that the compound contains 2 volumes of hydrogen (*H*) and 1 volume of oxygen (*O*). This compound is water (H_2O), and so wherever you see the formula you will know exactly what the substance is that the elements have made when combined. Where there is only 1 volume of an element used, as of oxygen (*O*) in the formula for water (H_2O), the figure 1 is not placed after it, but there is understood to be 1 volume, for if there were 2 or more, the number would be added to show it.

While the word *volume* has been used in the above explanation, an experiment given in Chapter IV, in which you analyze water (H_2O) by passing a current of electricity through it, shows that it is made up of 2 volumes of hydrogen (H) and 1 of oxygen (O). It also means that when 2 atoms of hydrogen (H) combine with 1 atom of oxygen (O) they produce a molecule of water (H_2O), and so it is with all other compounds.

What Equations are. When two or more elements are made to combine with each other and two or more other elements or compounds are produced by the reaction, it is called an *equation*, because the quantities you start with and those that you get in the end are exactly equal. Take, for instance, the first equation I have given in this book in Chapter V under the caption of "How to Make Hydrogen without an Acid," which is

$$Zn + KOH = K + ZnO + H \uparrow$$

In this experiment, zinc (Zn) which is an element, is added to potassium hydroxide(KOH),that is, caustic potash, and which is a compound made up, as its formula shows, of potassium (K), oxygen (O), and hydrogen (H). Now when these react on each other, the oxygen (O) of the potassium hydroxide (KOH) combines with the zinc (Zn) and forms zinc oxide (ZnO), and this sets the hydrogen (H) free, and as this is a gas it passes into the air, so that the potassium (K) is left behind.

In the end, though, there is exactly as much zinc (Zn), potassium (K), oxygen (O), and hydrogen (H) as there was in the beginning, and to show that they are equal before and after the reaction, the equality sign is used. The equality sign, however, is not used by chemists nearly as much now as it formerly was in writing equations, a horizontal arrow having taken its place thus:

$$Zn + KOH \rightarrow K + ZnO + H \uparrow$$

If now instead of reading $Zn + KOH$ *equals* $K + ZnO + H$, you will read it $Zn + KOH$ *makes* $K + ZnO + H$, it will be just as sensible, though not quite so definite. As I have mentioned in the experiments that have gone before, where you find an *arrow* pointing *up* after a symbol in an equation, it means that the element or substance which has been set free is a *gas*, and, oppositely, where you find an arrow pointing *down*, it means that the element or substance which has been set free is a *precipitate.*

CHAPTER XI.

FIRE, FLAME, HEAT, AND LIGHT

WHILE, as Darwin has pointed out, man and monkey bear a very strong resemblance to each other, especially in their anatomical make-up, still they are as widely separated as the poles in their mental attributes. One of the most marked features which differentiate them in this latter respect is that the first knows how to make and to use *fire*, and the second shows an utter lack of any such knowledge.

That man began to use fire long before he could make it, there is not the slightest doubt, and he learned how to make it ages before that primitive race, called the Aryans appeared on the Iranian plateau, whence the early Hindus, Persians, Egyptians, and other races branched off. And it is curious to note that the Aryans used the word *agir* for *fire*, and that the Latin word for it is *ignis*, while we use the word *ignite* when we want to convey the meaning that we have lit, or started, a fire.

What Fire Is. When a substance combines slowly with oxygen (*O*), the process is called *oxidation*, and when it combines rapidly with oxygen (*O*), it is said to *burn*, and the process is called *burning*, or *combustion*, while the result of it in throwing off heat and light is called *fire*. The words fire, burning, and combustion, are, however, all generally used to mean the same thing, and that is that a chemical change is going on which produces both heat and light. Fire is, then, the chemical combination of a substance with some other substance that will support combustion, and for all ordinary purposes it is the air that supplies the oxygen (*O*) for the latter purpose, and this it does in unlimited quantities.

What Flame Is. When a solid substance burns that is formed chiefly of charcoal (*C*) or coke (*C*) or anthracite coal (*C*), the molecules of it are heated to incandescence, and while this gives out heat and a glowing light, it does not produce a flame. But when a substance that is formed of a gas or has gas in it burns in another gas that will support combustion they combine chemically, and the heated molecules flare up where the two gases come together, and this makes a flame, or blaze, as it is popularly called.

What Heat Is. A particle of matter just large enough to be seen by a microscope of fairly high power is formed of 8 or 10 billions of molecules. Now when a substance burns, the rapid chemical combination that takes place between it and the oxygen (*O*), or other substance which supports combustion, sets the molecules of which they are formed into violent vibration, that is, it gives them a rapid to and fro movement. In turn, these swiftly moving molecules strike those of the air, and when these reach the body they set the *thermal nerves* of the latter into vibration; these vibrations are transmitted to the brain and we get the sensation of *heat*. Or if they impinge on some inanimate mass of matter they make the molecules of it vibrate, and so it in turn gets hot.

What Light is. When a substance of any kind burns it gives out *light*. Now in the same way that the vibrating molecules of a burning substance set the air into motion they also set the *ether* into motion. The ether is a very thin and transparent kind of matter that fills all space which is not actually taken up by matter of other kinds, and it fills the pores of the densest metals. It is the substance by, in, and through which not only light, but all other electromagnetic waves travel. When the light waves reach the optic nerves of your eyes they set up the sensation of light in your brain, and they also have a very decided action on substances of various kinds, as you will see later in the chapter on photography.

Ways of Making Heat and Light. Our sun is, of course, the original source of all heat and light, and however these are produced, they are *directly* traceable to the sun. Heat is not always accompanied by light, but burning is; on the other hand, light may be had without any appreciable amount of heat accompanying it.

When heat is produced without light it means that the molecules of the substance that is heated are not vibrating fast enough to produce light. Oppositely disposed, the molecules of certain substances are capable of vibrating fast enough to set up light and yet not slow enough to produce heat, as, for instance, the phosphorescent light of a fire-fly, or a glow-worm, or the Geissler tube when it is energized by an induction coil.

The three chief ways of making heat are by friction, by chemical action, and by electricity, and in all cases light follows if the heat set up is sufficient to make the molecules of the substance vibrate fast enough. The only kind of heat and light that we are interested in now is that produced by chemical action.

How a Candle Burns. Light a candle and examine the flame of it through a piece of tinted glass and you will see that it consists of three parts, as shown in Fig. 133, and these are an inner dark part containing gas which is waiting its turn to be burned; a middle bright cone where the particles of carbon (*C*) are heated to incandescence and which gives the light; and a thin outer cone of blue flame which is in direct contact with the air and gives little or no light.

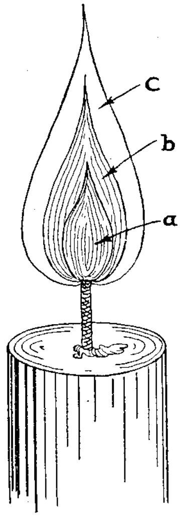

FIG. 133.—The Flame of a Candle.

Now this is what takes place when you light a candle. First, the heat melts the tallow, or wax, and this rises in the wick by *capillary attraction;*[1] as it reaches the tip of the wick where the heat is the greatest it is converted for the most part into a vapor, and this burns, which makes the flame. It is the carbon (*C*) of the tallow, or wax, which is raised to a white heat, while the hydrogen (*H*) of it burns with a blue flame outside of it and has no lighting power whatever.

How Ventilation Affects Combustion. Take a quart glass jar and fit a cork into the mouth of it; now bore two ¼-inch holes through the cork and push a glass tube 3 inches long through one of them and another tube 8 or 10 inches long through the other one so that the former will

[1] Any text-book on Physics will give you an explanation of this phenomenon.