for the reason that it sticks to the tools, but when 2 per cent of magnesium (*Mg*) is mixed with 98 per cent of it, they form an alloy called *magnalium* that is free from these difficulties.

Alloys of Iron and Steel. Pure iron (*Fe*) is quite soft and malleable, but what we call *cast iron* is really an alloy which contains a small per cent of carbon (*C*), sulphur (*S*), silicon (*Si*), and other substances, and it is these that make it grey and brittle. Wrought iron is purer, and for this reason it is malleable. Steel is simply iron (*Fe*) that has more carbon (*C*) in it than cast iron, and when it is heated to a certain temperature and allowed to cool slowly, it gets very hard and springy.

By mixing in various other metals, a wonderful series of *steel alloys* are produced; thus when 7 to 20 per cent of manganese (*Mn*) is added to steel it is called *manganese steel.* This alloy is exceedingly hard, and so it is used for making burglar-proof safes, the jaws of stone crushers, and railway frogs. When 1 per cent of chromium (*Cr*) and 15 per cent of vanadium (*V*) are mixed with steel, it makes an alloy called *chrome-vanadium steel*, and this not only has great tensile strength but it will bend double before it will break. It is used for the connecting-rods of engines and the frames and axles of motor-cars.

An alloy with 20 per cent of tungsten (*W*), ¾ per cent carbon (*C*), 3½ per cent of chromium (*C*r) and 1½ per cent of vanadium (*V*), and the rest steel, makes an alloy called *high-speed steel.* This is used to make tools for lathes and other machines, and these will cut steel very fast and without losing their temper even when the friction heats them red-hot. When 2 to 4 per cent of nickel (*Ni*) is added to steel it makes an alloy called *nickel-steel*, and this alloy is not only hard and springy but one that sea-water (H_2O) has but little effect upon. For these reasons it is used for propeller shafts, ships' cables that must be placed underseas, armor-plate for battle-ships, etc.

Another nickel-steel alloy is called *invar steel*, and this is made of 36 per cent of nickel (*Ni*) and the rest steel. While all other metals and alloys will either expand or contract on cooling, invar steel remains of the same dimensions under practically all degrees of temperature. Hence it is largely used for clock pendulums and measuring scales, the lengths of which must remain unchanged under all conditions.

Alloys of Tin and Lead. *Common solder* for roofing purposes is made of 50 per cent of tin (*Sn*) and 50 per cent of lead (*Pb*). *Fine solder* for soldering tinware is formed of 33⅓ per cent of lead (*Pb*) and 66⅔ per cent of tin (*Sn*). *Type metal* is made of 25 per cent of antimony (*Sb*) and 75 per cent of lead (*Pb*). *Pewter* is an alloy the components of which consist of 20 per cent of lead (*Pb*) and 80 per cent of tin (*Sn*). An alloy that has a ½ of 1 per cent of arsenic (*As*) in it and 99½ per cent of lead (*Pb*) is used for making shot and bullets. *Wood's metal* is an alloy that melts at a much lower temperature than that at which water (H_2O) boils, and it is used for electric fuses and safety plugs for steam boilers and automatic sprinklers. It is made of 1 part of tin (*Sn*), 1 part of cadmium (*Cd*), 2 parts of lead (*Pb*), and 4 parts of bismuth (*Bi*).

Alloys of Copper. One of the earliest alloys to be used is bronze, and it is made of varying proportions of lead

(*Pb*), tin (*Sn*), zinc (*Zn*) and copper (*Cu*), depending on what it is to be used for. *Brass*, of which there are also several varieties, is made of from 18 to 40 per cent of zinc (*Zn*) and the rest copper (*Cu*). *German silver* has no silver (*Ag*) in its make-up but is formed of 20 per cent of zinc (*Zn*), 20 per cent of nickel (*Ni*), and 60 per cent of copper (*Cu*); it looks something like silver (*Ag*) and does not easily tarnish; at one time it was much used for making spoons.

Gun metal is an alloy that consists of 10 per cent of tin (*Sn*) and 90 per cent of copper (*Cu*); these proportions give a metal that has a rich brownish-black color and is much used for making art objects and the like. *Monel metal* is made of 50 per cent of nickel (*Ni*) and 50 per cent of copper (*Cu*); it is largely used for sheet metal work. Finally, an alloy formed of 30 per cent of manganese (*Mn*) and 70 per cent of copper (*Cu*) makes a hard bronze that is used for the propellers of ships.

Silver Alloys. The alloy of silver (*Ag*) that is used for coins is 10 per cent of copper (*Cu*) and 90 per cent of silver (*Ag*), while that used for silverware is made of 20 per cent of copper (*Cu*) and 80 per cent of silver (*Ag*). In both cases the copper (*Cu*) is put in to make the metal harder.

Gold Alloys. To make gold (*Au*) hard enough for coinage and goldware, it is also alloyed with copper, and the proportion of gold used is measured by a unit called a *carat*. The carat in general use is equal to 3.168 grains, or 205 milligrams. Pure gold (*Au*) is said to be 24 *carats fine*. British sovereigns are 22 *carats fine*, and hence have 2/24 or 1/12 of copper (*Cu*) in them. American and French gold coins are 21 6/10 carats fine, that is, they contain 10 per cent of copper (*Cu*) and 90 per cent of gold (*Au*).

How Amalgams Are Made. An *amalgam* is an alloy in which one metal is dissolved in another metal. The word amalgam comes from two Greek words that mean *soft mass.* Mercury (*Hg*) is used to dissolve the other metal, and all the common metals will dissolve in mercury (*Hg*), although platinum (*Pt*) and iron (*Fe*) do so to the least extent.

A Sodium Amalgam. When 1 per cent of sodium (*Na*) is dissolved in 99 per cent of mercury (*Hg*), an amalgam is formed that is a soft mass, but when 2 per cent of sodium (*Na*) is dissolved in 98 per cent of mercury (*Hg*) it forms a solid mass. When metallic sodium (*Na*) is to be used, it is often better to make an amalgam, as the mercury (*Hg*) will not affect its action and it can be handled easier.

Zinc Amalgam. When the zinc (*Zn*) plates used in batteries are rubbed with mercury (*Hg*), the molecules of the former that are on the surface are mixed with those of the latter, and the plates are then said to be amalgamated. The amalgam thus formed prevents local currents from being set up between the impure particles in the zinc (*Zn*), and the zinc (*Zn*) itself, and also keeps the acid solution from eating the zinc (*Zn*) away so rapidly.

Tin and Zinc Amalgams. Formerly mirrors were made by coating glass (Na_2O, CaO, SiO_2) with a tin amalgam formed of 1 part of tin (*Sn*), 1 part of lead (*Pb*), and 2 parts of bismuth (*Bi*) dissolved in 4 parts of mercury (*Hg*). Mirrors are now made by coating them with a silver nitrate ($AgNO_3$) solution.

When 1 part of tin (*Sn*) and 2 parts of silver (*Ag*), or gold (*Au*), are dissolved in 2 parts of mercury (*Hg*), an amalgam is formed of these metals that will harden and expand. For these reasons, this amalgam is used by dentists for filling cavities in teeth.

A cheap amalgam for filling teeth is made by dissolving 1 part of pulverized zinc (*Zn*) in 2 parts of mercury (*Hg*).

CHAPTER X.

CHEMISTRY SIMPLY EXPLAINED

QUITE the least-interesting part of chemistry to the beginner is the theory of it, by which is meant just how and why different substances act and react on each other and produce other substances of an entirely different nature.

Now while making experiments of any kind, but especially those in chemistry, is the most fascinating part of the work, and you can get the same results if you follow the instructions given whether you know anything about the principles that underlie them or not, still, to work in this way is to miss much of the fun and more of the interest in it. So in this chapter I shall tell you about some things in chemistry which you cannot see with your physical eye but which you can visualize with your mind's eye.

What Matter Is. First of all, as you probably know, the world and everything in, on, or around it is made up of minute particles of different substances, and it is these that form the material bodies which we call *matter*. Now matter of whatever kind has certain *properties*, and the first two of these are called by the long names of *indestructibility* and *impenetrability*; then solids have half a dozen other properties, and these are *hardness*, *malleability*, *ductility*, *brittleness*, *elasticity*, and *flexibility*. Fluids include liquids and gases; the former are called *inelastic*, while gases have *elasticity*.

What the Properties of Matter Are. *Indestructibility* is a word used to mean that matter cannot be created or destroyed. It is easy to change the shape of solid bodies, to make two or more substances into an entirely different substance, to make a solid into a liquid, and the latter into a gas; then, the other way about, gases can be liquefied and these in turn can be solidified, though these latter processes are much more difficult than the former. But in any event there is exactly the same amount of matter left as there was before the operation.

Impenetrability means simply that no two particles of matter can be in the same place at the same time. This is perfectly obvious with solid bodies but not so much so with liquids and with gases. Now here are two experiments, the first of which shows easily enough the truth of the first statement, and the second *seems* to show the fallacy of it.

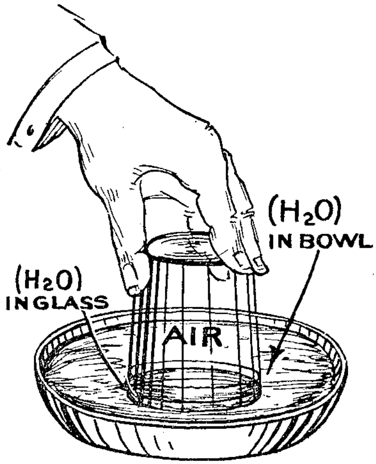

FIG. 127.—Clearly Two Bodies Cannot Occupy the same Space at the Same Time.

First Experiment. Hold a tumbler, or a beaker, by the bottom and put the open end into a soup-plate half full of water (H_2O), as shown in Fig. 127. You will see now that the level of the water (H_2O) in the glass is very much lower than it is outside of it. It is evident that the air in the glass prevents the water (H_2O) from rising in the glass and taking up the same space that the air occupies.

Second Experiment. Now here is an experiment of a different kind. Fill a beaker, or a tumbler, brimful of water (H_2O) and then take a tablespoonful of pulverized sugar ($C_{12}H_{22}O_{11}$) and slowly let it fall into the water (H_2O), a particle at a time, as shown in Fig. 128, so that the bubbles of air which stick to them will rise to the surface, and also to give the sugar ($C_{12}H_{22}O_{11}$) sufficient time to dissolve.

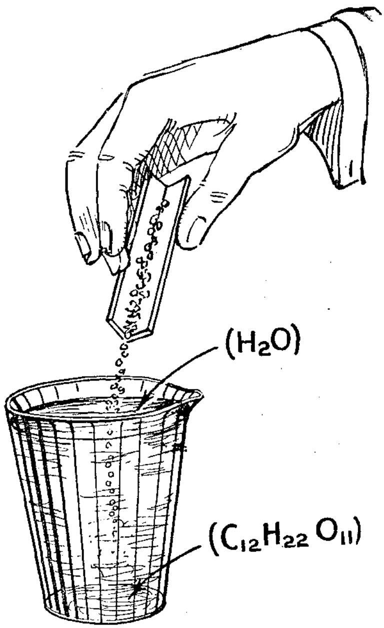

FIG. 128.—This Experiment seems to Show that Two Bodies Can Occupy the Same Space at the Same Time.

Curiously enough, as you put the sugar ($C_{12}H_{22}O_{11}$) into the water (H_2O), the latter does not increase in volume, and so run over the top of the glass. Now while it is true that two bodies cannot occupy the same space at the same time, these two substances seem to do this very thing. The explanation, however, is that the particles, or *molecules*, as they are called, of which the water (H_2O) and the sugar ($C_{12}H_{22}O_{11}$) are formed, are widely separated, and when the latter is dissolved in the former, the spaces between the particles of the one are filled up by the particles of the other.

Hardness is that property of a body which makes it tend to resist any change in shape. The degree of hardness is found by scratching one substance with another; thus iron (*Fe*) will scratch lead (*Pb*); glass (Na_2O, CaO, SiO_2) will scratch iron (*Fe*), and the diamond (*C*) will scratch glass (Na_2O, CaO, SiO_2).

Malleability is that property of matter which permits a solid, such as iron (*Fe*), silver (*Ag*), gold (*Au*), or platinum (*Pt*) to be rolled out into sheets. When red-hot, iron (*Fe*) is very malleable. This is also true of steel, which is iron (*Fe*) with a small amount of carbon (*C*) in it. In this heated state, steel is rolled into sheets, rails, girders, etc. You have seen in the foregoing chapter that gold (*Au*) possesses this property to such an extent that it can be beaten into sheets so thin it will take 250,000 of them to make a pile 1 inch high.

Ductility is a first cousin to malleability, for it is that property which permits a metal to be drawn out into a slender thread, or *wire*, as it is called. When metals of various kinds are drawn into wire, they have a greater strength than they would have if a cross-section of the same size were cut from a strip. Evidently the molecules of which they are formed are rolled closer together. *Brittleness* is just the opposite of malleability, and it is this property of matter that makes a sheet of glass crack when it is struck, and some metals are so brittle that they break when you try to bend them.

Elasticity is that property of solids and gases which makes them return to their original shape when they have been sprung by the application of a force which is then released, as for instance a steel spring when it is bent or twisted, or a gas when it is compressed. *Flexibility* is that property which enables a body to be bent out of shape, without breaking.

The Three Common Forms of Matter. The three forms of matter that we are best acquainted with are the solid, liquid, and gaseous, and, as I explained before, these may be changed one into the other. As an illustration, water

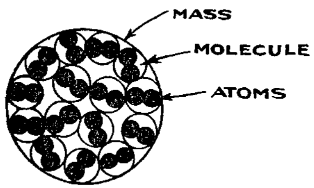

FIG. 129.—How Atoms Form the Molecule, and Molecules the Mass.

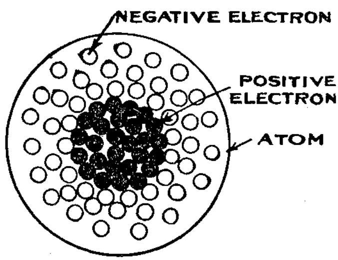

FIG. 130.—How the Negative and Positive Particles of Electricity form the Atom.

(H_2O) at ordinary temperatures is a liquid, but when it is heated to a high-enough temperature it becomes a gas, and when it is cooled to a low-enough temperature it becomes a solid. Since metals can be liquefied, and these liquids converted into gases, and gases can be liquefied and then changed into solids, it is safe to conclude that all the elements and some of the compounds follow the same laws.

What Matter Is Built Up of. The way we always see matter, even with the highest-power microscope, is in the