

2: THE LANGUAGE OF CHEMISTRY

One of the things that trips folks up when they study chemistry is that there is so much new terminology with which to become familiar. Each of these lessons will likely contain some terms that will be new to you. So let's begin by laying some groundwork in the area of definitions and symbols. You have probably already learned these in an earlier science course. Don't fret about having to go over it again. It'll be good review. It's so important to the study of chemistry that we must be sure you don't miss a single word. If you have been over this material before, it should be really easy for you. Right?

Elements

If you recall, all matter is made up of elements. **Elements** are defined as fundamental ("elementary") substances which cannot be broken down into simpler ones by ordinary physical or chemical means. As an example, suppose we have a piece of copper wire, and we cut it in half. Then we take one half, and slice it in half again. Suppose we continue this process of cutting the copper down by halves; assume we are even able, somehow, to divide the copper down to a submicroscopic level. Eventually we would get to the point where what is left is a single copper atom. While it is true that a copper atom is composed of still smaller subatomic particles (**protons**, **neutrons** and **electrons**), if we divide the copper atom any further, we won't have copper anymore. Copper is one of those fundamental substances—an element—*composed of a single type of atom*. It is distinguishable from every other type of atom by how many protons are in its nucleus.

As of the time this book went to press, there were 113 elements. (New ones are made in laboratories from time to time.) We will deal with only the most common ones, which amount to about 40% of them. Since atoms of one element combine with atoms of another element to form different compounds, it is convenient to have a shorthand method for referring to them. For this reason, each element has been given its own symbol. Table 1 shows the most common elements along with their symbols. The names of all the elements (and the tentative names of the elements that are as yet unnamed) are provided inside the front cover of this book in the **periodic table of the elements**—an orderly arrangement of the elements' symbols. We will discuss this table in great detail over time.

Hint: Memorize the symbols for the elements listed in Table 1. It will take you a little extra time now, but it will save you scads of time later.

Aluminum	Al	Copper	Cu	Oxygen	O
Antimony	Sb	Fluorine	F	Phosphorus	P
Argon	Ar	Gold	Au	Platinum	Pt
Arsenic	As	Helium	He	Potassium	K
Barium	Ba	Hydrogen	H	Radium	Ra
Beryllium	Be	Iodine	I	Silicon	Si
Bismuth	Bi	Iron	Fe	Silver	Ag
Boron	B	Lead	Pb	Sodium	Na
Bromine	Br	Lithium	Li	Strontium	Sr
Cadmium	Cd	Magnesium	Mg	Sulfur	S
Calcium	Ca	Manganese	Mn	Tin	Sn
Carbon	C	Mercury	Hg	Titanium	Ti
Chlorine	Cl	Neon	Ne	Tungsten	W
Chromium	Cr	Nickel	Ni	Uranium	U
Cobalt	Co	Nitrogen	N	Zinc	Zn

Please notice that each of the element symbols starts with a capital letter. Some then have a lower case letter following. To avoid confusion, it is very important to reproduce these symbols as written. For example, Co is the symbol for Cobalt, but CO is the formula for carbon monoxide. Also notice that some of the symbols appear to have no relation to the name of the element. That's because some of the symbols were derived from their Latin names. Tungsten was once known by its Latin name *wolfram*, and lead was known as *plumbum*. Thus, they have the symbols W and Pb, respectively. Table 2 shows the names of these elements and the Latin names from which they are derived. You needn't memorize these, but seeing them will help you to remember their correct symbols.

Table 2. Elements having symbols that are taken from their Latin names.		
Name	Symbol	Latin Name
Antimony	St	Stibium
Copper	Cu	Cuprum
Gold	Au	Aurum
Iron	Fe	Ferrum
Lead	Pb	Plumbum
Mercury	Hg	Hydragyrum
Potassium	K	Kalium
Silver	Ag	Argentum
Sodium	Na	Natrium
Tin	Sn	Stannum
Tungsten	W	Wolfram

Law of Definite Composition: A specific compound is comprised of a specific proportion (by mass) of elements.

Law of Multiple Proportions: A particular set of elements can combine in different ratios to produce different compounds.

Compounds

Remember, we observed earlier that elements combine to form other substances. **Compounds** are defined as substances that contain two or more elements chemically combined in definite proportions by mass. For example, water is a compound made up of the combination of hydrogen and oxygen; and it always contains one oxygen atom combined with two hydrogen atoms. This consistently gives it a definite composition of 11.2% H (two light atoms) and 88.8% O (one somewhat heavier atom) by mass. (Notice how I've started to sneak element symbols in on you?) That means if we had 100 g of water and we were able to separate it into its individual elements, we'd have 11.2 g of H and 88.8 g of O. The fact that specific compounds are comprised of specific proportions of elements by mass is called the **Law of Definite Composition**. This law basically says that water is water is water is water and that water will always have the composition of water. If the composition changes, it's no longer water. Do I make my point?

Hydrogen peroxide is another compound of H and O; but in this case two atoms of hydrogen and two atoms of oxygen are involved—different composition, different compound! The relative amounts of the two elements in hydrogen peroxide are 5.9% H and 94.1% O by mass. The ability of two or more elements to combine in *different* ratios to produce a variety of *different* compounds (such as water and hydrogen peroxide) is called the **Law of Multiple Proportions**. (See Figure 1.)

The most important thing to remember is that every specific compound has a very specific composition of elements. Compounds do not vary in this respect. One compound has a single, definite composition. If the composition changes, it's no longer the same compound. Likewise, every different compound has its own chemical formula that shows the ratio of the various atoms in the compound. Figure 2 shows the chemical formulas of water and hydrogen peroxide next to those molecules and explains how to understand those formulas. Figure 3 illustrates a variety of molecules and their chemical formulas. Studying them carefully will help you understand how to write chemical formulas of your own. Figure 4 shows how to name molecules that have repeating clusters of identical atoms.

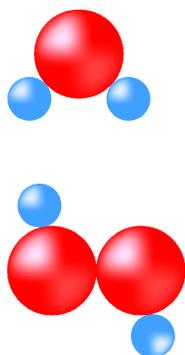


Figure 1. (Left) Water always consists of one atom of oxygen and two atoms of hydrogen. This gives all water a constant proportion by weight of hydrogen to oxygen. Likewise, hydrogen peroxide consists of two atoms of oxygen and two of hydrogen. This gives all hydrogen peroxide a constant proportion by weight of hydrogen to oxygen. Both are demonstrations of the law of constant composition. The fact that each of these compounds consists of only hydrogen and oxygen, but that the two have different proportions of the two elements, illustrates the law of multiple proportions.

Figure 2. (Right) The chemical formula of a substance provides the number of atoms of each element. The number of atoms is always subscripted to the right of the element's symbol. If no number is written next to an element's symbol, the number of atoms of that element is assumed to be one.

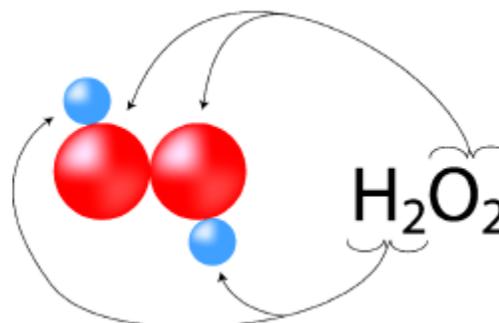
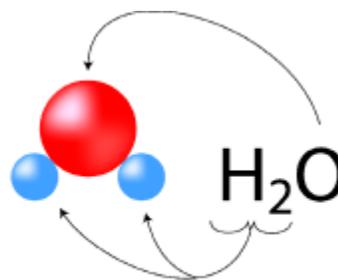
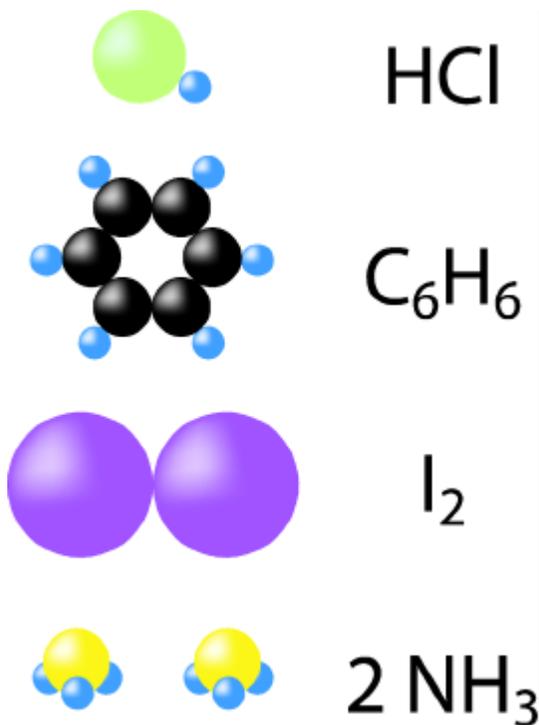


Figure 3. (Below) The figure shows one molecule of each of several substances with their chemical formulas. One of the molecules is not a compound. Do you know which?



Molecules

The most fundamental uncharged unit of a compound is called a **molecule**. Suppose we took a drop of water and started dividing it like we did earlier to our piece of copper. Eventually, we'd get down to a single molecule of water. If we divided any further, we wouldn't have water anymore. Figure 5 illustrates this principle using an unknown compound made up of two atoms. When you have divided any substance until the remaining quantity is a molecule, you would have to affect the structure of the molecule to divide that substance any further.

We write the formulas for compounds using the elements' symbols and the relative amounts of the various atoms. In the case of water, the **chemical formula** is H_2O . That means two H atoms combine with one O atom to form a water molecule.

While a compound, by definition, consists of more than one kind of atom, molecules may sometimes be composed of only one kind of atom. In fact, there are seven elements that exist primarily as **diatomic** molecules—molecules that contain two identical atoms. (Although the word *diatomic* literally means “two atoms,” not just any molecule containing two atoms is thought of as diatomic. The two atoms must be identical.) These seven elements are hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine and iodine. Therefore, when these elements are written to show the way they occur in nature, they are expressed as H_2 , N_2 , O_2 , F_2 , Cl_2 , Br_2 and I_2 .

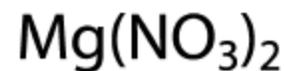
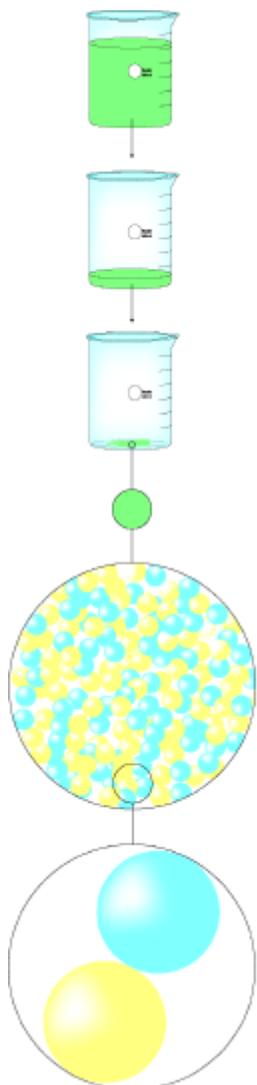


Figure 4. Notice that there are two identical groups of atoms in this molecule. Each consists of a single nitrogen atom (yellow) and three oxygen atoms (red). Each of those two groups is designated as NO_3 , so they show up in the formula as $(NO_3)_2$.



Exercises

- 1) Make a set of flashcards to help you in learning the element symbols. (A pack of colored flashcards and a marker are provided in your lab set.) Put the name of the element on one side of a card and its corresponding symbol on the other side. Drill with these cards until you have them down cold.
- 2) How many total atoms are present in each of the following molecules?
 - a) $(NH_4)_3PO_4$
 - b) $Ca(HSO_4)_2$
 - c) $Li_2(C_2H_3O_2)_2$
- 3) What is the difference in meaning in each of these pairs?
 - a) Si and SI
 - b) Pb and PB
 - c) 2 H and H_2
- 4) Which of the following molecules are termed *diatomic*?
 Cl_2 , Br_2 , CO, HI, H_2O , O_2 , F_2

Figure 5. Any substance may be divided into smaller and smaller portions until the tiniest portion of that substance is left. That tiniest, irreducible portion will be a single molecule. In this figure, the amount of a substance is being further and further reduced until a single molecule is all that is left. Notice that this molecule is composed of two atoms. They are bound together by the forces that attract them. If they were to be separated the result would no longer be the same substance.