2.1: Pure Substances and Mixtures

In Chapter 1, we learned that atoms are composed of electrons, protons and neutrons and that the number of protons in the nucleus of an atom (the atomic number) defines the identity of that element. For example, an atom with six protons in its nucleus is a carbon atom; seven protons makes it nitrogen; eight protons makes it oxygen, and so on. The periodic table organizes these elements by atomic number and there are currently over 118 known elements.

Because there are *clearly* more than 118 different *types* of substances in the world around us, we can see that most substances that we encounter are *not* pure elements, but are composed of different elements combined together. In chemistry, we refer to these as **compounds**, which we define as *a substance that results from the combination of two or more elements in a constant ratio.* For example, water is a compound composed of two hydrogen atoms *bonded* to one oxygen atom. We can show the ratio of hydrogen to oxygen in this compound by using subscripts on the chemical symbols for each element. Thus, water (two hydrogens and one oxygen) can be written as H_2O. This shorthand notation for water is called a **chemical formula**. For any compound, the chemical formula tells us the elements that are present and the *ratio* of the elements to each other. Later we will see that water is a member of a special sub-type of compound, called a molecular compound. In a **molecule**, the atoms are not only bonded together in a constant ratio, but they are bonded in a *specific geometric arrangement* as well. In the following chapter, we will look more closely at how elements are bonded together in compounds, but first we will examine some of the properties of chemical substances.

When we speak of a **pure substance**, we are speaking of something that contains only one kind of matter. This can either be one single element or one single compound, but every sample of this substance that you examine must contain exactly the same thing with a fixed, definite set of properties. If we take two or more pure substances and mix them together, we refer to this as a **mixture.** Mixtures can always be separated again into component pure substances,because *bonding* among the atoms of the constituent substances does not occur in a mixture. Whereas a compound may have very different properties from the elements that compose it, in mixtures the substances keep their individual properties. For example sodium is a soft shiny metal and chlorine is a pungent green gas. These two elements can combine to form the compound, sodium chloride (table salt) which is a white, crystalline solid having *none* of the properties of either sodium or chlorine. If, however, you *mixed* table salt with ground pepper, you would still be able to see the individual grains of each of them and, if you were patient, you could take tweezers and carefully separate them back into pure salt and pure pepper.

Mixtures fall into two types, based on the uniformity of their composition. The first, called a **heterogeneous mixture**, is distinguished by the fact that different samples of the mixture may have a different composition. For example, if you open a container of mixed nuts and pull out a series of small samples and examine them, the exact ratio of peanuts-to-almonds in the samples will always be slightly different, no matter how carefully you mix them. Common examples of heterogeneous mixtures include dirt, gravel and vegetable soup.

In a **homogeneous mixture,** on the other hand, any sample that you examine will have exactly the *same* composition as any other sample. Within chemistry, the most common type of homogeneous mixture is a **solution** which is one substance dissolved completely within another. Think of a solution of pure sugar dissolved in pure water. Any sample of the solution that you examine will have *exactly* the same ratio of sugar-to-water, which means that it is a homogeneous mixture. Even in a homogeneous mixture, the properties of the components are generally recognizable. Thus, sugar-water tastes sweet (like sugar) and is wet (like water). Unlike a compound, which has a fixed, definite ratio, in a mixture one can vary the amounts of each component. For example, when you add a little sugar to one cup of tea and a lot of sugar to another, each cup will contain a homogeneous mixture of tea and sugar but they will have a different taste. If you add so much sugar that some does not dissolve and stays on the bottom, however, the mixture is no longer homogeneous, it is heterogeneous;you could easily separate the two components.