4.2: Early Ideas About the Building Blocks of Matter

Chemistry is the study of the material world. What are different materials made of? How is their composition and structure related to their properties? How does one material become transformed into another? These are the sorts of questions that have driven the development of chemistry. People have been using chemistry for a very long time. Medicines were obtained from plants in early societies all over the world. People made dyes for clothing and paints for houses. Metallurgy was practiced in India and the Sahel, in Africa, before 1000 BC.

The Greek philosopher, Democritus, is often cited as the earliest person to formulate an idea of atoms, although similar ideas were recorded in India around the same time. Democritus thought that all things were made of atoms. Atoms were very small, he thought. They were also indivisible. Although you could cut a piece of wood in half, and cut each of those pieces in half, at some point you would reach the stage at which the wood could not be cut any longer, because you had a slice that was one atom thick.

Figure 2.2.1: *Democritus.*

There were an infinite variety of atoms, Democritus thought, making up an infinite variety of materials in the world. The properties of those atoms were directly responsible for the properties of materials. Water was made of water atoms, and water atoms were slippery. Iron was made of iron atoms, and iron atoms were strong and hard.

> *All of the materials in the world around us are made from atoms.*

A more practical aspect of chemistry has its roots in the Islamic Golden Age. Practitioners such as Jabir Ibn Hayyan developed laboratory apparatus and experimental methods to recrystallize and distill compounds from natural sources. Like Democritus, these early chemists wanted to know what the world is made of, but they were also trying to make improvements in practical applications such as tanning leather, making glass or rust-proofing iron.

The translation of Arabic texts into Latin helped spur the European Renaissance. Practical observations from the Islamic period, such as the fact that matter could be converted into different forms but did not disappear, gave rise to some of the most fundamental ideas of modern chemistry.

> *Conservation of mass: matter can be converted from one form to another, but it does not disappear.*

As is usually true in science, new developments in chemistry built on earlier work as well as the work of contemporary colleagues, continually improving our understanding of nature in small steps. In the 1600's, Robert Boyle adopted the Islamic emphasis on experimental work. Among his experiments, he was able to isolate the hydrogen gas formed by reacting metals with acids, as other scientists were doing at that time. In the 1700's, Joseph Priestley isolated several different "airs" or gases, including oxygen. Henry Cavendish showed that hydrogen combined with oxygen to form water. Antoine Lavoisier argued that oxygen and nitrogen, the other major component of air, are elements. The free exchange of ideas allowed people to rapidly advance our understanding of the material world.

Lavoisier, in particular, was important in bringing a number of important ideas together. He clearly stated that elements were the basic unit of matter, that could not be obtained from other materials. Compounds were made by combining different elements. His careful use of a balance to weigh reactants and products of an experiment clearly confirmed the idea of conservation of mass: the total mass of products after a reaction equals the total mass of reactants. These conclusions were more sophisticated versions of earlier ideas, and Lavoisier was able to present them in a way that eventually gained wide acceptance.

- A compound is a mixture of different elements bonded together.
- Conservation of mass, revised: the total mass of products after a reaction equals the total mass of reactants.

In the 1800's one of the principle proponents of the developing atomic theory was John Dalton. He advanced the idea that all atoms of a particular element are identical (as far as he could tell at that time). An element is a fundamental atomic building block from which other materials are made. Dalton performed analyses to try to deduce the atomic weights of different elements. Taking these ideas together, he showed that a particular compound always contained the same elements in the same ratio.

- An element is a fundamental atomic building block from which other materials are made.
- A compound is a mixture of different elements bonded together in a specific ratio.
- A compound may have a specific number of atoms of one type combined with a specific number of atoms of another type.
- Because all atoms have weight, we can also think of a compound as a specific weight of one kind of element combined with a specific weight of another element.

For example, water is a compound made from hydrogen and oxygen. It is crucial for life, of course. Water is about $1/9^{th}$ hydrogen by weight; the other $8/9^{ths}$ are oxygen. However, a different compound, hydrogen peroxide, is a rocket fuel. Hydrogen peroxide is only about $1/19^{th}$ hydrogen by weight. Those specific ratios of hydrogen to oxygen are inherent qualities of each compound.

Furthermore, Dalton found that he could make compounds through different methods. For example, he could make cupric oxide (CuO) by heating copper in air, or he could make it through various reactions involving copper and acids. It didn't matter how he made the cupric oxide; the ratio of copper to oxygen was always the same in the product.

There is one other compound containing copper and oxygen in a different ratio; it is called cuprous oxide, and it has the formula Cu_2O. However, it is very different from cupric oxide. The most obvious difference is that cuprous oxide is red whereas cupric oxide is black. Once again, when elements are combined in different ratios, different materials are produced, and they have properties that differ from each other and from they elements of which they are comprised.

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