4.1: Prelude to Atomic Structure

We have examined the theoretical implications and practical applications of John Dalton's ideas about atoms in our discussion on atoms, molecules and chemical reactions, and using chemical equations in calculations. Clearly the atomic theory is a powerful tool which aids our thinking about how much of one substance can combine with (or be produced from) a given quantity of another. The theory is much less helpful, however, when we try to speculate about what holds the atoms together in molecules such as Br_2, $HgBr_2$ and Hg_2Br_2. As you have seen, techniques are available for *experimental* determination of the formula of a new compound, but Dalton's theory is of little value in *predicting* formulas. Neither does it tell us which elements are likely to combine with which, nor indicate what chemical and physical properties are to be expected of the compounds which form.

The ability to make predictions about chemical reactivity and properties is very important because it guides chemists' efforts to synthesize new substances which are of value to society at large. Medicines, metals, transistors, plastics, textiles, fertilizers, and many other things that we take for granted today have been made possible by detailed knowledge of chemical and physical properties. Such knowledge also permits greater understanding of how the natural world works and what changes (favorable or detrimental) may be brought about by human activities.

Knowledge of chemical reactivity and properties may be approached on both the macroscopic and microscopic levels. Macroscopically this involves what is called **descriptive chemistry**. The person who first carries out a chemical reaction describes what happened, usually in terms of a balanced equation, and lists properties of any new substances. This enables other scientists to repeat the experiment if they wish. Even if the work is not carried out again, the descriptive report allows prediction of what would happen if it were repeated.

The microscopic approach uses theory to predict which substances will react with which. During the past century Dalton's atomic theory has been modified so that it can help us to remember the properties of elements and compounds. We now attribute structure to each kind of atom and expect atoms having similar structures to undergo similar reactions. Such work has led to the classification of groups of elements, for instance the alkali metals, halogens, alkaline earth metals, and many more. The additional complication of learning about atomic structure is repaid many fold by the increased ability of our microscopic model to predict macroscopic properties.

In the following sections, you will see that a number of quite different kinds of experiments contributed to the extension of Dalton's atomic theory to include subatomic particles and atomic structure. The periodic variation of valence and the periodic table's successful correlation of macroscopic properties indicate that atoms must have certain specific ways of connecting to other atoms. It is reasonable to assume that valence depends on some underlying atomic structure. Atoms which are similar in structure should exhibit the same valence and have similar chemical and physical properties. While the periodicity was initially based upon atomic weight, exceptions to periodic law based upon weight implied some other property led to periodicity.

The property on which periodicity is based is the *electronic structure* of atoms. Our model for electronic structure is both scientifically and philosophically interesting, because it is based on a wave model for electrons. To learn more about our current electronic structure for atoms and the discoveries that led to this understanding, watch the video below.

The discovery of radioactivity and transmutation implied that one kind of atom could change into another. This can he explained if atoms have structure. A change in that structure may produce a new kind of atom. Experiments with cathode-ray tubes indicated that electrons, which are very light and carry a negative charge, are present in all atoms. Rutherford's interpretation of the Geiger-Marsden experiment suggested that electrons occupy most of the volume of the atom while most of the mass is concentrated in a small positively charged nucleus. Moseley's x-ray spectra and the existence of isotopes made it quite clear that Dalton's emphasis on the importance of atomic weight would have to he dropped. The chemical behavior of an atom is determined by how many protons are in the nucleus. Changing the number of neutrons changes the atomic mass but has very little effect on chemistry. The identity of an element depends on its atomic number, not on its atomic weight. If the periodic law is restated as "When the elements are listed in order of increasing atomic *number*, their properties vary periodically," there are no exceptions.