2.6: Atomic Weights

Our discussion of the atomic theory has indicated that mass is a very important characteristic of atoms — it does not change as chemical reactions occur. Volume, on the other hand, often does change, because atoms or molecules pack together more tightly in liquids and solids or become more widely separated in gases when a reaction takes place. From the time Dalton's theory was first proposed, chemists realized the importance of the masses of atoms, and they spent much time and effort on experiments to determine how much heavier one kind of atom is than another.

Dalton, for example, studied a compound of carbon and oxygen which he called carbonic oxide. He found that a 100-g sample contained 42.9 g C and 57.1 g O. In Dalton's day there were no simple ways to determine the microscopic nature of a compound, and so he did not know the composition of the molecules (and hence the formula) of carbonic oxide. Faced with this difficulty, he did what most scientists would do — make the simplest possible assumption. This was that the molecules of carbonic oxide contained the minimum number of atoms: one of carbon and one of oxygen. Carbonic oxide was the compound we now know as carbon monoxide, CO, and so in this case Dalton was right. However, erroneous assumptions about the formulas for other compounds led to half a century of confusion about atomic weights.

Since the formula was CO, Dalton argued that the ratio of the mass of carbon to the mass of oxygen in the compound must be the same as the ratio of the mass of 1 carbon atom to the mass of 1 oxygen atom:

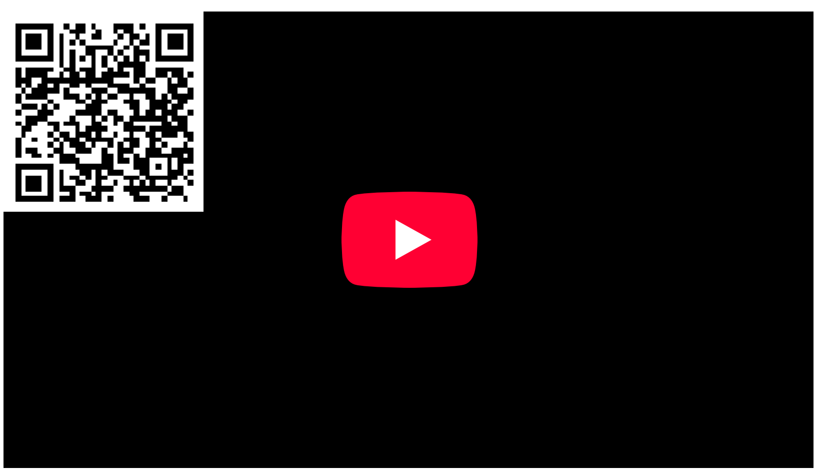
$$\frac{\text{Mass of 1 C atom}}{\text{Mass of 1 O atom}} = \frac{\text{mass of C in CO}}{\text{mass of O in CO}} = \frac{42.9\text{ g}}{57.1\text{ g}} = \frac{0.751}{1} = 0.751 \tag{2.6.1}$$

In other words, the mass of a carbon atom is about three-quarters (0.75) as great as the mass of an oxygen atom.

Notice that this method involves a *ratio* of masses and that the units *grams* cancel, yielding a pure number. That number (0.751, or approximately ¾) is the *relative mass* of a carbon atom compared with an oxygen atom. It tells nothing about the actual masses of carbon or oxygen atoms – only that carbon is three-quarters as heavy as oxygen.

The relative masses of the atoms are usually referred to as **atomic weights**. Their values are in the Table of Atomic Weights, along with the names and symbols for the elements. The atomic-weight scale was originally based on a relative mass of 1 for the lightest atom, hydrogen. As more accurate methods for determining atomic weight were devised, it proved convenient to shift to oxygen and then carbon, but the scale was adjusted so that hydrogen's relative mass remained close to 1. Thus nitrogen's atomic weight of 14.0067 tells us that a nitrogen atom has about 14 times the mass of a hydrogen atom.

The fact that atomic weights are ratios of masses and have no units does not detract at all from their usefulness. It is very easy to determine how much heavier one kind of atom is than another.



Example 2.6.1: Mass of Mercury Atom

Use the Table of Atomic Weights to show that the mass of a mercury atom is 2.510 times the mass of a bromine atom.

Solution

The actual masses of the atoms will be in the same proportion as their relative masses. The atomic weight of mercury is 200.59 and bromine is 79.904. Therefore:

$$\frac{\text{Mass of a Hg atom}}{\text{Mass of a Br atom}}=\frac{\text{relative mass of a Hg atom}}{\text{relative mass of a Br atom}}=\frac{200.59}{790.904}=2.5104$$

or: Mass of a Hg atom = 2.5104 · Mass of a Br atom

The atomic-weight table also permits us to obtain the relative masses of molecules. These are called **molecular weights** and are calculated by summing the atomic weights of all atoms in the molecule.

Example 2.6.2: Mass Comparison

How heavy would a mercurous bromide molecule be in comparison to a single bromine atom?

Solution

First, obtain the relative mass of an Hg_2Br_2 molecule (the molecular weight):

$$\begin{aligned} \text{2 Hg atoms: relative mass} = 2 \cdot 200.59 &= 401.18 \\ \text{2 Br atoms: relative mass} = 2 \cdot 79.904 &= 159.808 \\ \text{1 Hg2Br2 molecule: relative mass} &= 560.99 \end{aligned}$$

Therefore

$$\frac{\text{Mass of a } Hg_2Br_2 \text{ molecule}}{\text{Mass of a Br atom}}=\frac{5600.99}{790.904}=7.0208$$

The Hg_2Br_2 molecule is about 7 times heavier than a bromine atom.