4.2: Molar Mass

As we described in Section 4.1, in chemistry, the term **mole** can be used to describe a particular number. The number of things in a mole is large, *very* large (6.0221415 x 10^{23}). We are all familiar with common copy-machine paper that comes in 500 sheet reams. If you stacked up 6.02 x 10^{23} sheets of this paper, the pile would reach from the earth to the moon **80 billion times**! The mole is a *huge* number, and by appreciating this, you can also gain an understanding of how *small* molecules and atoms really are.

Chemists work simultaneously on the level of individual atoms, and on the level of samples large enough to work with in the laboratory. In order to go back and forth between these two scales, they often need to know how many atoms or molecules there are in the sample they're working with. The concept that allows us to bridge these two scales is **molar mass**. Molar mass is defined **as the mass in grams of one mole of a substance**. The units of molar mass are grams *per* mole, abbreviated as **g/mol**.

The mass of a single isotope of any given element (the **isotopic atomic mass**) is a value relating the mass of that isotope to the mass of the isotope carbon-12 ($^{12}_{6}C$); a carbon atom with six proton and six neutrons in its' nucleus, surrounded by six electrons. The **atomic mass** of an element is the relative average of *all* of the naturally occurring isotopes of that element and atomic mass is the number that appears in the periodic table. We have defined a mole based on the isotopic atomic mass of carbon-12. By definition, the *molar mass* of carbon-12 is numerically the same, and is therefore *exactly* 12 grams. Generalizing this definition, **the molar mass of any substance in grams *per* mole is numerically equal to the mass of that substance expressed in atomic mass units**. For example, the *atomic mass* of an oxygen atom is 16.00 amu; that means the *molar mass* of an oxygen atom is 16.00 g/mol. Further, if you have 16.00 grams of oxygen atoms, you know from the definition of a mole that your sample contains 6.022 x 10^{23} oxygen atoms.

The concept of molar mass can also be applied to compounds. For a molecule (for example, nitrogen, N_2) the mass of molecule is the sum of the atomic masses of the two nitrogen atoms. For nitrogen, the mass of the N_2 molecule is simply (14.01 + 14.01) = 28.02 amu. This is referred to as the **molecular mass** and the molecular mass of any molecule is simply the sum of the atomic masses of all of the elements in that molecule. The molar mass of the N_2 molecule is therefore 28.02 g/mol. For compounds that are *not molecular* (ionic compounds), it is improper to use the term "molecular mass" and "**formula mass**" is generally substituted. This is because there are no individual molecules in ionic compounds. However when talking about a mole of an ionic compound we will still use the term molar mass. Thus, the *formula* mass of calcium hydrogen carbonate is 117.10 amu and the *molar* mass of calcium hydrogen carbonate is 117.10 grams per mole (g/mol).

? Exercise 4.2.1

Find the molar mass of each of the following compounds:

- Sand - silicon dioxide (SiO_2)
- Draino - sodium hydroxide (NaOH)
- Nutrasweet - Aspartame ($C_{14}H_{18}N_2O_5$)
- Bone phosphate - calcium phosphate $Ca_3(PO_4)_2$