4.1: Measurement and Scale - The Mole Concept

One of the important concepts to grasp in chemistry is *scale*. Atoms and molecules are very small. A single atom of hydrogen has a mass of about 1.67 x 10^{-24} grams (that's 0.00000000000000000000000167 grams). One cubic centimeter of water (one mL) contains about 3.3 x 10^{22} water molecules (that's 33 sextillion molecules). Because chemists routinely use numbers that are both incredibly small and incredibly large, unique units of measurement have been developed to simplify working with these numbers. As we learned in Chapter 1, the atomic mass unit (amu) helps us talk about the mass of atoms on a scale appropriate to atoms (one grams is about 600 sextillion amu). In this chapter, we will introduce the concept of a mole to help us talk about numbers of atoms on a scale appropriate to the size of a sample we could work with in a laboratory (for example, in grams). The **mole** is defined as the number of atoms contained in *exactly* 12 grams of carbon-12 (the isotope $^{12}_{6}C$). Chemist have measured this number and it turns out to be 6.0221415 x 10^{23}. We can think of the term *mole* as a number, just like the word *dozen* represents the number 12. We will use the mole to represent this very large number (a *chemist's dozen*) and we will see that there is a special relationship between a mole of a pure substance and the mass of the substance measured in amu.

The origin of the mole concept is generally attributed to the Italian chemical physicist, Amadeo Avogadro. In 1811, Avogadro published an important article that drew a distinction between atoms and molecules (although these terms were not in use at the time). As part of his explanation of the behavior of gasses, he suggested *that equal volumes of all gases at the same temperature and pressure contained the same number of molecules.* This statement is referred to as **Avogadro's Hypothesis** and today we commonly refer to the number of *things* in a mole, (6.0221415 x 10^{23}) as **Avogadro's number** (this is rounded to 6.02 x 10^{23} for most calculations). Because a mole can be thought of as a *number*, you can convert any number to moles by dividing that number by 6.02 x 10^{23}. For example, at the time of this writing, the national debt of the United States is about 7.9 trillion dollars (7.9 x 10^{12} dollars). This could be expressed as *moles of dollars* as shown below:

$$\left(7.9 \times 10^{12} dollars\right)\left(\frac{1\ mol\ dollars}{6.02 \times 10^{23} dollars}\right) = 1.3 \times 10^{-11}\ mol\ dollars$$

The ratio of any number to the number of things in a mole is often referred to as a **mole fraction**.

Exercise 4.1.1

a. It is estimated there are 7 x 10^{22} stars in the universe. How many moles of stars is this?
b. It is estimated there are 7.5 x 10^{18} grains of sand on the earth. How many moles of sand grains is this?
c. You have 0.0555 moles of jelly donuts. What number of donuts would that be?
d. You drink a small bottle of drinking water that contains 13 moles of water. What is the number of molecules of water you drank?