4.4: Percentage Composition

We are all familiar with the term *percentage*. We take an exam that is worth 100 points, we get 96 correct and we describe our score as 96%. We arrive at 96% by first taking our score and dividing it by the total number of points to get the *fraction* that we got correct. To convert the fraction to a *percentage*, we multiply the fraction by 100.

$$\left(\frac{96\ points}{100\ points\ total}\right) \times 100 = 96\%$$

Applying this concept to molecules, we could describe HCl as consisting of one atom of hydrogen and one atom of chlorine. Likewise, we could use *mole* nomenclature and say that one *mole* of the molecule consists of one *mole* of hydrogen and one *mole* of chlorine, and that one *mole* of HCl has a mass of 36.46 grams. These descriptions, however, tell us nothing about how much of this mass is attributable to the hydrogen and how much comes from the chlorine. In order to do this, we need to speak of the **percentage composition** of a molecule, that is, what percent of the total mass arises from each element. These calculations are simple and involve taking the atomic mass of the element in question and dividing by the molar mass of the molecule.

For HCl, the *fraction* of hydrogen in HCl is given by the molar mass of hydrogen divided by the molar mass of HCl:

$$\frac{1.008\frac{g}{mol}}{36.46\frac{g}{mol}}$$

and the *percentage* of hydrogen in HCl is obtained by multiplying the *fraction* by 100:

$$0.02765 \times 100 = 2.765\%$$

Combining the steps, the *percentage* of chlorine in HCl can be calculated by dividing the molar mass of chlorine by the molar mass of HCl and multiplying by 100:

$$\frac{1.008\frac{g}{mol}}{36.46\frac{g}{mol}} = 0.02765$$

? Exercise 4.4.1

a. Find the percentage of fluorine in calcium fluoride (CaF_2).

These types of problems can also be presented as mass calculations. For example, determine the mass of calcium in 423.6 grams of CaF_2. Collecting our known, given and find values:

The known molar mass of Ca is

$$\frac{40.08g\ Ca}{1mol\ Ca}$$

The known molar mass of CaF_2 is

$$\frac{78.08g\ CaF_2}{1mol\ Cl_2}$$

We are given that we have a sample of CaF_2 with a mass of 423.6 grams and we want to find the mass of Ca in this sample. We could find the mass of Ca if we knew the fraction of Ca in CaF_2. We could then multiply this fraction by the known mass of CaF_2 to obtain the mass of calcium in the sample. The fraction of Ca in CaF_2 is the ratio of the two known molar masses (the percentage, before you multiply by 100). As always, to perform the dimensional analysis, we arrange the known and the given so that the units cancel, leaving only the units of the item we want to find.

$$(423.6g\ CaF_2) \times \left(\frac{1mol}{78.08g\ CaF_2}\right) \times \left(\frac{40.08g\ Ca}{1mol\ Ca}\right) = x\ g\ Ca = 217.4\ g\ Ca$$

Note that in this example, you want to use the fraction of Ca in CaF2, not the percentage; if you used percentage, you would have to divide your answer by 100 to get the proper number of grams of Ca in the sample.

Exercise 4.4.1

a. A sample of CaF_2 is known to contain 18.00 grams of calcium; what mass of fluorine is contained in this sample?
b. Carbon dioxide is a green house gas produced in combustion. What is the percentage of oxygen in CO_2?
c. Barium sulfate is use when x-raying the gastrointestinal track. Determine the mass of barium in 523 grams of $BaSO_4$.
d. Sulfuric acid, H_2SO_4 is the most used chemical in industrial processes. If a sample of sulfuric acid contained 3.67 g of hydrogen how many grams of sulfur would it contain?