4.8: Chemical Formulas, the Mole, and Percentage Composition

Chemical formulas represent the composition of chemical compounds. A number of chemical formulas have been shown so far including H_2O for water and NH_3 for ammonia. A chemical formula of a compound contains a lot of significant information as shown in Figure 4.11. Included is the following:

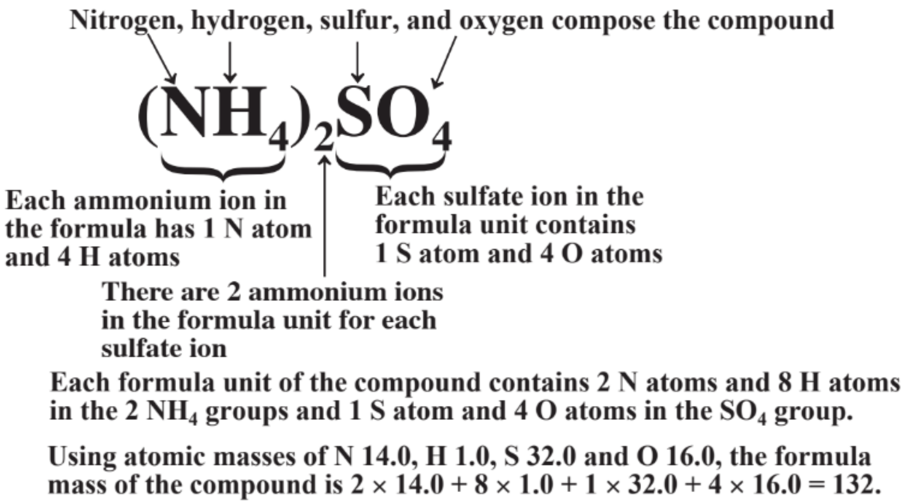

Figure 4.11. Information contained in a chemical formula

• The elements that compose the compound

• The relative numbers of each kind of atom in the compound

• How the atoms are grouped, such as in ions (for example, SO_4^{2-}) present in the compound

• With a knowledge of atomic masses, the molar mass of the compound

• With a knowledge of atomic masses, the percentage composition of the compound

Where the symbols of the elements represent letters in the alphabet of chemical language, the formulas of compounds represent words composed of those letters. As discussed in Chapter 5, formulas are put together in chemical equations that act as sentences in the chemical language to describe what chemical substances do.

The Mole

With a knowledge of atomic masses, the percentage composition of a compound is readily calculated from its formula. Before doing such a calculation for ammonium sulfate, however, it is useful to introduce the concept of the **mole**. Chemists use the mole to express quantities of materials containing a specific number of specified entities, which may be atoms of elements, molecules of elements that exist as diatomic molecules, formula units of ionic compounds, or molecules of covalent compounds. A mole of a substance is simply the atomic mass, molecular mass, or formula mass followed by *grams*. This quantity is called the **molar mass**. The masses of a mole of several typical substances are given below:

Atoms of neon, atomic mass 20.1: 20.1 g/mol

Molecules of H_2, atomic mass 1.0, molecular mass 2.0: 2.0 g/mole

Molecules of CH_4, molecular mass 16.0: 16.0 g/mole

Formula units of ionic CaO, formula mass 56.1: 56.1 g/mol

The number of specified entities in a mole of a substance is always the same regardless of the substance. This number is very large, 6.02×10^{23}, and is called **Avogadro's number**. As examples, a mole of neon contains 6.02×10^{23} neon atoms, a mole of elemental hydrogen contains 6.02×10^{23} H_2 molecules (but $2\times6.02\times10^{23}$ H atoms), and a mole of CaO contains 6.02×1023 formula units (pairs of Ca^{2+} and O^{2-} ions) of CaO.

The calculation of the percentage composition of $(NH_4)_2SO_4$ is given below. Note that the molar mass of the compound is 132 g/mol, each mol of the substance contains 2×1 = 2 mol of N, 2×4 = 8mol of H, 1 mol of S, and 4 mol of O.

$2 \text{ mol N} \times 14.0\text{g N/mol N} = 28.0\text{g N}, \text{ \% N} = \frac{28.0g}{132g} \times 100 = 21.2\% \text{ N}$

$8 \text{ mol H} \times 1.0 \text{ g H/mol H} = 8.0 \text{ g H}, \text{ \% H} = \frac{8.0g}{132g} \times 100 = 6.1 \text{ \% H}$

$1 \text{ mol S} \times 32.0 \text{ g S/mol S} = 32.0 \text{ g S}, \text{ \% S} = \frac{32.0g}{132g} \times 100 = 24.2\% \text{ S}$

$4 \text{ mol O} \times 16.0 \text{ g O/mol O} = 64.0 \text{ g O}, \text{ \% O} = \frac{64.0g}{132g} \times 100 = 48.5\% \text{ O}$

Example: Given the atomic masses Ca 40.0, C 12.0, and O 16.0, what is the percentage composition of calcium oxalate, CaC_2O_4?

Answer: 31.3% Ca, 18.8% C, 50.0% O