10.4 Empirical and Molecular Formulas

Recall that every chemical compound has a definite composition—a composition that is always the same wherever that compound is found. The composition of a compound is usually stated as the percent by mass of each element in the compound.

▶ **Percent composition** The percent of an element in a compound can be found in the following way.

$$\% \text{ by mass of an element} = \frac{\text{mass of element in 1 mol compound}}{\text{molar mass of compound}} \times 100$$

The example problem below shows you how to determine the **percent composition** of a compound, which is the percent by mass of each element in the compound.

Example Problem 10-7

Calculating Percent Composition

Determine the percent composition of calcium chloride ($CaCl_2$).

First, analyze the information available from the formula. A mole of calcium chloride consists of one mole of calcium ions and two moles of chloride ions.

Next, gather molar mass information from the atomic masses on the periodic table. To the mass of one mole of $CaCl_2$, a mole of calcium ions contributes 40.078 g, and two moles of chloride ions contribute 2×35.453 g = 70.906 g for a total molar mass of 110.984 g/mol for $CaCl_2$.

Finally, use the data to set up a calculation to determine the percent by mass of each element in the compound. The percent by mass of calcium and chlorine in $CaCl_2$ can be calculated as follows.

$$\% \text{ Ca in Ca } Cl_2 = \frac{40.078 \text{ g Ca}}{110.984 \text{ g } CaCl_2} \times 100 = 36.112\% \text{ Ca}$$

$$\% \text{ Cl in } CaCl_2 = \frac{70.906 \text{ g Cl}}{110.984 \text{ g } CaCl_2} \times 100 = 63.888\% \text{ Cl}$$

As a check, be sure that the percentages add up to 100%. In this case, the percentages add up to 100.000%.

Practice Problems

21. Calculate the percent composition of aluminum oxide (Al_2O_3).

22. Determine the percent composition of magnesium nitrate, which has the formula $Mg(NO_3)_2$.

23. Calculate the percent oxygen in potassium chlorate ($KClO_3$).

24. Calculate the percent nitrogen in ammonium hexacyanoiron(II), which has the formula $(NH_4)_4Fe(CN)_6$.

25. Acetylene gas has the molecular formula C_2H_2. How does the percent composition of acetylene compare with that of benzene (C_6H_6)?

26. A 134.50-g sample of aspirin is made up of 6.03 g of hydrogen, 80.70 g of carbon, and 47.77 g of oxygen. What is the percent by mass of each element in aspirin?

27. A 2.89-g sample of sulfur reacts with 5.72 g of copper to form a black compound. What is the percentage composition of the compound?

28. Aluminum oxide has a composition of 52.9% aluminum and 47.1% oxygen by mass. If 16.4 g of aluminum reacts with oxygen to form aluminum oxide, what mass of oxygen reacts?

Determine the percent composition for each of the elements in the compound.

1. aluminum sulfide Al_2S_3

2. nickel(II) iodide, NiI_2

3. calcium cyanide, $Ca(CN)_2$

4. Cobalt fluoride, CoF_3

5) Iron (III) oxide, Fe_2O_3

6) Aluminum acetate, $Al(C_2H_3O_2)_3$

7) Sodium aluminum sulfate, $Na_2Al_2(SO_4)_4$