

► **Empirical formulas** You can use percent composition data to help identify an unknown compound by determining its empirical formula. The **empirical formula** is the simplest whole-number ratio of atoms of elements in the compound. In many cases, the empirical formula is the actual formula for the compound. For example, the simplest ratio of atoms of sodium to atoms of chlorine in sodium chloride is 1 atom Na : 1 atom Cl. So, the empirical formula of sodium chloride is  $\text{Na}_1\text{Cl}_1$ , or  $\text{NaCl}$ , which is the true formula for the compound. The following example problem will show you how to determine empirical formulas.

### Example Problem 10-8

#### *Empirical Formula from Percent Composition*

The percent composition of an unknown compound is found to be 38.43% Mn, 16.80% C, and 44.77% O. Determine the compound's empirical formula.

Because *percent* means “parts per hundred parts,” assume that you have 100 g of the compound. Then calculate the number of moles of each element in the 100 g of compound. The number of moles of manganese may be calculated as follows.

$$\text{moles of Mn (in 100 g)} = \text{grams Mn (in 100 g)} \times \frac{1 \text{ mol Mn}}{\text{molar mass Mn}}$$

$$\begin{aligned} \text{moles of Mn (in 100 g)} &= 38.43 \text{ g Mn} \times \frac{1 \text{ mol Mn}}{54.938 \text{ g Mn}} = \\ &0.6995 \text{ mol Mn} \end{aligned}$$

By following the same pattern, the number of moles of carbon and oxygen per 100-g sample may be calculated.

$$\text{moles of C (in 100 g)} = 16.80 \text{ g C} \times \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 1.399 \text{ mol C}$$

$$\text{moles of O (in 100 g)} = 44.77 \text{ g O} \times \frac{1 \text{ mol O}}{15.999 \text{ g O}} = 2.798 \text{ mol O}$$

The results show the following relationship.

$$\text{mol Mn} : \text{mol C} : \text{mol O} = 0.6995 : 1.399 : 2.798$$

To obtain the simplest whole-number ratio of moles, divide each number of moles by the smallest number of moles.

$$\text{moles of Mn} = \frac{0.6995 \text{ mol Mn}}{0.6995} = 1 \text{ mol Mn}$$

$$\text{moles of C} = \frac{1.399 \text{ mol C}}{0.6995} = 2 \text{ mol C}$$

$$\text{moles of O} = \frac{2.798 \text{ mol O}}{0.6995} = 4 \text{ mol O}$$

The empirical formula for the compound is  $\text{MnC}_2\text{O}_4$ .

### Practice Problems

26. The composition of acetic acid is 40.00% carbon, 6.71% hydrogen, and 53.29% oxygen. Calculate the empirical formula for acetic acid.
27. An unknown compound is analyzed and found to be composed of 14.79% nitrogen, 50.68% oxygen, and 34.53% zinc. Calculate the empirical formula for the compound.
28. Calculate the empirical formula for a compound whose analysis is 74.97% aluminum and 25.03% carbon.
29. The composition of ascorbic acid (vitamin C) is 40.92% carbon, 4.58% hydrogen, and 54.50% oxygen. What is the empirical formula for vitamin C?