WKS 3-2 – Percent Composition & Empirical Formula; Hydrates
Problems pg. 106 #3.36, 3.39, 3.40, 3.48, 3.50; Empirical Formula & Hydrate Problems

3.36 Describe how the knowledge of the percent composition by mass of an unknown compound can help us identify the compound.

For a pure material, the percent composition is constant. So, to determine what a sample is, the percent composition will provide evidence of its formula.

3.39 Tin (Sn) exists in Earth's crust as SnO_2. Calculate the percent composition by mass of Sn and O in SnO_2.

$$\textbf{\%Sn} = \frac{118.7\text{ g/mol}}{150.7\text{ g/mol}} \times 100\% = \boxed{\mathbf{78.77\%}}$$

$$\textbf{\%O} = \frac{(2)(16.00\text{ g/mol})}{150.7\text{ g/mol}} \times 100\% = \boxed{\mathbf{21.23\%}}$$

3.40 Calculate the percent composition of chloroform ($CHCl_3$).

$$\%C = \frac{12.01\text{ g/mol}}{119.4\text{ g/mol}} \times 100\% = \boxed{\mathbf{10.06\%}}$$

$$\%H = \frac{1.008\text{ g/mol}}{119.4\text{ g/mol}} \times 100\% = \boxed{\mathbf{0.8442\%}}$$

$$\%Cl = \frac{3(35.45)\text{ g/mol}}{119.4\text{ g/mol}} \times 100\% = \boxed{\mathbf{89.07\%}}$$

Check: The sum of the percentages is (10.06% + 0.8442% + 89.07%) = 99.97%. The small discrepancy from 100% is due to the way we rounded off.

3.48 What is the mass of F, in grams, in 24.6 g of tin(II) fluoride (SnF_2)?

$$\%F = \frac{\text{mass of F in 1 mol SnF}_2}{\text{molar mass of SnF}_2} \times 100\% = \frac{2(19.00\text{ g})}{156.7\text{ g}} \times 100\% = 24.25\%\text{ F}$$

$$?\ \textbf{g F} = \left(\frac{24.25\text{ g F}}{100\text{ g SnF}_2}\right)(24.6\text{ g SnF}_2) = \boxed{\mathbf{5.97\ g\ F}}$$

Note: This problem could have been worked by the following conversions:
g of SnF_2 → mol of SnF_2 → mol of F → g of F

3.50 What are the empirical formulas of the compounds with the following compositions?
(a) 40.1 % C, 6.6 % H, 53.3 % O

$$n_C = 40.1\text{ g C} \times \frac{1\text{ mol C}}{12.01\text{ g C}} = 3.34\text{ mol C} \div 3.33 \approx 1$$

$$n_H = 6.6\text{ g H} \times \frac{1\text{ mol H}}{1.008\text{ g H}} = 6.5\text{ mol H} \div 3.33 \approx 2$$

$$n_O = 53.3\text{ g O} \times \frac{1\text{ mol O}}{16.00\text{ g O}} = 3.33\text{ mol O} \div 3.33 = 1$$

This gives the empirical formula, **CH_2O**.

(b) 60.1 % K, 18.4 % C, 21.5 % N

$$n_K = 60.1\text{g K} \times \frac{1\text{ mol K}}{39.10\text{ g K}} = 1.54\text{mol K}$$

$$n_C = 18.4\text{g C} \times \frac{1\text{ mol C}}{12.01\text{ g C}} = 1.53\text{ mol C}$$

$$n_N = 21.5\text{ g N} \times \frac{1\text{ mol N}}{14.01\text{ g N}} = 1.53\text{ mol N}$$

Dividing by the smallest number of moles (1.53 mol) gives the empirical formula, **KCN**.

A. An unknown hydrocarbon is found to contain 84.21% C by mass. What is its empirical formula?

Since it is a hydrocarbon, it contains only C & H. Thus it contains 15.79% H by mass.

$$\boldsymbol{n}_C = 84.21\text{ g C} \times \frac{1\text{ mol C}}{12.01\text{ g C}} = 7.012\text{ mol C} \div 7.012 = 1 \times 4 = 4$$

$$\boldsymbol{n}_H = 15.79\text{ g H} \times \frac{1\text{ mol H}}{1.008\text{ g H}} = 15.66\text{ mol H} \div 7.012 = 2.233 \times 4 = 8.933 \approx 9$$

2.233 ≈ 2.25, so we multiply both moles by 4 to get **C_4H_9**.

B. The general formula of Epson salts can be written as $MgSO_4 \cdot x\ H_2O$. When 5.061 g of this hydrate is heated to 250ºC, all the water of hydration is lost, leaving 2.472 g of $MgSO_4$. What is the value of x?

$$\text{Moles MgSO}_4 = 2.472\text{ g MgSO}_4 \times \frac{1\text{ mol MgSO}_4}{120.36\text{ g}} = 2.05 \times 10^{-2}\text{ mol MgSO}_4$$

Mass H_2O lost = 5.061 g – 2.472 g = 2.589 g H_2O

$$\text{Moles H}_2\text{O} = 2.589\text{ g H}_2\text{O} \times \frac{1\text{ mol H}_2\text{O}}{18.02\text{ g H}_2\text{O}} = 1.44 \times 10^{-1}\text{ mol H}_2\text{O}$$

$$x = \frac{1.44 \times 10^{-1}\text{ mol H}_2\text{O}}{2.05 \times 10^{-2}\text{ mol MgSO}_4} = 7.01 \approx 7$$ ($MgSO_4 \cdot 7\ H_2O$, magnesium sulfate heptahydrate)