Chemistry 11: Empirical and Molecular Formulae

1. When 0.224 g of tin, reacted with an excess of chlorine, 0.492 g of a tin chloride salt was obtained. What is the empirical formula of the salt?

\[
\begin{align*}
\text{mass } \text{Cl} &= 0.492 \text{g} - 0.224 \text{g} = 0.268 \text{g} \\
\text{mols } \text{Sn} &= \frac{0.224 \text{g}}{118.7 \text{g/mol}} = 1.89 \times 10^{-3} \text{mol} \\
\text{mols } \text{Cl} &= \frac{0.268 \text{g}}{35.5 \text{g/mol}} = 7.55 \times 10^{-3} \text{mol}
\end{align*}
\]

\[
\frac{\text{Sn}}{\text{Cl}} = \frac{1.89 \times 10^{-3}}{1.89 \times 10^{-3}} = 1:4
\]

The empirical formula is \( \text{SnCl}_4 \)

2. When 0.445 g of potassium reacted with excess oxygen, 0.809 g of a yellow oxide was obtained. What is the empirical formula of the oxide?

\[
\begin{align*}
\text{mass } \text{O} &= 0.809 \text{g} - 0.445 \text{g} = 0.364 \text{g} \\
\text{mols } \text{K} &= \frac{0.445 \text{g}}{39.1 \text{g/mol}} = 0.114 \times 10^{-2} \text{mol} \\
\text{mols } \text{O} &= \frac{0.364 \text{g}}{16.0 \text{g/mol}} = 2.28 \times 10^{-2} \text{mol}
\end{align*}
\]

\[
\frac{\text{K}}{\text{O}} = \frac{0.114 \times 10^{-2}}{2.28 \times 10^{-2}} = \frac{1.14 \times 10^{-2}}{2.28 \times 10^{-2}} = 1:2
\]

The empirical formula is \( \text{K}_2\text{O}_2 \)

3. Find the empirical formula of a compound that is 34.43% iron and 65.57% chlorine. Assume 100 g sample.

\[
\begin{align*}
\text{mass } \text{Fe} &= 34.43 \text{g} \text{ of 100 g} = 34.43 \text{g} \\
\text{mols } \text{Fe} &= \frac{34.43 \text{g}}{55.8 \text{g/mol}} = 0.617 \text{mol Fe} \\
\text{mass } \text{Cl} &= 65.57 \text{g} \text{ of 100 g} = 65.57 \text{g} \\
\text{mols } \text{Cl} &= \frac{65.57 \text{g}}{35.5 \text{g/mol}} = 1.85 \text{mol Cl}
\end{align*}
\]

\[
\frac{\text{Fe}}{\text{Cl}} = \frac{0.617}{1.85} = \frac{0.617}{0.617} = \frac{1}{3}
\]

The empirical formula is \( \text{FeCl}_3 \)

4. Find the empirical formula of a compound that is 63.5% carbon, 12.2% hydrogen, and 24.2% oxygen. Assume 100 g sample.

\[
\begin{align*}
\text{mol } \text{C} &= \frac{63.5 \text{g}}{12.0 \text{g/mol}} = 5.29 \text{mol} \\
\text{mol } \text{H} &= \frac{12.2 \text{g}}{1.0 \text{g/mol}} = 12.2 \text{mol} \\
\text{mol } \text{O} &= \frac{24.2 \text{g}}{16.0 \text{g/mol}} = 1.51 \text{mol}
\end{align*}
\]

\[
\frac{\text{C}}{\text{H}} = \frac{5.29}{1.51} = \frac{5.29}{1.51} = \frac{3.5}{8:1} \text{ or } 7:16:2
\]

The empirical formula is \( \text{C}_7\text{H}_{16}\text{O}_2 \)

5. The empirical formula of cyclohexane is \( \text{CH}_2 \), and its molar mass is 84.0 g/mol. What is the molecular formula of cyclohexane?

\[
\text{FW } \text{CH}_2 = 12.0\text{u} + 2(1.0\text{u}) = 14.0 \text{u} = 14.0 \text{g/mol}
\]

\[
\text{# of } \text{CH}_2 = \frac{84.0 \text{g/mol}}{14.0 \text{g/mol}} = 6 \text{ molecular formula is } \text{C}_6\text{H}_{12}
\]

6. Adipic acid, used to make some types of nylon, has the empirical formula \( \text{C}_3\text{H}_5\text{O}_2 \). Its molar mass is 114.0 g. What is the molecular formula of adipic acid?

\[
\text{FW } \text{C}_3\text{H}_5\text{O}_2 = 3(12.0\text{u}) + 5(1.0\text{u}) + 16.0 \text{u} = 57.0 \text{g/mol}
\]

\[
\text{# of } \text{C}_3\text{H}_5\text{O}_2 = \frac{114.0 \text{g/mol}}{57.0 \text{g/mol}} = 2 \text{ } \text{C}_3(\text{2})\text{H}_5(\text{2})\text{O}_2 \Rightarrow \text{C}_6\text{H}_{10}\text{O}_2
\]