Chemical Quantities Outline

(Percent Composition & Empirical Formulas)

Percent Composition

- Percent composition is the percent by mass of each element in a compound
- Using the mass of the element you solve using the following formula:

$$\%\text{ by mass of element} = \frac{\text{mass of element}}{\text{mass of compound}} \times 100$$

When a 13.60g sample of a compound containing only magnesium and oxygen is broken down, 5.40g of oxygen and 8.20g of Mg are obtained. What is the percent composition of this compound?

Oxygen

$$\frac{5.40\text{g Oxygen}}{13.60\text{g compound}} \times 100 = 39.7\%\text{ Oxygen}$$

Magnesium

$$\frac{8.20\text{g Mg}}{13.60\text{g compound}} \times 100 = 60.3\%\text{ Magnesium}$$

Percent Composition from a Chemical Formula

- Formula: $\%\text{ by mass of an element} = \frac{\text{molar mass of element}}{\text{molar mass of compound}} \times 100$

Propane (C_3H_8), the fuel commonly used in gas grills, is one of the compounds obtained from petroleum. Calculate the percent composition of propane.

$C \Rightarrow 3\left(12.01\frac{\text{g}}{\text{mole}}\right) = 36.03\text{g/mole}$

$H = 8\left(1.01\frac{\text{g}}{\text{mole}}\right) = 8.08\text{g/mole}$

Total Molar Mass = 44.11 g/mole

$C \Rightarrow \frac{36.03\text{ g/mole}}{44.11\text{ g/mole}} \times 100 = 81.8\%\text{ C}$

$H \Rightarrow \frac{8.08\text{ g/mole}}{44.11\text{ g/mole}} \times 100 = 18.3\%\text{ H}$

Empirical Formulas

- Empirical formulas are the lowest whole number ratio of the atoms or moles of elements in a compound
- May or may not be the same as the molecular formula
- Example using hydrogen peroxide:

$H_2O_2 \longrightarrow HO$

Chemical formula — Empirical formula

Molecular Formulas

- Either the same as the empirical formula or a simple whole number multiple of the empirical formula

- Some examples:

molecular formula		empirical formula
H_2O_2	=	HO
$C_6H_{12}O_6$	=	CH_2O
N_2O_6	=	NO_3
H_2O	=	H_2O
$C_2H_{10}O_2$	=	CH_5O
N_3O_2	=	N_3O_2
P_4O_{10}	=	P_2O_5

The Percent Composition of a compound can be used to calculate the empirical formula of that compound.

5 steps:

1. **Change % to grams**
2. **Convert mass to moles**
3. **Divide by smallest number of moles**
4. **If not whole numbers, multiply all by the smallest whole number that gives all whole numbers for answers**
5. **Write the whole numbers for step 4 as the subscripts for the elements in the empirical formula**

A compound is analyzed and found to contain 25.9% nitrogen and 74.1% oxygen. What is the empirical formula?

$N = 25.9\% = 25.9\,g$

$25.9\,g\,N\left(\frac{1\,mol}{14\,g\,N}\right) = \frac{1.85\,mol\,N}{1.85} = 1$

$1 \times 2 = 2$

$O = 74.1\% = 74.1\,g$

$74.1\,g\,O\left(\frac{1\,mol}{16.00\,g}\right) = \frac{4.63\,mol}{1.85} = 2.5$

$2.5 \times 2 = 5$

Empirical formula N_2O_5

Calculate the empirical formula for a compound that is 67.6% Hg, 10.8% S, and 21.6% O.

$Hg = 67.6\,g$

$S = 10.8\,g$

$O = 21.6\,g$

$67.6\,g\,Hg\left(\frac{1\,mol}{200.59\,g\,Hg}\right) = \frac{0.337\,mol}{0.337} = 1$

$10.8\,g\,S\left(\frac{1\,mol}{32.06\,S}\right) = \frac{0.337\,mol}{0.337} = 1$

$21.6\,g\,O\left(\frac{1\,mol}{16.00\,g\,O}\right) = \frac{1.35\,mol}{0.337} = 4$

Empirical formula $HgSO_4$

Calculate the molecular formula of a compound whose molar mass is 60.0g/mol and empirical formula is CH_4N

$C = 12.0\,\frac{g}{mol}$

$H = 4(1.01\,g/mol) = 4.04\,\frac{g}{mol}$

$N = 14.01\,\frac{g}{mol}$

Empirical formula mass

C = 12.01 g/mol
H = 4.04 g/mol
N = 14.01 g/mol
30.06 g/mol

Divide the molar mass by empirical formula mass

$\frac{60.0\ g/mol}{30.0\ g/mol} = 2$

Multiply the empirical formula by this value to figure out the molecular formula

$CH_4N \times 2 \Rightarrow C_2H_8N_2$

Find the molecular formula of ethylene glycol, which is used as antifreeze. The molar mass is 62.0 g/mol, and the empirical formula is CH_3O.

C = 12.01 g/mol
H = 3.03 g/mol
O = 16.00 g/mol
31.04 g/mol

$\frac{62.0\ g/mole\ \text{molar mass}}{31.04\ g/mole\ \text{empirical mass}} = 2$

$CH_3O \times 2 \Rightarrow C_2H_6O_2$