Empirical & Molecular Formulas

Chapter 3

Percent Composition

% Element   =   atomic mass of element x # atoms   x 100%
in compound   molar mass of the compound

Calculate the percent phosphorus in
calcium phosphate

Empirical and Molecular Formulas

- *Empirical Formula* - the smallest whole number ratio of atoms in a compound.

- *Molecular Formula* - the actual number of atoms in a molecule (multiple of the empirical formula).

- *Example:* Octane
  - Molecular formula = C_8H_{18}
  - Empirical formula = C_4H_9

Sample Problem: Empirical & Molecular Formulas

What is the molecular formula of the sugar ribose if it is 40.0% C, 6.7% H, and 53.3% O and it has a molecular mass of 150.1 g/mol?

- *First, determine the empirical formula:*

Step 1. Assume 100.0 g of the compound.

If you have 100g of the material, you will have the following masses of C, H, & O:

   40.0 g C   6.7 g H   53.3 g O

Step 2. Convert grams to moles:

$$\frac{40.0 \text{ g C} \quad 1 \text{ mol C}}{12.01 \text{ g C}} = 3.33 \text{ mol C}$$

$$\frac{6.7 \text{ g H} \quad 1 \text{ mol H}}{1.01 \text{ g H}} = 6.6 \text{ mol H}$$

$$\frac{53.3 \text{ g O} \quad 1 \text{ mol O}}{16.00 \text{ g O}} = 3.33 \text{ mol O}$$

Step 3. Find the smallest ratio of atoms.

C	3.33 / 3.33	= **1**
H	6.6 / 3.33	= 1.98 ≈ **2**
O	3.33 / 3.33	= **1**

Therefore, the *empirical formula* of ribose is

$$CH_2O$$
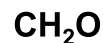
● *Next, determine the molecular formula.*

Step 4. Calculate the empirical formula mass.

C	=	12.01	x 1	=	12.01 g/mol
H	=	1.01	x 2	=	2.02 g/mol
O	=	16.00	x 1	=	16.00 g/mol

30.03 g/mol

Step 5. Calculate the number of empirical formula units within the molecular formula.

Multiply the subscripts of the empirical formula by this number to get the *molecular formula*.

$$\frac{150.1 \text{ g/mol}}{30.03 \text{ g/mol}} = 4.998 \approx 5$$

$$C_{1x5}H_{2x5}O_{1x5} = C_5H_{10}O_5$$
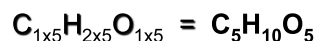
Example: Empirical Formulas

An oxide of osmium is a pale yellow solid. If 2.89 g of the compound contains 2.16g of osmium, what is its formula?

Example: Empirical & Molecular Formulas

A 30.5-g sample of acrylic acid, used in the manufacture of acrylic plastics, is found to contain 15.25 g C, 1.71 g H, and 13.54 g O.

In a separate experiment, the acrylic acid is found to have a molar mass of approximately 72 g/mol.

What are the empirical and molecular formulas of acrylic acid?

Calculating Waters of Hydration

● A 10.00–g sample of $CoCl_2 \cdot x\ H_2O$ is heated. The mass of the resulting solid was found to be 5.46 g.

  ● How many waters of hydration are in the formula unit?

  ● What is the formula & name of the hydrate?