Percent Composition

% Composition Formula: $\frac{\text{mass element}}{\text{mass compound}} \times 100$

Example 1: What percentage of ammonium phosphate is hydrogen?

$(NH_4)_3(PO_4)$

$N = 3 \times 14.01 = 42.03$

$H = 12 \times 1.01 = 12.12$

$P = 1 \times 30.97 = 30.97$

$O = 4 \times 16 = +64$

149.12

$\% H = \frac{\text{mass } 12\,H}{\text{mass } (NH_4)_3PO_4} \times 100$

$\% = \frac{12.12}{149.12} \times 100$

$\% H = 8.13\,\%$

Example 2: Which of the following compounds contains the greatest percentage of iron by mass?

(a) $FeCl_3$ $\% Fe = \frac{\text{mass } Fe}{\text{mass } FeCl_3} \times 100 = \frac{55.85}{162.2} \times 100 = 34.43\,\%$

(b) FeO $\% Fe = \frac{\text{mass } Fe}{\text{mass } FeO} \times 100 = \frac{55.85}{71.85} \times 100 = 77.73\%$

(c) Fe_2O_3 $\% Fe = \frac{\text{mass } 2Fe}{\text{mass } Fe_2O_3} \times 100 = \frac{(2 \times 55.85)}{159.7} \times 100 = 69.94\,\%$

(d) $FeCl_2$ $\% Fe = \frac{\text{mass } Fe}{\text{mass } FeCl_2} \times 100 = \frac{55.85}{126.75} \times 100 = 44.06\,\%$

Molecular Formula vs Empirical Formula

An empirical formula is: the simplest/most reduced ratio of atoms

A molecular formula is: the actual # of atoms in the molecule

CH_2O is a empirical $C_6H_{12}O_6$ is a molecular

- Empirical Formula is a reduced form of Molecular formula
- Different compounds can have the same **empirical formula** but different **molecular formulas**.

Empirical Formulas

Step 1: Change % sign to g - *if you are given grams, skip this step*
Step 2: Convert masses to moles using molar mass
Step 3: Divide all # of moles by the smallest value
Step 4: **If dividing gave you** .5, then multiply by 2
Step 5: **If dividing gave you** .3 **or** .7, then multiply by 3
Step 6: If step 5 or 6 do not apply, then Round step 3 values to a whole number
Step 7: **Once you know the** whole # ratio, **place them as** subscripts **in the formula**

Practice Problems:

1. A compound contains 3.26g of arsenic and 1.04g of oxygen. What is the empirical formula?

$\frac{3.26\text{ g As}}{} \left| \frac{1\text{ mol As}}{74.92\text{ g As}} \right. = .04351\text{ mol As} / .04351 = 1 \times 2 = 2\text{ mol As}$

$\frac{1.04\text{ g O}}{} \left| \frac{1\text{ mol O}}{16\text{ g O}} \right. = .065\text{ mol O} / .04351 = 1.5 \times 2 = 3\text{ mol O}$

Empirical = As_2O_3

2. Find the empirical formula of a compound that is 33.38% Na, 22.65% S, and 44.90% O.

$33.38\%\ Na = \frac{33.38\ g\ Na}{} \left| \frac{1\ mol\ Na}{22.99\ g\ Na} \right. = \frac{1.451935\ mol\ Na}{0.7062675} = 2\ mol\ Na$

$22.65\%\ S = \frac{22.65\ g\ S}{} \left| \frac{1\ mol\ S}{32.07\ g\ S} \right. = \frac{0.7062675\ mol\ S}{0.7062675} = 1\ mol\ S$

$44.90\%\ O = \frac{44.90\ g\ O}{} \left| \frac{1\ mol\ O}{16\ g\ O} \right. = \frac{2.80625\ mol\ O}{0.7062675} = 4\ mol\ O$

Empirical = Na_2SO_4

3. What is the empirical formula of a compound that is 62.10% C, 13.80% H, and 24.10% N?

$62.10\%\ C = \frac{62.10\ g\ C}{} \left| \frac{1\ mol\ C}{12.01\ g\ C} \right. = \frac{5.17069\ mol\ C}{1.720199857} = 3\ mol\ C$

$13.80\%\ H = \frac{13.80\ g\ H}{} \left| \frac{1\ mol\ H}{1.01\ g\ H} \right. = \frac{13.663366\ mol\ H}{1.720199857} = 8\ mol\ H$

$24.10\%\ N = \frac{24.10\ g\ N}{} \left| \frac{1\ mol\ N}{14.01\ g\ N} \right. = \frac{1.720199857\ mol\ N}{1.720199857} = 1\ mol\ N$

Empirical = C_3H_8N

Molecular Formulas

To find the molecular formula you must:

1. Find the empirical formula if not given
2. Determine the molar mass of the empirical formula
3. $\frac{\text{MM molecular formula}}{\text{MM empirical formula}} = \text{"X"}$
4. Multiply each subscript in the empirical formula by "X"

Practice Problems

1. The empirical formula of a compound is CH; the molecular molar mass is 78.11 g/mol. What is its molecular formula?

Empirical = CH

$MM_{MF} = 78.11$

$MM_{EF} = 13.02$

$$\frac{MM_{MF}}{MM_{EF}} = \frac{78.11}{13.02} = 6$$

Molecular = (CH) x 6 = $\boxed{C_6H_6}$

2. A compound has an empirical formula of CH_3O and a molecular mass of 62.00 g/mol. What is its molecular formula?

Empirical = CH_3O

$MM_{MF} = 62.00$ g/mol

$MM_{EF} = (12.01) + (3 \times 1.01) + (16) = 31.04$

$$\frac{MM_{MF}}{MM_{EF}} = \frac{62.00}{31.04} = 2$$

Molecular = $(CH_3O) \times 2 = C_2H_6O_2$

3. A compound is 26.70%C, 2.20% H, and 71.10% O. Its molecular mass is 90.00 g/mol. What is its molecular formula?

Summary

Determine the molecular and empirical formula for each:

a. C_6H_8 b. N_2O_6 c. $C_6H_{12}O_6$ d. BCl_3