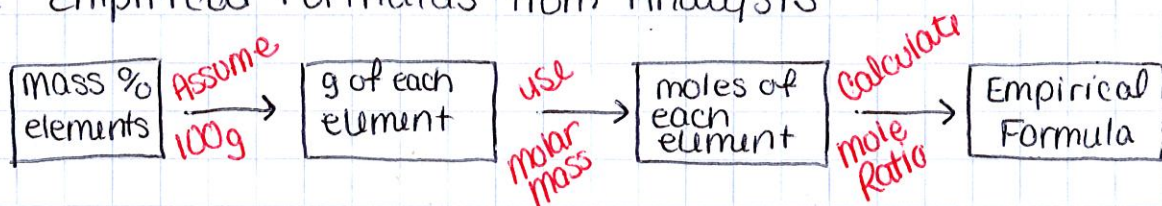


Ch 3 Reactions, mols, & Stoichiometry

1. Empirical Formulas from Analysis



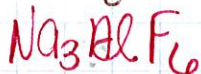
Ex) A sample of methyl benzoate, used in perfume manufacturing, contains 70.57% carbon, 5.93% hydrogen, and 23.49% oxygen. What is its empirical formula?

$\frac{\overset{\text{C}}{70.57\text{g}}}{12.01\text{g/mol}}$ $= \frac{5.875936\text{ mol}}{1.468125\text{ mol}}$ $= 4\text{C}$	$\frac{\overset{\text{H}}{5.93\text{g}}}{1.01\text{g/mol}}$ $= \frac{5.8771287\text{ mol}}{1.468125\text{ mol}}$ $= 4\text{H}$	$\frac{\overset{\text{O}}{23.49\text{g}}}{16.00\text{g/mol}}$ $= 1.468125\text{ mol}$ $= 1\text{O}$
$\text{EF} = \text{C}_4\text{H}_4\text{O}$		

Ex) Ascorbic acid, vitamin C, contains 40.92% carbon, 4.58% hydrogen, and the rest is oxygen. What is the empirical formula?

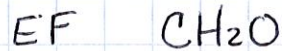
$\frac{\overset{\text{C}}{40.92\text{g}}}{12.01\text{g/mol}}$ $= 3.40716\text{ mol}$ $\frac{3.40625\text{ mol}}{3.40625\text{ mol}}$ $= (1\text{C})_3$ $= 3\text{C}$	$\frac{\overset{\text{H}}{4.58\text{g}}}{1.01\text{g/mol}}$ $= 4.53465\text{ mol}$ $\frac{3.40625\text{ mol}}{3.40625\text{ mol}}$ $= (1.33\text{H})_3$ $= 4\text{H}$	$100 - 40.92 - 4.58 = 54.5\%$ $\frac{54.5\text{g}}{16.00\text{g/mol}}$ $= 3.40625\text{ mol}$ $\frac{3.40625\text{ mol}}{3.40625\text{ mol}}$ $= (1\text{O})_3$ $= 3\text{O}$
$\text{EF} = \text{C}_3\text{H}_4\text{O}_3$		

Ex) A compound is found to contain 32.79% sodium, 13.02% aluminum, and 54.19% fluorine. What is the empirical formula?

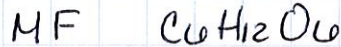


2. molecular Formula from Empirical Formula

- The subscripts in a molecular formula are always a whole-number multiple of the subscripts in an empirical formula.
- ∴ The mass of the molecular formula is always a multiple of the empirical formula.



$$\begin{array}{r} \text{C} = 12 \\ 2\text{H} = 2 \\ 1\text{O} = 16 \\ \hline 30 \end{array}$$



$$\begin{array}{r} 6\text{C} = 72 \\ 12\text{H} = 12 \\ 6\text{O} = 96 \\ \hline 180 \end{array}$$

This is 6x's heavier than this!

Ex) Mesitylene has an empirical formula of C_3H_4 . The experimentally determined molecular weight is 121 amu. What is the molecular formula?

$$\begin{array}{l} \text{C}_3\text{H}_4 \\ \downarrow \quad \downarrow \\ 36 + 4 = 40 \end{array}$$

$$\frac{121}{40} = 3$$

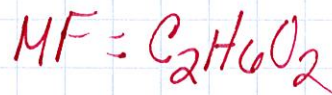
$$3(\text{C}_3\text{H}_4) = \frac{\text{MF}}{\text{EF}} = \text{C}_9\text{H}_{12}$$

Ex) Ethylene glycol, known as antifreeze, is composed of 38.7% carbon, 9.7% hydrogen, and 51.6% oxygen. Its molar mass is 62.1 g/mol. Determine its molecular formula.



$$12 + 3 + 16$$

$$= 31$$



$$\frac{62}{31} = 2$$

3. Combustion Analysis to determine an empirical formula

- When a substance (commonly containing mostly carbon & hydrogen), is completely combusted, all of the C is changed to CO₂ & all the H to H₂O. From the masses of CO₂ and H₂O produced, the moles of C & H in the original compound can be determined & then the empirical formula can be found.
 - If a 3rd element is in the original compound, its mass can be determined by subtracting the C & H masses from the mass of the original compound.

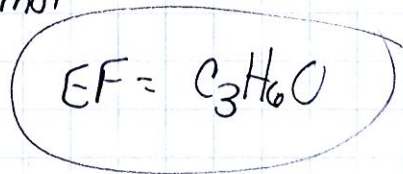
Ex) Caproic acid, responsible for the foul odor of dirty socks, is composed of C, H, & O. Combustion of a .225g sample of acid produces .512g CO₂ and .209g H₂O. What is the empirical formula?

$$\text{grams of C} = .512 \text{g CO}_2 \left(\frac{1 \text{ mol CO}_2}{44 \text{g CO}_2} \right) \left(\frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \right) \left(\frac{12 \text{g C}}{1 \text{ mol C}} \right) = .139 \text{g C}$$

$$\text{grams of H} = .209 \text{g H}_2\text{O} \left(\frac{1 \text{ mol H}_2\text{O}}{18 \text{g H}_2\text{O}} \right) \left(\frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) \left(\frac{1 \text{g H}}{1 \text{ mol H}} \right) = .0232 \text{g H}$$

$$\text{mass of O} = .225 \text{g} - .139 \text{g} - .0232 \text{g} = .0628 \text{g O}$$

$$\begin{array}{ccc} \frac{\text{C}}{.139 \text{g}} & \frac{\text{H}}{.0232 \text{g}} & \frac{\text{O}}{.0628 \text{g}} \\ \frac{12.01 \text{g/mol}}{.139 \text{g}} & \frac{1.01 \text{g/mol}}{.0232 \text{g}} & \frac{16.00 \text{g/mol}}{.0628 \text{g}} \\ = \frac{.011574 \text{ mol}}{.003925 \text{ mol}} & = \frac{.02297 \text{ mol}}{.003925 \text{ mol}} & = \frac{.003925 \text{ mol}}{.003925 \text{ mol}} \\ = 3 \text{ C} & = 6 \text{ H} & = 1 \text{ O} \end{array}$$



Ex) isopropyl alcohol, is composed of C, H, and O. Combustion of .255g is isopropyl alcohol produces .561g of CO₂ and .306g of H₂O. What is the empirical formula?

$$\text{grams C} = .561 \text{g CO}_2 \left(\frac{1 \text{ mol CO}_2}{44 \text{g CO}_2} \right) \left(\frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \right) \left(\frac{12 \text{g C}}{1 \text{ mol C}} \right) = .153 \text{g C}$$

$$\text{grams H} = .306 \text{g H}_2\text{O} \left(\frac{1 \text{ mol H}_2\text{O}}{18 \text{g H}_2\text{O}} \right) \left(\frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) \left(\frac{1 \text{g H}}{1 \text{ mol H}} \right) = .0340 \text{g H}$$

$$\text{grams O} = .255 \text{g} - .153 \text{g} - .0340 \text{g} = .0680 \text{g O}$$

$$\frac{.153 \text{g C}}{12.01 \text{g/mol}}$$

$$\frac{.0340 \text{g H}}{1 \text{g/mol}}$$

$$\frac{.0680 \text{g O}}{16.00 \text{g/mol}}$$

$$= \frac{.01274 \text{ mol C}}{.00425 \text{ mol}}$$

$$= \frac{.0340 \text{ mol H}}{.00425 \text{ mol}}$$

$$= \frac{.00425 \text{ mol O}}{.00425 \text{ mol}}$$

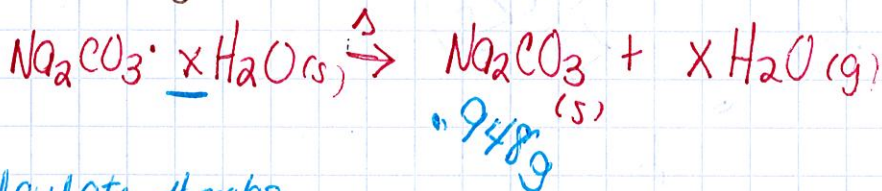
3C

8H

1O

EF = C₃H₈O

Ex) washing soda, a compound used to prepare hard water for washing laundry, is a hydrate, which means that a certain number of water molecules are included in the solid structure. Its formula can be written as Na₂CO₃ · x H₂O, where x is the number of moles of water molecules per mole of Na₂CO₃. When a 2.55g sample is heated at 25°C, all the water of hydration is lost, leaving .948g of Na₂CO₃. What is the value of x?



1st Calculate # moles
Na₂CO₃ → # moles
Na₂CO₃ · x H₂O

$$.948 \text{g Na}_2\text{CO}_3 \left(\frac{1 \text{ mol Na}_2\text{CO}_3}{106 \text{g}} \right) \left(\frac{1 \text{ mol Na}_2\text{CO}_3 \cdot x \text{H}_2\text{O}}{1 \text{ mol Na}_2\text{CO}_3} \right)$$

$$.00894 \text{ mol Na}_2\text{CO}_3 \cdot x \text{H}_2\text{O}$$

2nd Find the molar mass of the hydrate $\frac{2.55 \text{g}}{.00894 \text{mol}} = 285.23 \text{g/mol}$

$$\begin{aligned} 3^{\text{rd}} \text{ mm}(\text{Na}_2\text{CO}_3 \cdot x \text{H}_2\text{O}) &= \text{MM}(\text{Na}_2\text{CO}_3) + x(\text{MM H}_2\text{O}) \\ 285.23 \text{g/mol} &= 106 \text{g/mol} + x(18 \text{g/mol}) \\ 10 &= x \end{aligned}$$

Na₂CO₃ · 10H₂O

(4)

$$\begin{array}{r}
 285.23 \\
 -106 \\
 \hline
 179.23 \\
 \underline{18} \\
 10
 \end{array}
 = \frac{106}{106} + x(18)$$

$$\begin{array}{r}
 179.23 \\
 \underline{18} \\
 10
 \end{array}
 = \frac{x(18)}{18}$$

(106/106) = 1
 (18/18) = 1