

General and Organic Chemistry Lecture 3

Ch₃: Stoichiometry
22/10/2024
oct

* General and Organic Chemistry : Ch3 : Stoichiometry

L3

* Stoichiometry : The study of quantities of materials consumed and produced in chemical reactions
استهلاك المواد و انتاجها

- objects behave as though they were all identical, just like counting how many objects you have using a weight, you assume their weight to be the same

- Atoms are too small to count

- to ~~count~~ count, we need the average mass of an object

* Atomic Masses :

* ^{12}C is the standard for atomic mass, having a mass of exactly 12 atomic mass units

- we used it bc its the most common, and have high abundance naturally -

- the masses of all other atoms are given relative to this standard

- Element occur in nature as a mixture of isotopes

ex: Carbon = 98.89% ^{12}C

1.11% ^{13}C

< 0.01% ^{14}C

So for carbon we can't just say its atomic mass is 12 bc its a mixture of ^{12}C , ^{13}C , ^{14}C so we calculate the average atomic mass :

Formula :

$$\left(\text{Isotope 1 natural abundance} \right) \cdot \left(\text{atomic mass of Iso 1} \right) + \left(\text{Isotope 2 natural abundance} \right) \cdot \left(\text{atomic mass of Iso 2} \right) \dots$$

Percentage
↳ turn into decimal

so for carbon :

$$\left(0.9889 \right) \left(12 \text{ u} \right) + \left(0.0111 \right) \left(13.0034 \text{ u} \right) = \underline{\underline{12.01 \text{ u}}}$$

^{14}C is so small its negligible

①

- Even though natural carbon does NOT contain a single atom with mass 12.01, but for stoichiometric purposes we can consider carbon to be composed of only one type of atom with 12.01 mass

↳ this enables us to count atoms of natural carbon by weighing a sample of carbon

[Just like we are working with one type of atom instead of multiple isotopes]

* and for determining the number or count of isotopes we use the Mass Spectrometer device

* The Mole: Its the number equal to the number of carbon atoms in exactly 12 grams of pure ^{12}C

So: 1 mole of something was found to consist of 6.022×10^{23} units of that substance

Avogadro's number ↙

ex: 1 mole (and) of Eggs = 6.022×10^{23} Eggs

* yes 1 mole of anything is equal to 6.022×10^{23} of units of that thing but that doesn't mean it has the same mass to another 1 mole of a different thing *

* Just like how a dozen is = 12 so

a dozen Eggs = 12 Eggs

a dozen calculators = 12 calculators

a Mole = 6.022×10^{23} of something

(2)

* Molar mass: Mass in grams of 1 mole of the substance

$$\frac{n}{\text{moles}} = \frac{M \rightarrow \text{mass}}{MR \rightarrow \text{molar mass}}$$

↓

$MR = \frac{M}{n}$

ex: MR of $N = 14.01 \text{ mol}$
 MR of H_2O is MR of H_2 + MR of O
 $(2 \times 1.008g) + 16.00g$
= 18.02 g/mol

* Solve Exercises *

* Problem Solving strategies:

- 1- Read the Problem and see what's the goal -
- 2- work/thing from the final goal backwards to know where to start
- 3- Solve Does the answer make sense?

Ex: 100g samples of each [H_2O , CO_2 , H_2O , $C_3H_6O_2$, N_2O]
Rank from greatest to least number of O atoms

↳ ① goal

② we start by finding how many atoms of O are in each:

100g H_2O → How many moles of H_2O are in 100g?? → moles to atoms

$$100g \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 5.5 \text{ Moles of } H_2O \rightarrow 5 \text{ atoms } H_2O \cdot 6.022 \times 10^{23} \text{ molecules}$$

= 3.011×10^{24} molecules → atoms → 3.011×10^{24} atoms

So there is 3.011×10^{24} O atoms in 100g of H_2O

↳ This is how many molecules of H_2O are in 5 mol and not how many atoms of H or O

③

- Now we do it for N_2O :
 $Mr(N) = 14.01 \text{ g/mol}$
 $Mr(O) = 16.00 \text{ g/mol}$

$$Mr N_2O = 2(14.01) + 16.00 \\ = \underline{\underline{44.02 \text{ g/mol}}}$$

100g N_2O $\xrightarrow{1}$ How many moles does it have? $\xrightarrow{2}$ How many N_2O molecules are in 100g of it

to convert to mole we multiply with it \leftarrow How many O atoms are in the molecules? $\leftarrow 3$

$$100g N_2O \cdot \frac{1 \text{ mole } N_2O}{44.02 \text{ g } N_2O} = \boxed{2 \text{ mol } N_2O}$$

$$2 \text{ mol } N_2O \cdot \frac{6.022 \times 10^{23} \text{ molecules } N_2O}{1 \text{ mol } N_2O} = \boxed{1.2 \times 10^{24} \text{ molecules } N_2O}$$

$$1.2 \times 10^{24} \frac{\text{molecules}}{N_2O} \cdot \frac{1 \text{ O atom}}{1 \text{ } N_2O \text{ molecule}} = \boxed{1.2 \times 10^{24} \text{ O atoms}}$$

* $\frac{1 \text{ O atom}}{1 \text{ } N_2O \text{ molecule}}$ means that there is 1 atom of O in every 1 N_2O molecule

we do the same for the rest

Solution : H_2O
 CO_2
 $C_3H_6O_2$
 N_2O

↑
No of O atoms

4

* Percent Composition of Compounds :

- Mass percent of an element :

$$\text{Mass\%} = \frac{\text{mass of element in compound}}{\text{mass of whole compound}} \cdot 100\%$$

ex: 100g samples [H_2O , CO_2 , N_2O , $\text{C}_3\text{H}_6\text{O}_2$]
rank from greatest to least Percent oxygen by mass
↳ goal

① H_2O
~~100g H_2O~~ → ~~100g H_2O~~ Find O

$$\text{O\%} = \frac{16.00}{16.00 + 2(1.008)} \cdot 100\% = 88.8\% \text{ Oxygen in } \text{H}_2\text{O}$$

because it's a percent that means its value is fixed no matter the volume of states ~~parameters~~ the compound

So the answer is the same still whether its 10g H_2O

- 20g - 1000000g H_2O — always 88.8% will be oxygen in (H_2O)

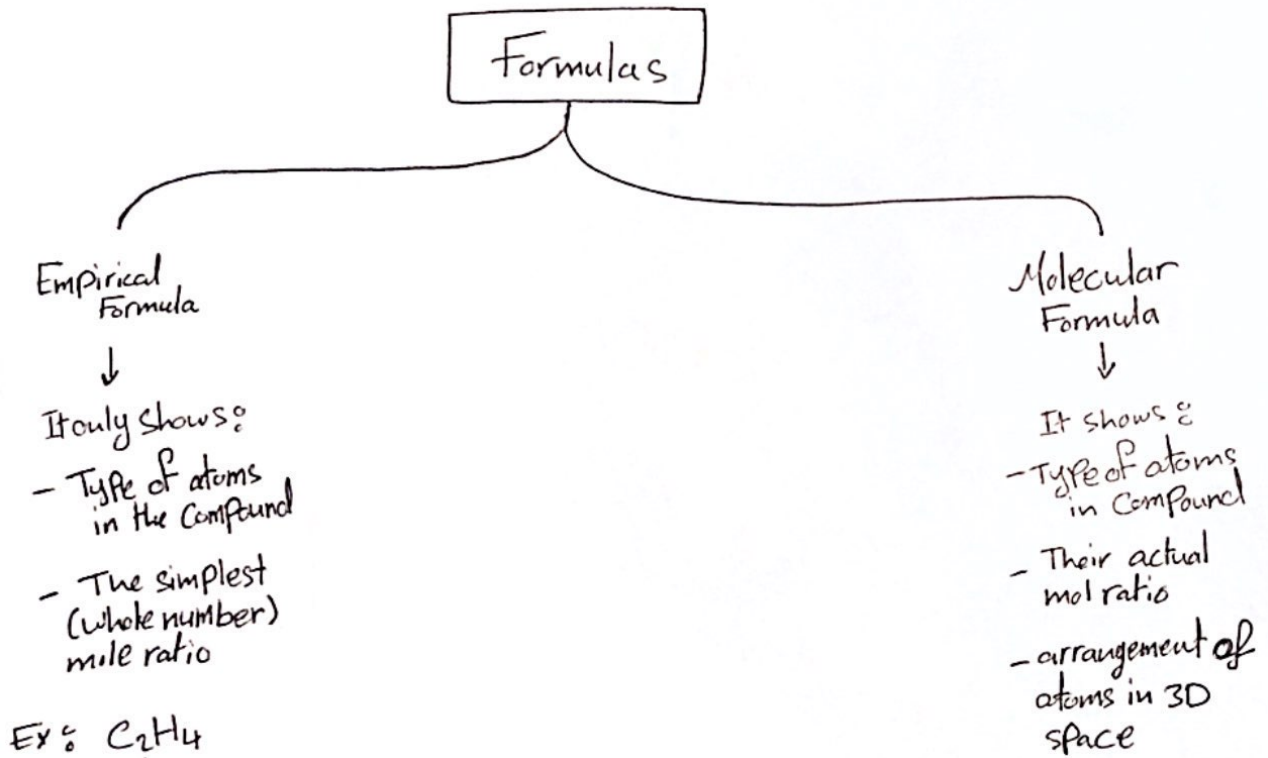
- we do the same for the rest:

H_2O
 CO_2
 $\text{C}_3\text{H}_6\text{O}_2$
 N_2O

↑ O%

⑤

* Determining the Formula of a Compound :



* So :

$$\text{Molecular Formula} = (\text{Empirical Formula})_n$$

an integer ←
[1, 2, 3, ...]

M.F = E.F
when $n=1$

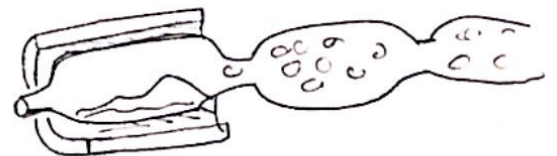
Ex: CH_4

this is both molecular and Empirical

- we use a Combustion Device to:

- Determine the Mass Percent of each Element in a Compound

(6)



* Exercise on formulas

- Compound with 146 g/mol Molar mass

49.3% is C

6.9% is H

43.8% is O

by mass percentage

Find Empirical Formula (E.F) and
Molecular Formula (M.F)

Mr of

C = 12.01 g/mol

H = 1.008 g/mol

O = 16.00 g/mol

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

~~Mr of~~

$$\text{C} \% \quad 49.3\% \times 146 = \frac{49.3}{100} \times 146 = \boxed{71.978 \text{ g/mol}}$$

$$(\text{Mr of C})n = 71.978$$

$$(12.01)n = 71.978$$

$$\boxed{n=6} \text{ so } C_6$$

Same for the rest

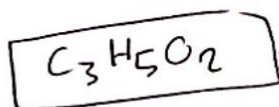
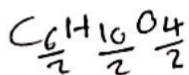
$$\text{H} \% \quad \frac{6.9}{100} \times 146 = 10.074 \text{ g/mol}$$

$$(1.008)n = 10.074$$

$$\boxed{n=10} \quad C_6H_{10}$$

Same

Formula: $\boxed{C_6H_{10}O_4}$ → This is M.F because we can still divide to get E.F



→ This is now the E.F

(7)