SOME BASIC CONCEPTS OF CHEMISTRY

PERCENTAGE COMPOSITION

❖ PERCENTAGE COMPOSITION
TYPES OF FORMULAE

As already stated in section 1.10, a formula is a group of symbols of the elements which represents one molecule of the substance. Formula represents chemical composition of the substance. There are three kinds of formulae in the case of compounds.

(i) Empirical formula: It represents the simplest relative whole number ratio of atoms of each element present in the molecule of the substance.

For example, CH is the empirical formula of benzene in which ratio of the atoms of carbon and hydrogen is 1: 1. It also indicates that the ratio of carbon and hydrogen is 12: 1by mass.

(ii) Molecular formula: Molecular formula of a compound is one which expresses as the actual number of atoIris of each element present in one molecule. C6H6 is the molecular formula of benzene indicating that six carbon atoms and six hydrogen atoms are present in a molecule of benzene. Thus,

$$\text{Molecular formula } = n \times \text{ Empirical formula}$$

$$\text{where, } n = \frac{\text{Molecular formula mass}}{\text{Empirical formula mass}}$$

Molecular formula gives the following information:

(i) Various elements present in the molecule.

(ii) Number of atoms of various elements in the molecule.

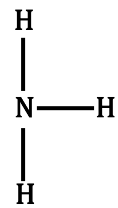
(iii)Mass ratio of the elements. present in the molecule. The mass ratio of carbon and oxygen in CO_2 molecule is 12: 32 or 3: 8.

(iv)Molecular mass of the substance.

(v) The number written before the formula indicates the number of molecules, e.g., $2C0_2$ means 2 molecules of carbon dioxide.

(iii) Structural formula: It represents the way in which atoms of various elements present in the molecule is linked with one another.

For example, ammonia is represented as:



The formula indicates that three hydrogen atoms are linked to one nitrogen atom by three single covalent bonds.

DETERMINATION OF EMPIRICAL AND MOLECULAR FORMULAE

The. following steps are followed to detinning he empirical formula of the compound:

(i) The percentage composition of the compound is detained by quantitative analysis.

(ii) The percentage of each element is divided by its atomic mass. It gives atomic ratio of the elements present in the compound.

(iii) The atomic ratio of each element is the divided by the minimum value of atomic ratio as to get the simplest ratio of the atoms of elements present in the compound.

(iv) If the simplest ratio is fractional, then values of simplest ratio of each element is multiplied by a smallest integer to get a simplest whole number for each of the element.

(y) To -get the empirical fondle, symbols of various elements present are written side by side with their respective whole number ratio as a subscript to the lower right hand comer of the symbol.

The molecular frenula of a substance may be determined from the empirical fondle if the molecular mass of the substance is known. The molecular fondle is always a simple multiple of empirical fondle and the value of simple multiple is obtained by dividing molecular mass with empirical fondle mass.

Calculate the empirical formula for a compound that contains 26.6% potassium, 35.4% chromium and 38.1% oxygen.

[Given K 39.1; Cr= 52; 0 = 16]

Solution:

Element	Per-centage	Atomie mass	Relative number of atoms	Simplest ratio	Simplest whole number ratio
Potassium	26.6	39.1	$\frac{26.6}{39.1} = 0.68$	$\frac{0.68}{0.68} = 1$	$1 \times 2 = 2$

Chromium	35.4	52.0	$\frac{35.4}{52} = 0.68$	$\frac{0.68}{0.68} = 1$	$1 \times 2 = 2$
Oxygen	38.1	16.0	$\frac{38.1}{16} = 2.38$	$\frac{2.38}{0.68} = 3.5$	$3.5 \times 2 = 7$
Therefore, empirical formula is K, Cr, O_7.					

A compound of carbon, hydrogen and nitrogen contains these elements in the ratio 9: 1: 3.5. Calculate the empirical formula. If its molecular mass is 108, what is the molecular formula?

Solution:

Element	Per- centage	Atomie mass	Relative number of atoms	Simplest ratio
Carbon	9	12	$\frac{9}{12} = 0.75$	$\frac{0.75}{0.25} = 3$
Hydrogen	1	1	$\frac{1}{1} = 1$	$\frac{1}{0.25} = 4$
Nitrogen	3.5	14	$\frac{3.5}{14} = 0.25$	$\frac{0.25}{0.25} = 1$
The empirical formula $= C_3H_4\ N$ Empirical formula mass $= (3 \times 12) + (4 \times 1) + 14 = 54$ $n = \frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{108}{54} = 2$				

Thus, molecular formula of the compound

$$= 2 \times \text{Empirical formula}$$

$$= 2 \times C_3H_4\ N = C_6H_3N_2$$

A carbon compound containing only carbon and oxygen has an approximate molecular mass of 290. On analysis, it is found to contain 50% by mass of each element. What is the molecularformula of the compound?

Solution:

Element Per- centage	Atomic mass	Relative number of atoms	Simplest ratio	Simplest whole number ratio
Carbon 50.0	12	4.166	$\frac{4.166}{3.125} = 1.33$	4
Oxygen 50.0	16	3.125	$\frac{3.125}{3.125} = 1$	3
The empirical formula $= C_4O_3$				

Empirical formula mass $= (4 \times 12) + (3 \times 16) = 96$

Molecular mass $= 290$

$$n = \frac{\text{Mol. mass}}{\text{Emp. mass}} = \frac{290}{96} = 3 \text{ approximately}$$

Molecular formula $= n \times$ Empirical formula

$= 3 \times C_4O_3 = C_{12}O_9$

GRAVIMETRIC ANALYSIS

Once we get a balanced chemical equation then we can interpret a chemical equation by following ways

1. Mass - mass analysis
2. Mass - volume analysis
3. Mole - mole analysis
4. Vol - Vol analysis (separately discussed as eudiometry or gas analysis)

Now you can understand the above analysis by following example

1. Mass - Mass Analysis

Consider the reaction $2\,KClO_3 \longrightarrow 2KCl + 3O_2$ According to stoichiometry of the reaction

mass-mass ratio: 2×122.5: 2×74.5: 3×32

or $$\frac{\text{Mass of } KClO_3}{\text{Mass of KCl}} = \frac{2\times122.5}{2\times74.5} \quad \frac{\text{Mass of } KClO_3}{\text{Mass of } O_2} = \frac{2\times122.5}{3\times32}$$

Ex. Calculate the weight of iron which will be converted into its oxide by the action of 36 g of steam.

(Given: $3Fe + 4H_2O \longrightarrow Fe_3O_4 + H_2$)

Sol. Mole ratio of reaction suggests,

$$\frac{\text{Mole of Fe}}{\text{Mole of } H_2O} = \frac{3}{4}$$

$\therefore$ Mole of Fe $= \frac{3}{4} \times$ mol of H_2O

$$= \frac{3}{4} \times \frac{36}{18} = \frac{3}{2}$$

wt. of Fe $= \frac{3}{2} \times 56 = 84$ g

Ex. In a gravimetric determination of P of an aqueous solution of dihydrogen phosphate in $H_2PO^-_4$ is treated with a mixture of ammonium and magnesium ions to precipitate magnesium ammonium phosphate, $Mg(NH_4)PO_4.6H_2O$. This is heated and decomposed to magnesium pyrophosphate, $Mg_2P_2O_7$. A solution of $H_2PO^-_4$ yielded 2.054 g of ($Mg_2P_2O_7$) which is weighed. What weight of NaH_2PO_4 was present originally?

Sol. $NaH_2PO_4 + Mg^{2+} + NH_4{}^+ \longrightarrow Mg(NH_4)PO_4.6H_2O \xrightarrow{\Delta} Mg_2P_2O_7$

As P atoms are conserved, applying POAC for P atoms, moles of P in NaH_2PO_4 = Moles of P in $Mg_2P_2O_7$

$\Rightarrow$ 1 × Moles of NaH_2PO_4 = 2 × Moles of $Mg_2P_2O_7$

$$\therefore \quad \frac{W_{SH_2PO_4}}{M_{NH_2PO_4}} = 2 \times \frac{W_{Mg_2P_2O_7}}{M_{Mg_2P_2O_7}} \Longrightarrow \frac{W_{NaH_2PO_4}}{120} = 2 \times \frac{2.054}{222}$$

$$\therefore \quad W_{NaH_2PO_4} = 2.22 \text{ g}$$

2. Mass - Volume Analysis

Now again consider decomposition of $KClO_3$

$$2\ KClO_3 \longrightarrow 2KCl + 3\ O_2$$

mass volume ratio: 2 × 122.5 g: 2 × 74.5 g: 3 × 22.4 L at STP

we can use two relations for volume of oxygen

$$\frac{\text{Mass of } KClO_3}{\text{volume of } O_2 \text{ at STP}} = \frac{2\times122.5 \text{ g}}{3\times22.4 \text{ L}} \qquad \text{.........(i)}$$

And $$\frac{\text{Mass of KCl}}{\text{volume of } O_2 \text{ at STP}} = \frac{2\times74.5 \text{ g}}{3\times22.4 \text{ L}} \qquad \text{........(ii)}$$

Ex. How much marble of 90.5 % purity would be required to prepare 10 litres of CO_2 at STP when the marble is acted upon by dilute HCl?

Sol. $CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$

100 g 22.4litre

22.4 L of CO_2 at STP will be obtained from 100 g of $CaCO_3$

$\therefore$ 10 L of CO_2 at STP will be obtained from pure $CaCO_3 = \frac{100}{22.4} \times 10 = 44.64$ g

$\therefore$ Impure marble required $= \frac{100}{90.5} \times 44.64 = 49.326$ g

3. Mole - Mole Analysis

This analysis is very much important for quantitative analysis point of view.

Now consider again the decomposition of $KClO_3$.

$$2\ KClO_3 \longrightarrow 2\ KCl + 3\ O_2$$

In very first step of mole-mole analysis you should read the balanced chemical equation like 2 moles $KClO_3$ on decomposition gives you 2 moles KCl and 3 moles O_2 and from the stoichiometry of reaction we can write

$$\frac{\text{Moles of } KClO_3}{2} = \frac{\text{Moles of KCl}}{2} = \frac{\text{Moles of } O_2}{3}$$

Now for any general balance chemical equation like

$$a\,A + b\,B \longrightarrow c\,C + d\,D$$

you can write.

$$\frac{\text{Moles of A reacted}}{a} = \frac{\text{Moles of B reacted}}{b} = \frac{\text{Moles of C reacted}}{c} = \frac{\text{Moles of D reacted}}{d}$$