Some Basic Concepts In Industrial Chemistry

Dr. U. GAYATHRI
ASST. PROF. & HEAD IN CHEMISTRY,
S.T.E.T.WOMEN'S COLLEGE,
MANNARGUDI.

Introduction

- Industrial chemistry deals with number of problems and theirsolutions through industrial processes such as environmental protection, biochemical processes, new sources of energy , new materials etc.

Definition and Explanation of Important Basic Terms

Solution = solute + solvent

Solution: - A solution is a homogeneous mixture of two or more substances.

(A homogeneous mixture means its composition and properties are uniform throughout the mixture.)

Solute:- The component of solution which is present in smaller proportion (quantity) is called solute.

Solvent:- The component of solution which is present in larger proportion (quantity) is called solvent.

Binary solution:- A solution of two components is called binary solution.

- **Dilute solution**:- A solution in which the quantity of solute is very small as compared with the solvent is called dilute solution.

(A solution containing a relatively low concentration of solute is called dilute solution.)

- **Concentrated solution**:- A solution in which the quantity of solute is large as compared with the solvent is called concentrated solution.

(A solution containing a relatively high concentration of solute is called concentrated solution)

- **Aqueous solution**:- Solution prepared in water.
- **Non- Aqueous solution**:- Solution prepared in solvent other than water.

Different Types of Solution

Type of solution	Solute	Solvent	Example
Gaseous Solution	Gas	Gas	Mixture of oxygen and nitrogen gases
	Liquid	Gas	Chloroform mixed with nitrogen gas
	Solid	Gas	Camphor in nitrogen gas
Liquid solution	Gas	Liquid	Oxygen dissolved in water
	Liquid	Liquid	Ethanol dissolved in water
	Solid	Liquid	Glucose dissolved in water
Solid solution	Gas	Solid	Solution of hydrogen in palladium
	Liquid	Solid	Amalgam of mercury with sodium
	Solid	Solid	Copper dissolved in gold

Solvents

Solvents are classified as

1. Polar solvent:-

The solvent whose molecules have a net permanent dipole ($\mu \neq 0$) are called polar solvent.

Eg. Water, ethyl alcohol, HCl etc. ($\epsilon \geq 15$)

2. Non-Polar solvent:-

The solvent whose molecules have no net permanent dipole ($\mu = 0$) are called non-polar solvent. ($\epsilon < 15$)

Eg. Benzene, CCl_4, kerosene etc.

Note

Solvents are also classified as

1. Protic solvent:-

The solvent which contain hydrogen attached to an electronegative atom (N, O) is termed as Protic solvent.

Eg. H-O-H, R-O-H, R-CO- NH_2 etc.

2. Aprotic solvent:-

The solvent in which hydrogen is not attached to an electronegative atom (N, O) is termed as aprotic solvent.

Eg. $CHCl_3$, CH_3 O CH_3 , CH_3NO_2 etc.

Saturated, Unsaturated and Super Saturated Solution

Depending upon the amount of solute present in the given volume of solvent, the solution is classified into *three* categories.

1.Saturated Solution:- *The solution which contain maximum amount of solute at given temperature and pressure is called saturated solution.*

2.Unsaturated Solution:- *The solution which contains less solute than saturated solution is called unsaturated solution.*

3.Super Saturated Solution:- *The solution which contains more solute than saturated solution is called supersaturated solution.*

Equivalent Weight

"Equivalent Weight of a substance is defined as that weight of the substance which combines with or displaces 1 part by weight of hydrogen or 8 parts by weight of oxygen or 35.5 part by weight of chlorine."

Explanation:-

1. $C + 2H_2 \rightarrow CH_4$
2. $2Cu + O_2 \rightarrow 2CuO$
3. $Mg + Cl_2 \rightarrow 2MgCl_2$

1. $C + 2H_2 \rightarrow CH_4$

***4 part by weight of hydrogen* combine with *12 part by weight of carbon*. Therefore *1 part by weight of hydrogen* will combine with**

$$\frac{12 \times 1}{4} = 3$$ ***part by weight of carbon*.**

Hence equivalent weight of Carbon will be 3.

2. $2Cu + O_2 \rightarrow 2CuO$

32 part by weight of Oxygen **combine with** ***127 part by weight of Copper*****.** ***Therefore*** ***8 part by weight of Oxygen*** ***will*** **combine** ***with***

$$\frac{127 \times 8}{32} = 31.75$$ ***part by weight of Copper***

Hence equivalent weight of ***Copper*** will be **31.75.**

3. $Mg + Cl_2 \rightarrow 2MgCl_2$

***71 part by weight of Chlorine* combine with *24 part by weight of Magnesium*. Therefore *35.5 part by weight of Chlorine* will combine with**

$$\frac{24 \times 35.5}{71} = 12$$ ***part by weight of Magnesium*.**

Hence equivalent weight of ***Magnesium*** will be **12**.

Gram Equivalent Weight

Equivalent Weight expressed in grams is called gram Equivalent Weight.

Eg. Equivalent weight of Chlorine is 35.5 hence it's gram Equivalent Weight is 35.5 g

11.2 dm^3 of hydrogen at STP weighs 1.008 g

Hence, weight in grams of element *combine with Or displaces* 11.2 dm^3 of hydrogen at STP , is the *gram Equivalent Weight of the element.*

Molecular Weight

"Molecular weight of a substance is defined as the average relative weight of its one molecule obtained by comparing it with $(1/12)^{th}$ weight of ^{12}C atom having its isotopic mass 12."

$$\text{Mol. Wt.} = \frac{\text{Average Wt. of one molecule of the substance.}}{(1/12)^{th}\ \text{weight of one atom}\ ^{12}C}$$

Molecular weight is unitless quantity.

Gram Molecular Weight

Molecular Weight expressed in grams is called gram molecular Weight.

Eg. Molecular weight of Carbon Monoxide (CO) is 28 hence it's gram Molecular Weight is 28 g.

It is also called "one molemolecule" which refers to Avogadro's number of molecule.

Basicity Of Acid

The number of ionisable hydrogenatoms (H^+ Ion) present in a molecule of an acid is known as basicity of acid.

Example:-

1. **HCl, HNO_3, CH_3COOH are monobasic acids.**
   (Basicity = 1)
2. **H_2SO_4, $H_2C_2O_4$ are dibasic acids.**
   (Basicity = 2)
3. **H_3PO_4, H_3AsO_4 are tribasic acids.**
   (Basicity = 3)

Acidity Of Base

The number of ionisable hydroxyl radicals (OH^+ Ion) present in a molecule of a base is known as acidity of base.

Example:-

1. **NaOH, KOH are monoacidic bases.**

   (Acidity = 1)

2. **$Ca(OH)_2$, $Ba(OH)_2$ are diacidic bases.**

   (Acidity = 2)

3. **$Al(OH)_3$, $Fe(OH)_3$ are triacidic bases.**

   (Acidity = 3)

Ways of Expressing Concentration of solution

Concentration of solution= >

Amount of solution dissolved in a specific amount (1 m^3 or dm^3)of solution.

$$\text{Concentration} = \frac{\text{Amount of solute}}{\text{Volume of solvent or solution}}$$

It expressed in various ways or units.

Ie. N, M, m, W/W, V/V, W/V etc.

Normality

Normality (N) is defined as the number of gram equivalents of solute present in 1 dm^3 (litre) of solution.

If X gram equivalents of solute are present in Y dm^3 of solution, then normality of solution will be given by N = X / Y.

$$\text{Normality (N)} = \frac{\text{no. of gram equivalents of solute X}}{\text{Volume of solution Y } dm^3}$$

equivalents of

substance (solute) X can be calculated as,

$$\text{No. of g. equivalents of solute X} = \frac{\text{Wt. of the substance (Ws)}}{\text{g. Eq. wt. of the substance (Es)}}$$

Hence,

$$N = \frac{\text{Wt. of the substance (Ws)}}{\text{g. Eq. Wt. of the substance (Es)}} \times \frac{1}{\text{Vol. of solution Y dm}^3}$$

Ie.

$$N = \frac{Ws}{Es} \times \frac{1}{Y\ (dm^3)}$$

* **gram Equivalent Weight is also called Equivalent weight**

Eg. Normality of solution containing 4.9 g of H_2SO_4 In 1 dm^3 of solution.

Solution:-

$$N = \frac{\text{Wt. of the substance (Ws)}}{\text{g. Eq. Wt. of the substance (Es)}} \times \frac{1}{\text{Vol. of solution Y } dm^3}$$

Ie.

$$N = \frac{4.9}{49} \times \frac{1}{1} = 0.1\ N\ H_2SO_4$$

Since,

$$\text{Eq. Wt. of } H_2SO_4 = \frac{\text{Molecular Wt. of } H_2SO_4}{\text{Basicity of } H_2SO_4} = \frac{98}{2} = 49$$

Formulae for calculation of Equivalent Weight of substance

$$\text{Eq. Wt. of an Acid} = \frac{\text{Strength of Acid}}{\text{Normality of Acid}}$$

$$\text{Eq. Wt. of a Base} = \frac{\text{Strength of Base}}{\text{Normality of Base}}$$

Normality of Acid = Molarity × Basicity

Normality of Base = Molarity × Acidity

Formulae for calculation of … substance

$$\text{Eq. Wt. of an Acid} = \frac{\text{Molecular Wt. of acid}}{\text{Basicity of acid}}$$

$$\text{Eq. Wt. of a Base} = \frac{\text{Molecular Wt. of base}}{\text{Acidity of base}}$$

$$\text{Eq. Wt. of a Salt} = \frac{\text{Formula Weight}}{\text{Valency of Metal atom}}$$

In redox reaction,

$$\text{Eq. Wt. of an Ion} = \frac{\text{Formula Weight}}{\text{Change in oxidation no.}}$$

Eg. Calculate the Normality of solution when

5.6 g of KOH is dissolved in 1 dm^3 of solution.

Solution:- Given

Wt.of the KOH =W♦ = 5.6 g , Vol. of solution Y dm^3 = 1

$$\text{Eq. Wt. of KOH} = \frac{\text{Molecular Wt. of KOH}}{\text{Acidity of KOH}} = \frac{56}{1} = 56$$

Formula

$$N = \frac{\text{Wt. of the substance (Ws)}}{\text{g. Eq. Wt. of the substance (Es)}} \times \frac{1}{\text{Vol. of solution Y } dm^3}$$

$$N = \frac{5.6}{56} \times \frac{1}{1} = 0.1\ N\ KOH$$

Eg. Calculate the Normality of NaOH solution containing 10×10^{-3} kg of it dissolved in 2 dm³ of water.

Solution:- Given Wt. of the NaOH = Ws = 10×10^{-3} kg

Vol. of solution Y dm³ = 2

$$\text{Eq. Wt. of NaOH} = \frac{\text{Mol. Wt. of NaOH}}{\text{Acidity of NaOH}} = \frac{40 \times 10^{-3}\ \text{kg}}{1} = 40 \times 10^{-3}\ \text{kg}$$

$$N = \frac{\text{Wt. of the substance (Ws)}}{\text{g. Eq. Wt. of the substance (Es)}} \times \frac{1}{\text{Vol. of solution Y dm}^3}$$

$$N = \frac{10 \times 10^{-3}\ \text{kg}}{40 \times 10^{-3}\ \text{kg}} \times \frac{1}{2} = 0.125\ \text{N NaOH}$$

Molarity (M):-

Molarity (M) is defined as number of moles of solute present in 1 dm^3 (litre) of solution.

$$\text{Molarity (M)} = \frac{\text{number of moles of solute (X)}}{\text{Volume of solution in } dm^3 \text{ (Y)}}$$

1 molar NaOH solution means ***1 mol (40 g) of NaOH is dissolved in*** *1 litre (1 dm^3) of water.*

* Molarity depends upon ***temperature.***

The number of moles substance (solute) X can be calculated as,

$$\text{No. of moles X} = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}}$$

Hence,

$$M = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1}{\text{Vol. of solution in dm}^3\text{ (Y)}}$$

Ie.

$$M = \frac{Ws}{Ms} \times \frac{1}{Y(dm^3)}$$

solution containing 4 g of NaOH in 2 dm^3 solution.

Solution:-

$W_s = 4$, $M_s = 40$ (Na = 23, H = 1, O = 16)

$Y = 2\ dm^3$

(23+1+16=40)

$$M = \frac{W_s}{M_s} \times \frac{1}{Y(dm^3)}$$

$$M = \frac{4}{40} \times \frac{1}{2} = 0.05\ M\ NaOH$$

Ex. Calculate the molarity of a solution when 3.65 g of HCl is dissolved in 2 dm^3 solution.

Solution:-

Ws = 3.65, Ms = 36.5 Y = 2 dm^3

$$M = \frac{Ws}{Ms} \times \frac{1}{Y(dm^3)}$$

$$M = \frac{3.65}{36.5} \times \frac{1}{2} = 0.05 \text{ M HCl}$$

Eg. Calculate Normality & Molarity of solution containing 9.8 g of H_2SO_4 In 1 dm³ of solution.

Solution:-

Solution:- Given

Ws = 9.8 g , Vol. of solution (Y) = 1 dm³

Eq. Wt. of H_2SO_4 = 98 / 2 = 49 g, Ms = 98 N & M =?

$$N = \frac{Ws}{Es} \times \frac{1}{Y\,(dm^3)}$$

$$N = \frac{9.8}{49} \times \frac{1}{1} = 0.2\ N\ H_2SO_4$$

$$M = \frac{Ws}{Ms} \times \frac{1}{Y\,(dm^3)}$$

$$N = \frac{9.8}{98} \times \frac{1}{1} = 0.1\ M\ H_2SO_4$$

Molality (m):-

Molality (m) is defined as number of moles of solute present in 1000 g (1 Kg) of solution.

$$\text{Molality (m)} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in gram}} \times 1000$$

1 molal KCl solution means *1 mol (74.5 g) of KCl is dissolved in 1 Kg of water.*

* Molality ***dose not*** depends upon ***temperature***.

The number of moles substance (solute) X can be calculated as,

$$\text{No. of moles X} = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}}$$

Hence,

$$m = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1000}{\text{Mass of solvent in gram (Y)}}$$

Ie.

$$m = \frac{Ws}{Ms} \times \frac{1000}{Y(gram)}$$

Ex. Calculate molality of 2.5 g of ethanoic acid (CH_3COOH) in 75 g of benzene.

Solution:- Molecular weight of $C_2H_4O_2$:

$$12 \times 2 + 1 \times 4 + 16 \times 2 = 60\ g\ mol^{-1}$$

$$m = \frac{Ws}{Ms} \times \frac{1000}{Y\ g} = \frac{2.5 \times 1000}{60 \times 75} = 0.556\ m$$

4 g of NaOH is dissolved in 100 g of water.

Solution:- Molecular weight of NaOH: $23 + 16 + 1 = 40\ g\ mol^{-1}$

$$m = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1000}{\text{Mass of solvent in gram (Y)}}$$

$$m = \frac{4}{40} \times \frac{1000}{100\ g} = 1\ m\ NaOH$$

sodium carbonate containing 25 g $Na_2CO_3.10H_2O$ in water. The volume of resulting solution is 200 ml and it's density is 1.04g/ml.

Solution:- Ws = 25 g, Ms = 286 g, Y = 200 ml = 0.2 dm^3

$$M = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1}{\text{Vol. of solution in } dm^3 \text{ (Y)}}$$

$$M = \frac{Ws}{Ms} \times \frac{1}{Y\,(dm^3)}$$

$$M = \frac{25}{286} \times \frac{1}{0.2} = 0.437\ N$$

Molality(m)

$$m = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1000}{\text{Mass of solvent in gram (Y)}}$$

Ws = 25 g, Ms = 286 g, mass of solvent (Y)g= ?

$$\text{Vol. of sol}^{n} = \frac{\text{Mass of solution}}{\text{Density}}$$

Mass of solution = Vol. of sol^{n} × Density

Mass of solution = 200 × 1.04 = 208 g

Mass of solution =
Mass of solute ($Na_2CO_3.10H_2O$) + Mass of solvent(Water)

208 = 25 + Mass of solvent(Water) Y
Mass of solvent(Water) (Y) = 208 – 25 = 183

Hence molality (m) is

$$m = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1000}{\text{Mass of solvent in gram (Y)}}$$

$$m = \frac{Ws}{Ms} \times \frac{1000}{Y\ g}$$

$$m = \frac{25}{286} \times \frac{1000}{183} = 0.4776\ m$$

Molarity of Mixed Solution

A mixture of different solutions of same or different substances or solutes (acids, bases, salt) has the molarity as given by the relation,

$$M_1 V_1 + M_2 V_2 + M_3 V_3 + \ldots\ldots\ldots\ldots\ldots\ldots = M_m V_m$$

Where,

M_1, M_2, M_3 …. Are the molarities of different components of the mixture. And

V_1, V_2, V_3 …. Are their volumes in the mixture.

M_m & V_m are the molarity and volume of resultant mixure. ($V_m = V_1 + V_2 + V_3 + \ldots\ldots$)

Similarly, we can determine the normality of mixed solution as,

$$N_1 V_1 + N_2 V_2 + N_3 V_3 + \ldots\ldots\ldots\ldots\ldots\ldots = N_m V_m$$

$$(V_m = V_1 + V_2 + V_3 + \ \ldots\ldots)$$

N_m & V_m are the Normality and volume of resultant mixture.

Eg. Compare the molarity of a solution obtained by mixing 10 ml M/5 HCl and 30 ml M/10 Hcl.

Solution:-

$M_1 = M/5 = 0.2$ $V_1 = 10$

$M_2 = M/10 = 0.1$ $V_2 = 30$

$V_m = V_1 + V_2 = 10 + 30 = 40$ ml $M_m = ?$

$$M_1 V_1 + M_2 V_2 = M_m V_m$$

$$(0.2 \times 10) + (0.1 \times 30) = M_m \times 40$$

$$2 + 3 = M_m \times 40 \rightarrow M_m = 5/40 = 0.125 \text{ M}$$

Hence ,

Molarity of resultant mixture is 0.125 M

Eg. Compare the molarity of mixtue containing 40 ml 0.05M HCl, 50 ml 0.1M H_2SO_4 and 10 ml 0.1 M HNO_3.

Solution:- $M_1 = 0.05$ M , $V_1 = 40$

$M_2 = 0.1$ M $V_2 = 50$ $M_3 = 0.1$ M , $V_3 = 10$

$V_m = V_1 + V_2 + V_3 = 40 + 50 + 10 = 100$ ml $M_m = ?$

$$M_1 V_1 + M_2 V_2 + M_3 V_3 + = M_m V_m$$

$$(0.05 \times 40) + (0.1 \times 50) + (0.1 \times 10) = M_m \times 100$$

$$2 + 5 + 1 = M_m \times 100 \rightarrow M_m = 8/100 = 0.08 M$$

Hence ,

Molarity of resultant mixture is 0.08 M

Eg. 25 cm^3 of a decinormal solution of HCl exactly neutralised 20 cm^3 of a base containing 4.8 g/litre of the base. Find the normality & equivalent weight of base.

Solution:-

$N_1 = 0.1\ N \quad V_1 = 25\ dm^3 \quad V_2 = 20\ dm^3 \quad N_2 = ?$

$N_1 V_1 = N_2 V_2$

$$N_1 = \frac{N_2 V_2}{V_1} = \frac{0.1 \times 20}{25} = 0.125\ N$$

Normality= 0.125 N & Strength = 4.8 g/ml

$$\text{Eq. Wt. of a Base} = \frac{\text{Strength of Base}}{\text{Normality of Base}} = \frac{4.8}{0.125} = 38.4$$

Mole fraction(x):-

"The ratio of number of moles of the substance to the total number of moles of all the substances present in the solution."

For binary solution,If

n_A = Number of moles of component A and

n_B = Number of moles of component B then,

$$\text{Mole fraction of A}(x_A) = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of B}(x_B) = \frac{n_B}{n_A + n_B}$$

n = M/W

Further, the sum of mole fractions of solute and solvent is

$$x_A + x_B = \frac{n_A}{n_A + n_B} + \frac{n_B}{n_A + n_B} = \frac{n_A + n_B}{n_A + n_B} = 1$$

Hence, sum of mole fraction of all the component of solution is always **unity**.

Note:- *1. Mole fraction is* ***temperature*** *independent quantity.*

2. Mole fraction is unit less quantity.

If W is the weight and M is the molecular weight of substance, then number of moles (n) will be given by,

$$\text{No. of moles (n)} = \frac{\text{Wt. of the substance}}{\text{Mol. Wt. of the substance}} = \frac{W}{M}$$

For example, in a solution containing 4 moles of alcohol and 6 moles of water,

$$\text{Mole fraction of alcohols} = \frac{4}{4 + 6} = \frac{4}{10} = 0.4$$

$$\text{Mole fraction of water} = \frac{6}{4 + 6} = \frac{6}{10} = 0.6$$

Eg. A solution contain 25% water, 25% ethyl alcohol & 50% acetic acid by mass . Calculate mole fraction of each component ... on.

Solution:-

$$\text{Mole fraction of A } (x_A) = \frac{n_A}{n_A + n_B}$$

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

Molecular wt. of H_2O = 18, $n_A(H_2O)$ = 25/18 = 1.38

Molecular wt. of C_2H_5OH = 46, $n_B(C_2H_5OH)$ = 25/46 = 0.54

Molecular wt. of CH_3COOH = 60, $n_C(CH_3COOH)$ = 50/60 = 0.83

$$x_A(H_2O) = \frac{n_A}{n_A + n_B + n_C} = \frac{1.38}{1.38 + 0.54 + 0.83} = 0.5018$$

$$x_B(C_2H_5OH) = \frac{n_A}{n_A + n_B + n_C} = \frac{0.54}{1.38 + 0.54 + 0.83} = 0.1963$$

$$x_C(CH_3COOH) = \frac{n_A}{n_A + n_B + n_C} = \frac{0.83}{1.38 + 0.54 + 0.83} = 0.3018$$

Eg. Calculate mole fraction of HCl in a solution of hydrochloric acid in water containing 36%(w/w).

Sol[n] :- Solution contain 36 g HCl & 64 g H_2O

Mol. wt. of HCl = 36.5, n_A(HCl) = 36/36.5 = 0.99

Mol. wt. of H_2O = 18, n_B(H_2O) = 64/18 = 3.55

$$x_A(HCl) = \frac{n_A}{n_A + n_B} = \frac{0.99}{0.99 + 3.55} = 0.218$$

$$x_B(H_2O) = \frac{n_B}{n_A + n_B} = \frac{3.55}{0.99 + 3.55} = 0.781$$

Weight fraction

"The ratio of weight of the substance to the total weight of all the substances present in the solution."

For binary solution, If

W_A = Weight of component A and

W_B = Weight of component B then,

$$\text{Weight fraction of A} = \frac{W_A}{W_A + W_B}$$

$$\text{Weight fraction of B} = \frac{W_B}{W_A + W_B}$$

OR

$$\text{Weight fraction of solute} = \frac{\text{Wt. of solute}}{\text{Wt. of (Solute + solvent)}}$$

$$\text{Weight fraction of solvent} = \frac{\text{Wt. of solvent}}{\text{Wt. of (Solute + solvent)}}$$

Percentage of Solution

Percentage of Solution is nothing but parts of solute present in 100 parts of solution.

It is also designated as Percentage composition of Solution.

It described in different formsas,

- **Percentage composition by weight (W/W)**
- **Percentage composition by volume (V/V)**
- **Percentage composition by weightand volume (W/V)**

Percentage composition by weight (W/W):-

"The weight of solute in gram dissolved in solvent **to form 100 gram of solution** is called *Percentage composition by weight(weight %)*."

$$\text{Percentage composition by weight} = \frac{\text{Wt. of solute}}{\text{Total Wt. of solution}} \times 100$$

$$\text{Percentage composition by weight} = \frac{\text{Wt. of solute}}{\text{Wt. of solute} + \text{Wt. of solvent}} \times 100$$

Eg. 10% glucose in water means ***10 g of glucose dissolved in 90 g of water resulting in 100 g solution.***

Eg. 40 g solute is dissolved in 1000 g of solvent. Calculate the weight percentof solute.

Solution:-

$$\text{Percentage composition by weight} = \frac{\text{Wt. of solute}}{\text{Total Wt. of solution}} \times 100$$

$$(\text{weight}\%) = \frac{\text{Wt. of solute}}{\text{Wt. of solute} + \text{Wt. of solvent}} \times 100$$

$$(\text{weight}\%) = \frac{40 \times 100}{40 + 1000} = \frac{4000}{1040} = 3.85\ \%$$

Percentage composition by volume (V/V):-

"The volume of the solute per 100 parts by volume of the solution is known as volume percentage."

$$\text{Percentage composition by volume} = \frac{\text{Vol. of solute}}{\text{Total Vol. of solution}} \times 100$$

Eg. 10 % ethanol in water means ***10 ml of ethanol is dissolved in water such that the total volume of the solution is 100 ml.***

Note:-

1. Volume is temperature dependence quantity; hence percentage by volume changes with temperature.
2. Total volume of the solution ≠ (volume of the solute + volume of the solvent)

Because, solute particle may occupy empty space (ie. voids) present in the structure of liquids.

3. Percentage by volume unite is used when both the component ie solute and solvent are liquids.

Percentage composition by weight and volume (W/V):-

"The mass of solute dissolved in 100 ml of the solution is known as mass by volume percentage."

$$\%\ \text{composition by weight and volume} = \frac{\text{Wt. of solute}}{\text{Total Vol. of solution}} \times 100$$

This unit is commonly used in medicine and pharmacy.

ppm, ppb and ppt solutions

When a solute is present in **trace** quantities, it is convenient to express concentration in **ppm, ppb and ppt.**

1. Parts per million (ppm):-

It is defined as,

$$\text{Parts per million} = \frac{\textbf{Weight of substance}}{\textbf{Total Weight of solution}} \times 10^6$$

2. Parts per billion (ppb):-

It is defined as,

$$\text{Parts per billion} = \frac{\text{Weight of substance}}{\text{Total Weight of solution}} \times 10^9$$

3. Parts per trillion (ppt):-

It is defined as,

$$\text{Parts per trillion} = \frac{\text{Weight of substance}}{\text{Total Weight of solution}} \times 10^{12}$$

Eg. ***A solution contains 0.008 g of the substance in 1 Kg of solution. What will be its concentration in ppm?***

- Solution:- Wt. of substance = 0.008 g
- Wt. of solution = 1000 g
- Weight of substance
- Parts per million = ----------------------------------
--

×

10^6

- Total Weight of solution

If

weig ht of solution is 100 g. What is the amount of glucose in the solution?

Solution:- *Wt. of solution = 100 g Wt. of substance = ?*

$$\text{Parts per million} = \frac{\text{Weight of substance}}{\text{Total Weight of solution}} \times 10^6$$

$$24 = \frac{\text{Wt. of substance}}{100} \times 10^6$$

$$\text{Wt. of substance} = \frac{24 \times 100}{10^6} = 0.0024\ g$$

Eg. **25** cm^3 of caustic soda of unknown strength were found by titration to neutralise **24** cm^3 of 0.1 N HCl solution. Find the normality of caustic soda (NaOH)& strength in **Kg per dm³**.

Solution:-

$N_1 = 0.1\ N \quad V_1 = 24\ dm^3 \quad V_2 = 25\ dm^3 \quad N_2 = ?$

$N_1 V_1 = N_2 V_2$

$$N_1 = \frac{N_2 V_2}{V_1} = \frac{0.1 \times 24}{25} = 0.096\ N$$

Normality= 0.096 N Strength = ? kg/dm³

$$\text{Eq. Wt.} = \frac{\text{Strength}}{\text{Normality}}$$

$$\text{Strength} = \text{Normality} \times \text{Eq. Wt.}$$

$$\text{Eq. Wt. of a Base} = \frac{\text{Molecular Wt. of base}}{\text{Acidity of base}}$$

$$\text{Eq. Wt. of NaOH} = \frac{\text{Mol. Wt. of NaOH}}{\text{Acidity of NaOH}} = \frac{40}{1} = 40$$

$$\text{Strength} = \text{Normality} \times \text{Eq. Wt.}$$

$$= 0.096 \times 40 \times 10^{-3} = 3.84 \times 10^{-3}\ \text{Kg/dm}^3$$

Eg. Determine the molar and normal concentration of a 40 % solution of H_2SO_4 having relative density 1.307. (5.33, 10.66)

Eg. A solution is prepared by mixing 46 g alcohol (C_2H_5OH) & 18 g water (H_2O). Calculate mole fraction ...e solution.

Solution:-

Mole fraction of A (x_A) $= \dfrac{n_A}{n_A + n_B}$

$n = \dfrac{M}{W}$

Mole. wt. of H_2O = 18, $n_A(H_2O) = 18/18 = 1$

Mole. wt. of C_2H_5OH = 46, $n_B(C_2H_5OH) = 46/46 = 1.$

$x_A(H_2O) = \dfrac{n_A}{n_A + n_B} = \dfrac{1}{1+1} = 0.5$

$x_B(C_2H_5OH) = \dfrac{n_B}{n_A + n_B} = \dfrac{1}{1+1} = 0.5$

Ex. If 46 g ethyl alcohol is dissolved in 1000 g of water, gave a **solution of specific gravity 0.992, find the molarity of solution and mole fraction of water and ethyl alcohol.**

Solution:- **Ws = 46 g**, Ms = **46 g**, Y = ? M = ?

$$\text{Vol. of sol}^n = \frac{\text{Mass of solution}}{\text{Density}} = \frac{\text{Mass of(solute + solvent)}}{\text{Density}}$$

$$\text{Vol. of sol}^n = \frac{46 + 1000}{\text{Density}} = \frac{1046}{0.992} = 1054 \text{ ml} = 1.054 \text{ dm}^3$$

Molarity(M)

$$M = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1}{\text{Vol. of solution in dm}^3\text{ (Y)}}$$

$$M = \frac{Ws}{Ms} \times \frac{1}{Y\ (dm^3)} = \frac{46}{46} \times \frac{1}{1.054} = 0.95\ M$$

Mole fraction

of water. The density of the resulting solution was found to be 0.997 cm^3. Calculate molarity & molality of NaCl solution.

Solution:- Ws = 5 g, Ms = 58.5 g,

m = ? Volume of solvent = 1.1 Kg = 1100 g, M = ? Molality (m)

$$m = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1000}{\text{Mass of solvent in gram (Y)}}$$

$$m = \frac{Ws}{Ms} \times \frac{1}{Y\,g} = \frac{5}{58.5} \times \frac{1000}{1100} = 0.8547\ m$$

$$\text{Vol. of sol}^n = \frac{\text{Mass of sol}^n}{\text{Density}} = \frac{\text{Mass of solute + Mass of Solvent}}{\text{Density}}$$

$$\text{Vol. of sol}^n = \frac{1105}{0.997} = 1108.32 \text{ ml} = 1.108 \text{ dm}^3$$

$$M = \frac{\text{Wt. of the substance (Ws)}}{\text{Mol. Wt. of the substance (Ms)}} \times \frac{1}{\text{Vol. of solution in dm}^3\text{ (Y)}}$$

$$M = \frac{5}{58.5} \times \frac{1}{1.108} = 0.07713 \text{ M}$$

Eg. What is the Normality of solution of NaCl containing 10×10^{-3} Kg of it dissolved in 2 dm^3 of water.

Solution:- Ws = 10×10^{-3} Kg = 10 g Y = 2 dm^3

$$N = \frac{\text{Wt. of the substance (Ws)}}{\text{g. Eq. Wt. of the substance (Es)}} \times \frac{1}{\text{Vol. of solution Y } dm^3}$$

$$\text{Eq. Wt. of NaOH} = \frac{\text{Molecular Wt. of NaOH}}{\text{Acidity of NaOH}} = \frac{40}{1} = 40$$

$$N = \frac{Ws}{Es} \times \frac{1}{Y\ dm^3} = \frac{10}{40} \times \frac{1}{2} = 0.125\ N\ \text{NaOH}$$

THANK YOU