THEORY OF DILUTE SOLUTIONS

I. Mole percent of a component

$$= \frac{\text{Number of moles of that component}}{\text{Total number of moles in solution}} \times 100$$

II. Molarity of the solution

$$= \frac{\text{Number of moles of the solute}}{\text{Volume of the solution in litres}}$$

III. Molality of the solution

$$= \frac{\text{Number of moles of the solute}}{\text{Mass of the solvent in kg}}$$

IV. Formality of the solution

$$= \frac{\text{Number of formula masses of the solute}}{\text{Volume of the solution in litres}}$$

V. Normality of the solution

$$= \frac{\text{Number of gram equivalents of the solute}}{\text{Volume of the solution in litres}}$$

VI. $\text{Normality} = \text{Molarity} \times \frac{\text{Molar mass}}{\text{Equivalent mass}}$

VII. Normality (for acids) = Molarity × Basicity

VIII. Normality (for bases) = Molarity × Acidity

Types of Solutions

	Physical state of			
S.No.	**Solute**	**Solvent**	**Solution**	**Examples**
I	Solid	Solid	Solid	Alloys geme etc
II	Liquid	Solid	Solid	Mercury in zinc or gold (amalgams) etc.
III.	Gas	Solid	Solid	Hydrogen in palladium etc.
IV.	Solid	Liquid	Liquid	Sugar in water, salt in wate etc.
V.	Liquid	Liquid	Liquid	Alcohol in water, benzene in toluene etc.
VI.	Gas	Liquid	Liquid	Oxygen in water, CO_2 in water etc.
VII.	Solid	Gas	Gas	Dust particles in air, iodine in air etc.
VIII.	Liquid	Gas	Gas	Water in air (like humidity) etc.
IX.	Gas	Gas	Gas	Mixture of various gases, air etc.

Solution, Solute and Solvent

A solution is a homogeneous mixture of two or more substances. A solution of two substances is called a binary solution. Its two components are called as solute and solvent.

A substance which is dissolved into another substance is called as **solute** and another substance which dissolves the solute into it is called as solvent. In sugar solution sugar is solute and water is **solvent**.

Solubility

The maximum amout of any solute that can be dissolved in 100 g of solvent at a particular temperature is called the solubility of that solute at particulare temperature. Which depends upon

(*i*) nature of solute

(*ii*) nature of solvent

(*iii*) temperature of the solution

(*iv*) pressure (for gases)

1. Normality (N) $= \frac{w}{W} \times \frac{1000}{E}$; where, V in ml.

2. $$\mathrm{N} = \frac{\text{gm. litre}^{-1}}{\text{Eq. wt}}$$

$$= \frac{\text{wt. of solute in gm./litre soln.}}{\text{Eq. wt. of solute}}$$

3. $$\text{Molarity (M)} = \frac{\text{gram. litre}^{-1}}{\text{Molecular wt.}}$$

4. $$\mathrm{M} = \frac{\mathrm{w}}{\mathrm{V}} \times \frac{1000}{\text{Mol. wt.}}\text{; where, V in ml.}$$

5. $V_1S_1 + V_2S_2 + V_3S_3 + ... = V_m \times S_m$.
For mixture containing all acids or alkalies.

6. $\{V_1S_1$ (acid one) $+ V_2S_2$ (acid two) $+ ....\} -$
$V'S'$(alkali one) $+ V''S''$(alkali two) $+ ....$
$= V_mS_m$; For mixture containing acids and alkalies.

7. Factor

$$= \frac{\text{wt. of the solute taken}}{\text{wt. of the solute required for desired strength}}$$

8. Actual Strength = Factor × Approximate Strength.

(*a*) For mono-basic acid (HCl) or mono-acidic base (KOH); Molarity (M) = Normality (N);
[∵ Mol. wt. = Eq.wt.]

(*b*) For di-basic acid (H_2SO_4) or di-acidic base [$Ca(OH)_2$];
M = 2(N); [∵ Mol. wt. = 2 × Eq. wt.]

(*c*) For tri-basic acid (H_3SO_4) or tri-acidic base [$Al(OH)_3$]; M = 3(N);
[∵ Mol. wt. = 3 × Eq. wt.]

Osmotic Pressure (P)

1. $$P = \frac{nRT}{V} = \frac{m}{M} \times \frac{RT}{V} = CRT$$

where, n = no. of moles of solute
T = temp. in °K
V = volume in litres containing *x* gm mole of solute,
C = molar concentration of a solution
R = solution constant and is analogous to gas constant.

2. PV = RT; where V = vol. in litre containing 1 gm mole

3. $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ (in case of two solutions)

4. For two isotonic solutions at the same temp., $\frac{V_1}{n_1} = \frac{V_2}{n_2}$

5. For two isotonic solutions, if $V_1 = V_2$ then $n_1 = n_2$ at the same temp.

6. In case of dissociation : $\frac{M_c}{M_o} = \frac{P_o}{P_c} = 1 + (n - 1)\alpha$ where, α is degree of dissociation.

7. In case of association of molecules, $\frac{M_c}{M_o} = \frac{P_o}{P_c} = \left(\frac{n-1}{n}\right)\alpha$

   where, o stands for observed or abnormal value and c stands for theoretical or calculated or normal value.

- In case of dissociation : Actual concentration $= \{1 + (n - 1)\alpha\}$ C and
  $P_c = \{1 + (n - 1)\alpha\}$ CRT

Lowering of Vapour Pressure (ΔP)

1. Lowering of vapour pressure $(\Delta P) = P - P_s$
   where, P = V.P. of pure solvent and P_s
   = V.P. of solution.

2. $$\frac{\Delta P}{P} = \frac{P - P_s}{P} = \frac{n}{n + N};$$

   $$\left[\frac{n}{n + N} = \text{mole fraction of the solute}\right]$$

3. $$\frac{\Delta P}{P} = \frac{P - P_s}{P} = \frac{m}{w} \times \frac{W}{M}$$

   where, M = mol. wt. of solute
   W = mol. wt. of solvent
   m = wt. of solute in gm. and
   w = wt. of solvent in gm.

$$\frac{\Delta P}{P} = \frac{P - P_s}{P} = \text{Relative lowering of V.P.}$$

Elevation in Boiling Point (B.P.) (ΔT_b)

1. ΔT_b = B.P. of solution – B.P. of pure solvent
2. $\Delta T_b \propto C_m$ (Raoult's law)
   where, C_m is the molal or molar concentration of solution.
3. $\Delta T_b = \dfrac{K_b \times 10^3 \times w}{W \times M}$

where w = mass of solute in gm.
W = mass of solvent in gm
M = mol. wt of solute and
K_b = molal elevation constant of a solute

4. $K_b = \dfrac{RT^2}{10^3 \times L} = \dfrac{0.002T^2}{L}$

where, L = Latent heat

T = Boiling point and

R = 2 cals deg^{-1} mole^{-1}

5. $M = \dfrac{K_b \times 10^3 \times w}{\Delta T_b \times W}$

Depression in Freezing Point (ΔT_f)

1. ΔT_f = F.P. of pure solvent – F.P. of solution

2. $\Delta T_f = \dfrac{K_f \times 10^3 \times w}{W \times M}$

3. $K_f = \dfrac{0.002T^2}{L}$

   where, K_f is molal depression const. of a solvent and T is F.P.

4. Mol. wt. (M) = $\dfrac{K_f \times 10^3 \times w}{W \times \Delta T_f}$

5. For same solution $\dfrac{\Delta T_b}{\Delta T_f} = \dfrac{K_b}{K_f}$