

Spring days school
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Subject-chemistry.
Class --12th
Chapter 2--Solution

Definition-- If a mixture of obtained on mixing two or more than two substance is homogeneous, this mixture is called solution. For example sugar solution and brass.

Constituent of solution

there are two constituent of solution.

1---solute

2---solvent

A solution formed by two components having the same physical state. One with low quantity is called solute and other which is in excess is called solvent.

Types of solution--

1)**On the basis of physical state--** On this basis solutions are of three type..

Gaseous solution

Liquid solution

Solid solution

Table 2.1. Types of Solutions			
S. No.	Solute	Solvent	Example
1.	Gas	Gas	Mixture of gases, such as air.
2.	Gas	Liquid	Soda water (CO ₂ in H ₂ O).
3.	Gas	Solid	Adsorption of gases on metals <i>e.g.</i> , adsorption of H ₂ on Pd.
4.	Liquid	Gas	Evaporation of water in air, evaporation of liquids.
5.	Liquid	Liquid	Solution of alcohol in water.
6.	Liquid	Solid	Mercury in gold, mercury in silver, water of crystallisation present in hydrated salts like CuSO ₄ .5H ₂ O, Na ₂ SO ₄ .10H ₂ O.
7.	Solid	Gas	Evaporation of solids like camphor or naphthalene gives a solution of solid in gas, smoke.
8.	Solid	Liquid	Sugar in water, salt in water.
9.	Solid	Solid	Homogeneous mixture of two or more metals (alloys), <i>e.g.</i> , Zn in Cu (brass), Cu in Au, stainless steel etc.

2)**On the basis of concentration--** On this basis solution are classified into five type..

1--dilute solution--a solution in which a relatively small amount of solute is dissolved in the solvent is called dilute solution. In this solution amount of solute is minimum and amount of solvent is maximum.

2--concentrated solution--a solution in which a relatively large amount of the solute is dissolved in the solvent is called concentrated solution. In this type of solution amount of solute is maximum and amount of solvent is minimum.

3--saturated solution--a solution in which no more solute can be dissolved at a given temperature is called a saturated solution.

4--unsaturated solution--a solution in which some more solute can be dissolved at a given temperature is called an unsaturated solution.

5--supersaturated solution--a solution in which excess of solute is dissolved that can be present in a saturated solution is called a supersaturated solution.

Method for expressing concentration of a solution

1)**Strength--** Amount of solute in grams in 1 litre that is 1000 ml solution is known as strength. It is expressed in grams per litre.

2) **Molarity(M)--** Molarity of a solution is defined as the number of moles of the solute dissolved in 1 litre of a solution. It can be expressed by the formula--

$$M=w \times 1000 / m \times V$$

3)**Molality(m)--** Molality of a solution is defined as the number of moles of the solute dissolved in kilograms it is denoted by *m*.

$$m=w \times 1000 / m \times W$$

4)**Normality (N)--** Normality is defined as the number of equivalent or gram equivalent of solute in one litre solution it is denoted by *N*.

$$N=w \times 1000 / E \times V$$

5) **Mole fraction--** In a solution ratio of number of mole of solute to number of moles of solute and solvent is known as mole fraction of solute. Ratio of number of mole of solvent to number of moles of solute and solvent is

known as mole fraction of solvent. If number of mole of solute and solvent in a solution are n and N.respectively then number of mole of solution =n+N. Therefore

Mole fraction of solute=n/n+N
Mole fraction of solvent=N/n+N

6)**Formality (F)**-- Number of gram formula mass of solute in one litre solution is known as its formality it is denoted by F. Formality can be formulated by the formula...

F=w×1000/Fm×V

7)**Concentration of solution in parts per million (ppm)**---Number of parts of solute in 1 million parts of solution by weight is known as concentration parts per million.. it can be formulated by the formula--

ppm=mass of solute in gram/mass of solution in gram×1000000
--

Solubility of gas in liquid

Solubility is the maximum amount of solute dissolve in definite amount of solvent at a given temperature. its value depend on nature of solute ,nature of solvent ,temperature and pressure. solubility of a gas in a particular liquid at given temperature and one atmospheric pressure is volume of 8 in cubic centimetre at STP needed to prepare saturated solution in 1 cubic centimetre of solvent.

Factors affecting the solubility of gas in liquid---

There are four factors which affect the solubility of gas in liquid---

- 1)Nature of the gas and the liquid
- 2)Effect of temperature
- 3)Effect of impurities
- 4)Effect of pressure

Henry's law-- Solubility of gases in liquids is highly affected by pressure. Solubility increases on increasing pressure. It can be explain on the basis of Henry's law.Henry stated quantitative relation between solubility of a gas in solvent and pressure.He proposed Henry's law for this. According to this law the mass of a gas dissolved in a given volume of the liquid at constant temperature is directly proportional to the pressure of the gas present in equilibrium with the liquid.

m ∞ p
m=K_H.p

Where m is the mass of gas dissolved in unit volume of liquid p is pressure of the gas at equilibrium and K_H is constant which is known as Henry constant.

mole fraction of the gas in a solution is directly proportional to partial pressure of the gas present over the gas

Limitations of Henry's law

There are are several limitations of Henry's law--

- 1)this law is applicable to dilute solution only if the gas is highly soluble in the solvent this is not obeyed perfectly.
- 2)Pressure and temperature should be low and high respectively.
- 3)Gas should not react with the liquid. Gas should neither associate or dissociate in liquid.

Application of Henry's law

- 1) This law is applicable in carbonated beverage industry in soft drink and soda water the bottle is sealed under high pressure to increase the solubility of CO₂
- 2)This is also applicable for respiration in deep sea deep. Sea divers use compressed air for respiration at high pressure oxygen, nitrogen are more soluble in blood. Oxygen gets used up during metabolism but nitrogen remains in blood .it is present in blood as bubbles.These bubbles affect nerve impulse and produce a disease called bends. it is dangerous to life and painful ,also to avoid bend as well as toxic effect of it in the tanks used for respiration by deep sea divers.
- 3)This law is also applicable at high altitude respiration. Partial pressure of oxygen at high altitude is lower than ground level.This is the reason of low concentration of oxygen in tissues and blood of climbers and people living here this cause weakness and decrease in thinking ability the symptoms are called anoxia.

Colligative properties of solution

some properties of a solution depend on the number of solute particles like atoms molecules or ions present in definite volume of it these are called colligative properties these properties do not depend on chemical structure or composition of solute but depend on number of particles of solute present indefinite amount of the solvent some colligative properties are--

- 1)Relative lowering of vapour pressure
- 2)Elevation of boiling point
- 3)Depression in freezing point

4) Osmotic pressure of solution

1) Relative lowering of vapour pressure

The maximum pressure exerted by vapours of a liquid at a definite temperature when the vapours and liquid phases are in equilibrium is called the vapour pressure of the liquid. In simple terms the pressure exerted by vapours is called vapour pressure.

If a non-volatile solute is added to a volatile liquid, its vapour pressure decreases i.e. vapour pressure of the solution is lower than the vapour pressure of the pure solvent. In case of a pure solvent the whole surface of liquid is occupied by molecules of the liquid but in case of a solution a part of the surface of the solution is occupied by the solute particle. This decreases the number of molecules of liquid at the surface of the solution. Thus, fewer solvent molecules will escape to form vapours, thereby lowering the vapour pressure of the liquid. The lowering of vapour pressure relative to the vapour pressure of the pure solvent is termed as relative lowering of vapour pressure.

Raoult's Law- The vapour pressure of a pure solvent is decreased when a non-volatile solute is dissolved in it. This lowering of vapour pressure depends upon the concentration of the dissolved solute. The empirical relationship between relative lowering of vapour pressure and the concentration was given by F. Raoult. He stated that "the vapour pressure of any solution containing a non-volatile solute in a volatile solvent is proportional to the mole fraction of the solvent in the solution".

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solute. F. Raoult, a French scientist studied the vapour pressure of a large number of solutions. He gave an empirical relation connecting the relative lowering of vapour pressure and the concentration of the solute in the solution. It is known as Raoult's law, which states that :

The vapour pressure of any solution containing a non-volatile solute in a volatile solvent, is proportional to the mole fraction of the solvent in the solution.

Vapour pressure of solution (p_s) \propto mole fraction of solvent

$$p_s \propto x_1$$

$$p_s = p^\circ x_1 \quad \dots(i)$$

Hence if mole fraction of solvent is plotted against vapour pressure of solution, a straight line will be obtained.

Relative lowering of vapour pressure- If n_1 mole of solute are dissolved in n_2 mole of solvent.

Mole fraction of solvent in solution

$$x_1 = \frac{n_2}{n_1 + n_2} \quad \dots(ii)$$

Substituting this value in equation (i)

$$\frac{p_s}{p^\circ} = \frac{n_2}{n_1 + n_2}$$

On subtracting both sides from 1

$$1 - \frac{p_s}{p^\circ} = 1 - \frac{n_2}{n_1 + n_2}$$

or

$$\frac{p^\circ - p_s}{p^\circ} = \frac{n_1}{n_1 + n_2} \quad \dots(iii)$$

In this equation (iii) $p^\circ - p_s$ shows lowering of vapour pressure. $\frac{p^\circ - p_s}{p^\circ}$ shows relative lowering in vapour pressure and $\frac{n_1}{n_1 + n_2}$ denotes mole fraction of solute. Hence at constant temperature, relative lowering of vapour pressure of non-volatile solute is equal to mole fraction of the solute. This is called Raoult's law.

Determination of molecular mass of the non-volatile solute by relative lowering of vapour pressure :

We know that :

$$\frac{p^\circ - p_s}{p^\circ} = \frac{n_1}{n_1 + n_2} \quad \dots(1)$$

If W_1 gm of solute is dissolved in W_2 gm of solvent and the respective molecular weights of solute and solvent are M_1 and M_2 , then

No. of mole of solute, $n_1 = \frac{W_1}{M_1}$ and No. of mole of solvent, $n_2 = \frac{W_2}{M_2}$.

Fig. 2.4. Graphical representation between vapour pressure of solution and mole fraction of solvent

Must Remember

➤ When a non-volatile solute is dissolved in a solvent, its vapour pressure gets lowered. This lowering is governed by Raoult's Law. According to Raoult's law relative lowering in vapour pressure of a solvent is equal to the mole fraction of the solute. If solution has both volatile liquid components it obeys Raoult's law in other form. Mathematically this law is $P_{\text{total}} = p_1^\circ x_1 + p_2^\circ x_2$, where p_1° and p_2° are partial pressures of components A and B respectively. x_1 and x_2 are mole fractions of A and B. Thus it is clear from Raoult's law that relative lowering in vapour pressure is a colligative property.

Substituting these values in equation (1), we get :

$$\frac{p^\circ - p_s}{p^\circ} = \frac{\frac{W_1}{M_1}}{\frac{W_1}{M_1} + \frac{W_2}{M_2}} = \frac{n_1}{n_1 + n_2} \quad \dots(2)$$

For dilute solutions, $n_1 \ll n_2$, thus

$$\frac{p^\circ - p_s}{p^\circ} \approx \frac{n_1}{n_2}$$

$$\frac{p^\circ - p_s}{p^\circ} \approx \frac{W_1/M_1}{W_2/M_2}$$

$$\boxed{\frac{p^\circ - p_s}{p^\circ} = \frac{W_1 \times M_2}{W_2 \times M_1}} \quad \dots(3)$$

By knowing the experimental values of $\frac{p^\circ - p_s}{p^\circ}$ and the molecular weight of the solvent (M_2), the molecular weight of the solute (M_1) can be calculated from the above equations.

2) Elevation of boiling point-- A liquid boils at a definite temperature which is called its boiling point. At this temperature the vapour pressure of the liquid becomes equal to the atmospheric pressure. A pure solvent at the room temperature t_1 has a definite pressure P_1 . On heating the solvent its temperature rises to t_2 and its pressure equals the atmospheric pressure. At this temperature it begins to boil. When a non-volatile substance is

added to the solvent then at temperature t_1 its vapour pressure decreases from P_1 and P . now when this solution is heated then at temperature t_2 its pressure becomes equal to P_1 and at temperature t_3 its pressure becomes equal to atmospheric pressure. Thus the boiling point is now elevated from t_2 to t_3 and solution of non volatile substance boils at higher temperature than the pure solvent the rise in temperature that result by the addition of a nonvolatile solute in a solvent is termed as elevation in boiling point.

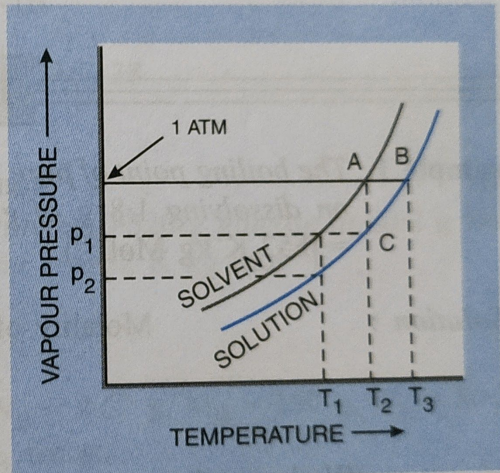


Fig. 2.5. Elevation in boiling point

It is observed that elevation of boiling point is proportional to the lowering of vapour pressure.

$$\Delta T_b \propto p - p_s$$

Elevation in boiling point is also directly proportional to the number of moles of solute dissolved in the solvent.

or

$$\Delta T_b \propto m \text{ (molality)}$$

or

$$\Delta T_b = K_b m$$

Here, m is the number of moles dissolved in one kg of the solvent and K_b is the proportionality constant called **molal boiling point elevation constant or ebullioscopic constant**.

When $m = 1$ i.e., 1 mole of solute is dissolved in 1000 g of solvent then $K_b = \Delta T_b$. Thus,

Molal elevation constant may be defined as the boiling point elevation produced when one mole of solute is dissolved in one kg (1000 g) of solvent.

Table 2.5. Molal Elevation Constants of Some Solvents (K_b)

S. No.	Solvent	Boiling Point (in K)	K_b (K Kg mole ⁻¹)
1.	Water	373.0	0.52
2.	Ethyl alcohol	351.2	1.20
3.	Benzene	353.3	2.63
4.	Chloroform	334.4	3.83
5.	Carbon tetrachloride	350.0	5.03
6.	Carbon disulphide	319.4	2.34
7.	Ether	307.8	2.02

If in W_A gram of a solvent, W_B gram of solute of molecular mass M_B is dissolved then,

$$\text{Molality of the solution, } m = \frac{1000 \times W_B}{M_B \times W_A}$$

Substituting the value of m in the equation $\Delta T_b = K_b m$,

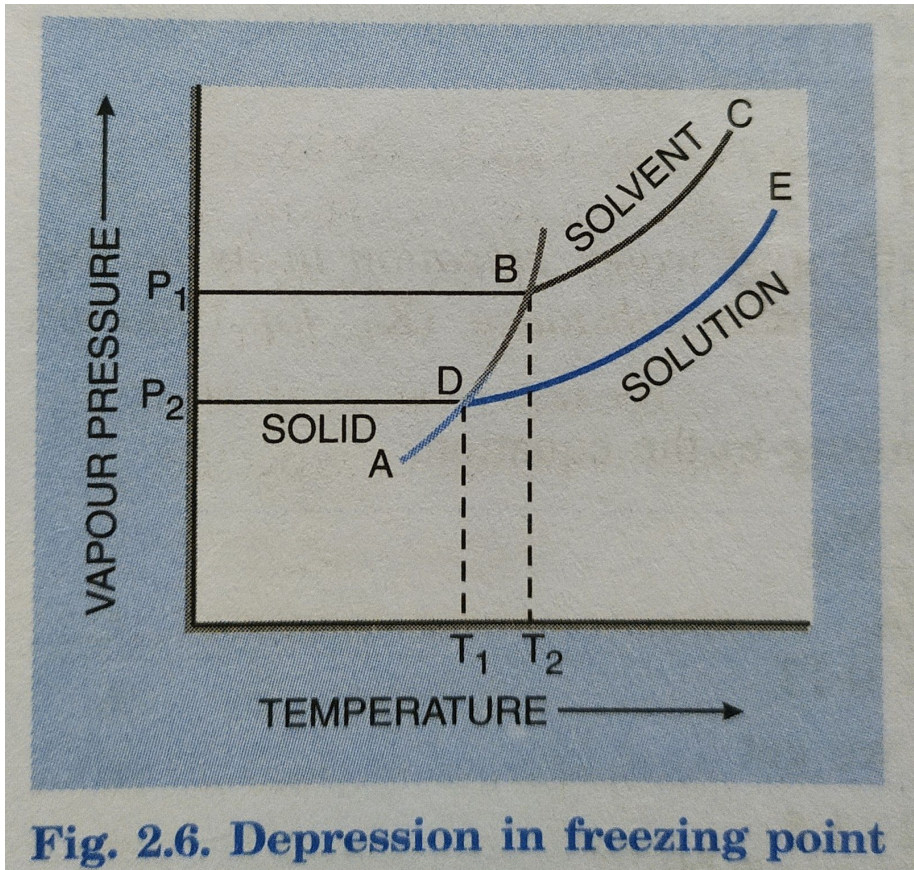
$$\Delta T_b = \frac{1000 \times K_b \times W_B}{M_B \times W_A}$$

Molecular weight of solute B

$$M_B = \frac{1000 \times K_b \times W_B}{\Delta T_b \times W_A}$$

3)depression in freezing point-- A liquid freezes or solidify when cool to a certain temperature.this temperature is called the freezing point of the liquid. at this temperature the vapour pressure of solid and liquid states of a substance are equal and the liquid and solid States coexist at equilibrium. When a non volatile substance is added to the solvent then the vapour pressure of the solvent decreases,thus the freezing point of the solution is also lowered i.e.freezing point of solution is lower than the freezing point of the pure solvent. This decrease in

the freezing point of the pure solvent is referred to as the depression in freezing point.



The graph between vapour pressure and temperature for a pure solvent and solution is shown above. the curve BC gives the vapour pressure of the pure solvent and the curve DE represents the vapour pressure of the solution. curve AB represent the vapour pressure of the solid solvent at various temperature. B represent the point Where vapour pressure of liquid and solid solvent meet thus this point B corresponds to the freezing point of the pure solvent that is T₂. similarly temperature T₁ is the freezing point of the solution since T₂>T₁ the freezing point of the solution is lower than that of the pure solvent.this difference(T₂-T₁) is called the depression in freezing point.

It has been observed that depression in freezing point is directly proportional to the molal concentration of the solute.

$$\Delta T_f \propto m$$
$$\Delta T_f = K_f \times m$$

Where k_f is a constant called molal depression constant. [Molar depression constant may be defined as" the freezing point depression produced when 1 mole of solute is dissolved in 1 kilograms of the solvent.,"](#)

Calculation of molecular mass of non-volatile solute by depression in freezing point

Molecular mass of non-volatile solute may be determined from the depression in freezing point.

Let, Mass of the solute = W_B gm and Mass of the solvent = W_A gm

Molar mass of the solute = M_B

\therefore No. of moles of the solute $n_B = \frac{W_B}{M_B}$

and Molality $m = \frac{n_B \times 1000}{W_A} = \frac{W_B \times 1000}{M_B \times W_A}$

But, $\Delta T_f = K_f m$

$\therefore \Delta T_f = \frac{K_f \times W_B \times 1000}{M_B \times W_A}$

Or, Molar mass of the solute, $M_B = \frac{K_f \times W_B \times 1000}{\Delta T_f \times W_A}$

If the value of K_f is given, the molecular weight of the solute can be calculated.

4)Osmotic pressure--

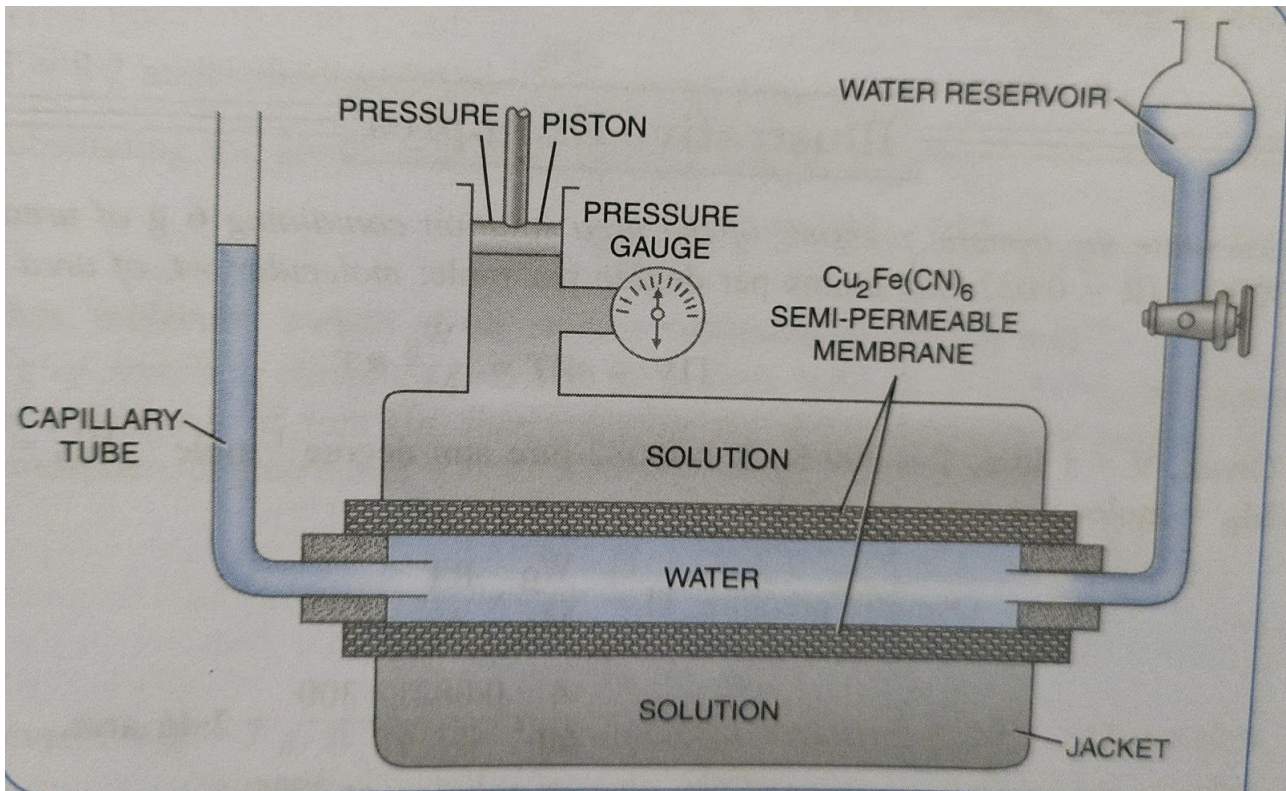
Osmosis-- The spontaneous flow of solvent through a semipermeable membrane from a solution of low concentration of one of the higher concentration is termed as osmosis.

Osmosis	Diffusion
1. Osmosis takes place only in solution.	1.diffusion takes place in both gases and liquids.
2.semipermeable membrane is necessary for the	2. Semipermeable membrane is not required in

process of osmosis to take place.	diffusion.
3.the solvent molecules in the process of osmosis move from low concentration to high concentration .	3. The molecules in diffusion move from a region of high concentration to a region of low concentration.
4. In osmosis only the movement of solvent molecules takes place.	4. In diffusion both solute and solvent molecules move freely.

Osmotic pressure-- Osmotic pressure is equal to that of hydrostatic pressure which develops when a solution is separated from a solvent through a semipermeable membrane.

Measurement of osmotic pressure-- Convenient method for the determination of osmotic pressure is Berkeley and Hartley method .This apparatus consist of a porous pot fitted into a bronze cylinder. The port is open at both end having a copper ferrocyanide membrane fused in its wall. The porous pot is connected with a site you on one end and a water reservoir at the other end. The bronze cylinder contains the solution and is fitted with a piston upon which weight may be placed to exert external pressure on the solution. Water level is maintained at the mark of the site you when the experiment is started. osmosis takes place and water moves into the solution through the semipermeable membrane. this is represented by the fall in water level in the capillary tube. This flow of water into the solution can be stopped by the application of external pressure on the solution with the help of piston. The pressure applied on the piston is equal to the osmotic pressure of the solution.



Berkeley and Hartley method is is more suitable and useful to measure osmotic pressure as compared to other method due to the following reason--

- 1-osmotic pressure is balanced by external pressure therefore membrane is not strained and remain safe.
- 2-it is less time consuming.
- 3-concentration of solution is not change.

Theory of dilute solution

To explain the parallel relationship between the behaviour of solution and gases Van't Hoff put forward the theory of dilute solution. According to this theory" **a substance in a dilute solution behaves exactly like a gas and the Oscar matic pressure of a dilute solution is equal to the pressure which the solute would exert if it were a gas at the same temperature and occupying the same volume as the solution"**

According to above theory Van't Hoff established the following equation for dilute solution which is parallel to general gas equation.

General Gas Equation ($PV = nRT$).

$$\Pi V = nRT$$
$$\Pi = \frac{n}{V}RT$$

$$\Pi = CRT$$

Where π = osmotic pressure of the solution V =volume of solution in litres
 n =number of moles of the solute
 C =molar concentration
 R =solution constant
 T =temperature of the solution in kelvin

In above equation if at a definite temperature R and T are constant hence π will be proportional to C. therefore osmotic pressure of the solution does not depend upon the nature of the solute but on the number of moles of the solute present thus **osmotic pressure is also a colligative property**.

Isotonic Solution- If two solution are separated by a semipermeable membrane and there is no flow of solvent across the membrane. the solution are said to be isotonic solution.

Hypotonic solution- Solution which have osmotic pressure less than given solution are called hypotonic solution.

Hypertonic solution-- Solution which have osmotic pressure more than given solution are called hypertonic solution.

Reverse osmosis- If a pressure greater than the osmotic pressure is applied on the solution the solvent will flow from the solution into the pure solvent through semipermeable membrane. This process is called reverse osmosis. the process of reverse osmosis has an important application in the the desalination of seawater.

Van't Hoff Factor

On comparing the colligative properties of electrolyte and nonelectrolyte it is observed that osmotic pressure depression in freezing point and elevation in boiling point of electrolyte is greater than that of non electrolyte expressed the colligative properties of both type of substance by the factor (i). Which is known as Van't Hoff Factor.

Van't Hoff's factor, $i = \frac{\text{Observed value of colligative property}}{\text{Calculated value of colligative property}}$

$= \frac{\text{Actual number of particles}}{\text{Number of particles in normal state}}$

i.e., $i = \frac{\text{Number of particles after association or dissociation}}{\text{Number of particles in normal state}}$

As colligative properties are inversely related to molecular mass hence a new relation may be derived.

or $i = \frac{\Pi_{obs}}{\Pi_{cal}} = \frac{\Delta p_{obs}}{\Delta p_{cal}} = \frac{\Delta T_{obs}}{\Delta T_{cal}} = \frac{M_{cal}}{M_{obs}}$

$i = \frac{\text{Observed osmotic pressure}}{\text{Normal osmotic pressure}} = \frac{\text{Theoretical molecular mass}}{\text{Observed molecular mass}}$

Normally, observed magnitude of colligative property
 $= i \times \text{Calculated magnitude of colligative property}$
 Where i = Van't Hoff's factor.

Degree of ionization of electrolyte may be calculated from these relations. If degree of dissociation is known, experimental value of colligative property may be calculated. It is denoted as :

Osmotic pressure, $\Pi = i CRT$

Must Remember

➤ Quantitatively the extent to which a solute dissociates or associates in a solution is expressed by Van't Hoff's factor 'i'. This factor is expressed as a ratio of actual molar mass to that determined experimentally or as the ratio of observed colligative property to the calculated property.