2

SOLUTIONS

INTRODUCTION

Definition of solution : When two or more chemically non-reacting substances are mixed and form homogeneous mixture is called solution.

(i) **Solute :** The component present in lesser amount than other component in solution is called solute.

(ii) **Solvent :** The component present in greater amount than any or all other components is called the solvent.

(iii) Solution = solute + solvent

(iv) Physical state of solvent and solution is same.

(v) When the solution is composed of only two chemical substances, it is termed a binary solution, similarly, it is called ternary and quaternary if it is composed of three and four components respectively.

PROPERTIES OF A SOLUTION

(i) A solution consists of a single phase i.e. it is a monophasic system.

(ii) A solution is uniform throughout, so it uniform properties such as density refractive index etc.

(iii) The components of a solution can not be easily separated by physical methods.

(iv) Size of solute particles in a solution is the order of $10^{-7} - 10^{-8}$cm.

(v) The properties of a solution are the properties of its components. i.e. the components do not lose their properties when they form a solution.

(vi) Certain properties of solution such as density, viscosity, surface tension, boiling point, freezing point etc. Vary with the composition of the solution.

TYPE OF SOLUTION

(On the bases of phase of solute or solvent)

There may be the following Nine types of binary solutions.

S.No.	Solute	Solvent	Example
1.	Gas	Gas	Air
2.	Gas	Liquid	CO_2 in soda water
3.	Gas	Solid	Hydrogen in Pd/Pt.
4.	Liquid	Gas	Fog
5.	Liquid	Liquid	Alcohol in water, benzene in toluene
6.	Liquid	Solid	Mercury in zinc amalgam
7.	Solid	Gas	Smog
8.	Solid	Liquid	Sugar in water
9.	Solid	Solid	Alloys

Generally the solution of liquid in gas or solid in gas is not possible because the constituents can not form a homogenous mixture.

TYPE OF SOLUTIONS

(On the bases of concentration of solution)

(i) **Dilute solution :** A solution in which relatively a small amount of solute is dissolved in large amount of solvent is called a dilute solution.

(ii) **Concentrated solution :** A solution in which relatively a large amount of solute is dissolved in small amount of solvent is called a concentrated solution.

(ii) **Saturated solution :** The maximum amount of solute is grams, that can be dissolved in 100 gm of a solvent at a particular temperature is called solubility of the solute and such a solution is called saturated solution.

(iv) **Supersaturated solution :** A solution containing more amount of solute than that required for saturation of a given amount of solvent at a particular temperature, is called a supersaturated solution. It is unstable system.

EXPRESSION OF STRENGTH/CONCENTRATION OF SOLUTION

The amount of solute which dissolved in unit volume of solution is called concentration of solution".

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

Weight – weight percentage (w/W) :

Weight of solute present in 100 gm of the solution.

$$\text{Weight percent} = \frac{\text{Weight to solute (gm)}}{\text{Weight of solution (gm)}} \times 100$$

$$\%\text{ by weight} = \frac{w}{W} \times 100$$

w = weight of solute ; W = weight of solution

Example 1 :

What is the weight percentage of urea sol^n in which 10 gm urea dissolved in 90 gm of water.

Sol. Weight percentage of urea

$$= \frac{\text{Weight to urea}}{\text{Weight of solution}} \times 100 = \frac{10}{90+10} \times 100$$

= 10% urea sol^n (w/W)

Volume – volume percentage (v/V) :

(In liquid – liquid solution)

Volume of solute in ml. present in 100 ml of the solution is called, volume – volume percentage.

Volume – volume percentage

$$= \frac{\text{Volume of solute (ml)}}{\text{Volume of solute (ml)}} \times 100\ ;\ \%\text{ by volume} = \frac{v}{V} \times 100$$

Example 2 :

A solution is prepared by mixing of 10 ml ethanol with 190ml of water. What is volume percentage of ethanol.

Sol. Volume percentage of ethanol

$$= \frac{\text{Volume of ethanol}}{\text{Volume of solution}} \times 100 = \frac{10}{10+190} \times 100 = 5\%$$

Thus 5% ethanol aqueous solution.

Weight – volume percentage (w/V) :

Weight of solute in gm. present in 100 ml of the solution is called weight — volume percentage.

$$\text{Weight} - \text{volume}\ \% = \frac{\text{Weight of solute (gm)}}{\text{Volume of solution (ml)}} \times 100$$

$$\%\ \text{of strength} = \frac{w}{v} \times 100$$

Example : 5% of urea (w/V) : 5 gm urea present in 100 ml of the solution.

Normality : The number of gram equivalents of the solute dissolved per litre of the solution.

It is denoted by 'N' :

$$\text{Normality} = \frac{\text{Number of gram equivalents of solute}}{\text{Volume of solution (lit)}}$$

$$\because\ \text{Gram equiv. of solute} = \frac{\text{Weight of solute (gm)}}{\text{Equivalent weight of solute}}$$

$$\therefore\ \text{Normality} = \frac{\text{Weight of solute (gm)}}{\text{Equivalent weight of solute}} \times \frac{1}{\text{Volume of solution (lit)}}$$

Formula : $N = \frac{w}{E}\frac{1}{V(\text{lit.})}$ .... (i)

$N = \frac{w}{E}\frac{1000}{V(\text{ml})}$ .... (ii)

$N = n_E \times \frac{1}{V(\text{lit.})}$ .... (iii)

$n_E = N \times V$ .... (iv)

w = weight of solute (gm), E = Equivalent weight of solute,
V = volume of solution,
n_E = number of gram equivalent of solute.
Number of Gram equivalents
= Normality of solution × volume of solution (lit.)
Milli gram equivalents = Normality of solution × volume of solution (ml)
1 gram equivalent = 1000 milli equivalent.

$\frac{N}{2}$	$\frac{N}{5}$	$\frac{N}{10}$	$\frac{N}{100}$	$\frac{N}{1000}$	N	5N	10N
Semi normal	Penti normal	Deci normal	Centi normal	milli normal	normal	Penta normal	Deca normal

gm. Equivalent per litre →

$\frac{1}{2}$ $\frac{1}{5}$ $\frac{1}{10}$ $\frac{1}{100}$ $\frac{1}{1000}$ 1 5 10

If density and weight of the solution is given then :

$$\text{Normality} = N = \frac{w}{E} \times \frac{d}{W} \times 1000 \qquad .... (v)$$

(where d = density of solution)

$N = \frac{10.x.d.}{E}$ (W = Weight of solution)

$x = \frac{w}{W} \times 100$ = Weight-weight percentage

Example 3 :

4 gm NaOH is present in 100 ml of the solution what is the normality ?

Sol. $\text{Normality} = \frac{w}{E} \times \frac{1000}{V(\text{ml})} = \frac{4}{40} \times \frac{1000}{100} = 1N$

Example 4 :

12.6 gm oxallic acid present in 550 gm of the solution. Density of the solution is 1.10gm/ml. What is the normality ?

Sol. $N = \frac{w}{E} \times \frac{d}{W} \times 1000 = \frac{12.6}{63} \times \frac{1.10}{550} \times 1000 = 0.4\,N$

n factor :

* Equivalent mass $= \frac{\text{Molar mass}}{\text{n-factor}}$

* No. of equivalent

$$= \frac{\text{Mass of the species}}{\text{Equivalent mass}} = \frac{\text{Mass of the species}}{\frac{\text{Molar mass}}{\text{n-factor}}}$$

* **For oxidizing/reducing agents :**
No. of e^- involved in oxidation/reduction half reaction per mole of oxidising agent/reducing agent.
e.g., $5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{2+} + H_2O$; n-factor = 5

* **For acid/base reactions :**
no. of H^+ ions displaced / OH^- ions displaced per mole of acid/base. e.g., NaOH : n-factor = 1, H_2SO_4 : n-factor = 2

* **For salt :**
n = total charge on cations or total charge on anions } Simple salts
e.g., $Al_2(SO_4)_3$; n-factor = charge on the cation = 2 × 3 = 6

Molarity : The number of gram moles of the solute dissolved per litre of the solution. It is denoted by 'M'.

$$\text{Molarity} = \frac{\text{Number of gram moles of solute}}{\text{volume of solution (lit.)}}$$

$$\because \quad \text{Gram moles} = \frac{\text{weight of solute (gm)}}{\text{Molecular weight of solute}}$$

$$\therefore \quad \text{Molarity} = \frac{\text{weight of solute (gm)}}{\text{Molecular weight of solute}} \times \frac{1}{\text{volume of solution (lit.)}}$$

Formula :

$$M = \frac{w}{M'} \times \frac{1}{V(\text{lit.})} \quad \text{................ (i)}$$

$$M = \frac{w}{M'} \times \frac{1000}{V(\text{ml})} \quad \text{................. (ii)}$$

$$M = n_M \times \frac{1}{V(\text{lit.})} \quad \text{................. (iii)}$$

$$n_M = M \times V(\text{lit.}) \quad \text{.................. (iv)}$$

Where, w = weight of solute, M' = Molecular weight of solute, V = volume of solution, n_M = number of gram moles.

Gram moles = Molarity of solution × volume of solution (litre)

Milli moles = Molarity of solution × volume of solution(ml)

1 Gram mole = 1000 milli moles

$\frac{M}{2}$	$\frac{M}{5}$	$\frac{M}{10}$	$\frac{M}{100}$	$\frac{M}{1000}$	M	5M	10M
Semi	Penti	Deci	Centi	Milli	Molar	Penta	Deca
molar soln	molar soln	molar soln	molar soln	molar soln	soln	molar soln	molar soln
No. of gm moles							
$\frac{1}{2}$	$\frac{1}{5}$	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$	1	5	10

If density and weight of the solution is given then.

$$\text{Molarity} = M = \frac{w}{M'} \times \frac{d}{W} \times 1000 \quad \text{......... (v)}$$

$$M = \frac{10.x.d}{M'} \quad \text{.......... (vi)}$$

where, d = density of sol^n, W = weight of sol^n, then volume of $\text{sol}^n = V = \frac{W}{d}$

$$x = \frac{w}{W} \times 100 = \text{weight} - \text{Weight percentage}$$

Note : Normality = n-factor × molarity

Example 5 :

3.65 gm HCl gas present in 100 ml of its aqueous sol^n. What is the molarity ?

Sol. $\text{Molarity} = \frac{w}{M'} \times \frac{1000}{\text{volume(ml.)}} = \frac{3.65}{36.5} \times \frac{1000}{100} = 1\text{M}$

"1M sol^n of HCl"

Molality : The number of gram moles of solute dissolved in 1000 gm or 1 kg of the solvent.

It is denoted by 'm'

$$\text{molality} = \frac{\text{Gram moles of solute}}{\text{weight of solvent (kg)}}$$

$$\therefore \quad \text{Gram moles of solute} = \frac{\text{weight of solute (gm)}}{\text{Molecular weight of solute}}$$

$$\text{Molality} = \frac{\text{weight of solute (gm)}}{\text{Molecular weight of solute}} \times \frac{1}{\text{weihgt of solvent (kg)}}$$

Formula :

$$m = \frac{w}{M} \times \frac{1}{W(\text{kg})} \quad \text{.......... (i)}$$

$$m = \frac{w}{M} \times \frac{1000}{W(\text{gm})} \quad \text{......... (ii)}$$

$$m = n_M \times \frac{1}{W(\text{kg})} \quad \text{......... (iii)}$$

where, w = weight of solute,

M = molecular weight of solute, W = weight of solvent,

n_M = no. of moles of solute

Example 6 :

8 gm NaOH dissolved in 500 ml of its aqueous sol^n. if density of the solution is 1.2 gm/ml. then find the molality of the solution.

Sol. Weight of solute = 8 gm

Volume of solution = 500 ml

Density of sol^n = 1.2 gm/ml

∴ Weight of solution = 500 × 1.2 = 600 gm.

∴ Weight of solvent = weight of solution–weight of solute = 600 – 8 = 592 gm

$$\therefore \quad m = \frac{w}{M} \times \frac{1000}{W} = \frac{8}{40} \times \frac{1000}{592} = 0.34$$

Formality : The no. of gram formula weight of a solute dissolved per litre of the solution is called formality of the solution. It is denoted by 'F'.

$$\text{Formality} = \frac{\text{weight of solute (gm)}}{\text{Formula weight of solute}} \times \frac{1}{\text{Volume of solution (lit.)}}$$

$$F = \frac{w}{f} \times \frac{1}{V(\text{litre})} \qquad \text{........... (i)}$$

$$F = \frac{w}{f} \times \frac{1000}{V(\text{ml})} \qquad \text{.......... (ii)}$$

Where, w = weight of solute, f = formula weight of solute, V = volume of solution, n_f = no. of gram formula weight.

$$F = n_f \times \frac{1}{V(\text{litre})} \qquad \text{........ (iii)}$$

Example 7 :

CH_3COOH exists as dimer in benzene 1.2 gm of the acid was dissolved and the volume was made up to one litre by benzene, what is the formality ?

Sol. Molecular weight of $CH_3COOH = 60$

Formula weight of the associated molecule of the acid

$= 2 \times 60 = 120$

weight of $CH_3COOH = 1.2$ gm

volume of solution = 1 litre.

$$\text{Formality} = \frac{1.2}{120} \times \frac{1}{1} = .01F$$

Mole fraction : The mole fraction of a component in a solution is the ratio of the number of moles of that component to the total number of moles present in the solution.

$$\text{Suppose : } \left.\begin{matrix} A - \text{Solute} \\ B - \text{Solvent} \end{matrix}\right\} \text{Solution}$$

n_A = No. of moles of solute,

n_B = No. of moles of solvent

$$\text{Then mole fraction of solute} = X_A = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of solvent } = X_B = \frac{n_B}{n_A + n_B}$$

$$X_A + X_B = 1$$

For gaseous mixture :

A binary system of two gases A & B

P_A = Partial pressure of A

P_B = Partial pressure of B

$P = P_A + P_B$ = Total pressure of gaseous mixture

$$\text{Mole fraction of gas A } \; X_A = \frac{P_A}{P_A + P_B} = \frac{P_A}{P}$$

$$\text{Mole fraction of gas B } \; X_B = \frac{P_B}{P_A + P_B} = \frac{P_B}{P}$$

Mole percentage :

Mole percentage = Mole fraction × 100

Mole percent of A = $X_A \times 100$

Mole percent of B = $X_B \times 100$

ppm. (Part per million) : The parts of the component per million parts (10^6) of the solution. It use when the amount of solute is negligible, $\text{ppm} = \frac{w}{w + W} \times 10^6$

where, w = weight of solute, W = weight of solvent

Demal Unit : One mole of solute is present in 1 litre solution at 0°C.

TITRATION

Titration is a procedure of determination of concentration of unknown solution with the help of known concentrated sol^n.

In this procedure for determining the concentration of solution A by adding a carefully measured volumes of a solution with known concentration of B until the reaction of A & B is just complete.

The fundamental basis of titration is the 'Law of equivalence" which states that at end point of a titration volumes of the two titrants reacted have the same number of equivalents or milli equivalents.

Acid base Titration : One gm equivalent of acid neutralised by one gm equivalent of base.

It means : One equivalent of acid = one equivalent of base

Acid $[N_1V_1]$ = Base $[N_2V_2]$

[∵ gm equivalent = Normality × volume]

Example 8 :

Find the no. of milli equivalents of H_2SO_4 present in 10 ml of N/2 H_2SO_4 sol^n.

Sol. milli equivalents = Normality × volume (ml)

$$= \frac{1}{2} \times 10 = 5 \text{ milli equivalent of } H_2SO_4$$

Example 9 :

10 milli equivalent KOH are present in its 100 ml sol^n . What is the normality ?

Sol. $\text{Normality} = \frac{\text{milli equivalents of solute}}{\text{volume of solution (ml)}} = \frac{10}{100} = \frac{1}{10}$

$= 0.1$ N sol^n of KOH

Example 10 :

What is the volume of N/4 NaOH required to neutralize 100 ml of N/2 HCl ?

Sol. $N_1V_1(\text{Acid}) = N_2V_2\,(\text{Base})$

$$\frac{1}{2} \times 100 = \frac{1}{4} \times V_2 \;;\; V_2 = 200 \text{ ml.}$$

Example 11 :

What is the volume of 10 N acetic acid required to prepare 400 ml of N–solution ?

Sol. Equivalents of acetic acid in N sol^n = Equivalents of acetic acid in 10 N sol^n. $N_1V_1 = N_2V_2$

$1 \times 400 = 10 \times V_2$

$V_2 = 40$ ml.

Example 12 :

What is mole fraction of solute in its one molal aqueous solution ?

Sol. $n_A = 1$ and $n_B = \frac{1000}{18} = 55.4$

$$\text{Mole fraction} = \frac{n_A}{n_A + n_B} = \frac{1}{1+55.4} = \frac{1}{56.4} = 0.018$$

Example 13 :

15 gram of methyl alcohol is dissolved in 35 gram of water. What is the mass percentage of methyl alcohol in solution?

Sol. Total mass of solution = (15 + 35) gram = 50 gram

mass percentage of methyl alcohol

$$= \frac{\text{Mass of methyl alcohol}}{\text{Mass of solution}} \times 100 = \frac{15}{50} \times 100 = 30\%$$

Example 14 :

A solution has 25% of water, 25% ethanol and 50% acetic acid by mass. Calculate the mole fraction of each component?

Sol. Since 18 g of water = 1 mole

$$25 \text{ g of water } = \frac{25}{18} = 1.38 \text{ mole}$$

Similarly, 46 g of ethanol = 1 mole

$$25 \text{ g of ethanol } = \frac{25}{46} = 0.55 \text{ moles}$$

Again, 60 g of acetic acid = 1 mole

$$50 \text{ g of acetic acid } = \frac{50}{60} = 0.83 \text{ mole}$$

$$\therefore \text{ Mole fraction of water } = \frac{1.38}{1.38+0.55+0.83} = 0.50$$

$$\text{Mole fraction of ethanol } = \frac{0.55}{1.38+0.55+0.83} = 0.19$$

$$\text{Mole fraction of acetic acid } = \frac{0.83}{1.38\ 0.55+0.83} = 0.3$$

TRY IT YOURSELF - 1

Q.1 A sugar syrup of mass 214.2g contains 34.2 g sugar. Calculate molality and mole fraction.

Q.2 Calculate molarity and normality of a caustic soda solution containing 1g of NaOH per 100 mL of solution.

Q.3 Calculate the weight of oxalic acid ($H_2C_2O_4, 2H_2O$) that must be dissolved to get 250 mL of seminormal solution.

(A) 7.875g (B) 5.875g
(C) 3.875g (D) 31.5g

Q.4 The density of 3M aqueous hyposolution is 1.25 g mL^{-1}. Calculate mole fraction of sodium thiosulphate and molalities of Na^+ and $S_2O_3^{--}$ ions.

Q.5 Calculate mole fraction of solute in an aqueous 1 molal solution.

Q.6 Concentrated H_2SO_4 is labelled as 49% by weight and its density is 1.5 g mL^{-1}. Calculate M and N.

Q.7 Calculate the mass of urea (NH_2CONH_2) required in making 2.5 kg of 0.25 molal aqueous solution.

(A) 27.5 g (B) 17.5 g
(C) 37.5 g (D) 67.5 g

Q.8 A solution of glucose in water is labelled as 10 percent w/w, if the density of the solution is 1.2 g mL^{-1}, then what shall be the molarity of the solution ?

(A) 0.37 mol L^{-1} (B) 0.67 mol L^{-1}
(C) 0.17 mol L^{-1} (D) 0.27 mol L^{-1}

Q.9 One gm of calcium was burnt in excess of O_2 and the oxide was dissolved in water to make up one litre solution. Calculate Normality of alkaline solution.

Q.10 How much volume of 1M H_2SO_4 is needed to neutralize 10 ml of 1M NaOH solution ?

ANSWERS

(1) 0.56 M, 0.0099
(2) 0.25 M, 0.25 N
(3) (A)
(4) 0.097, 11.86, 5.93
(5) 0.018
(6) 7.5 M, 15 N
(7) (C)
(8) (B)
(9) 0.05
(10) 5ml

VAPOUR PRESSURE

If a pure liquid is placed in a closed container that was initially evacuated, the liquid evaporates to fill up the space above the liquid. At any given temperature when the equilibrium is established, the pressure exerted by the vapours of the liquids is called the vapour pressure of the pure liquid P^0.

$$H_2O\,(\ell) \rightleftharpoons H_2O\,(g)$$

Some important points regarding P^0.

1. P^0 is independent of the volumes of the two phases and also of areas and curvature of the liquid-vapour boundary.

   For example at 25°C, $P^0_{H_2O} = 24$ torr .

2. P^0 is independent of the presence of other gases in the vapour phase.

3. Raising the temperature of the system also increases by the P^0 of a liquid.

   B.P. – The boiling point of a liquid is defined as the temperature at which its vapour pressure becomes equals to the applied pressure. If the applied pressure is 1 atm, the B.P. is called the normal B.P. of the liquid.

4. A liquid with a higher vapour pressure is said to be more volatile and this liquid will have a lower boiling point since boiling point and vapour pressure are inversely dependent on each other.

5. Pressure of vapour (P) must be distinguished from vapour pressure (P^0)

   ($P \le P^0$, P cannot be more than P^0 at equilibrium)

6. Vapour pressure depends upon the following factors :

   (a) Nature of solvent
   (b) Temperature
   (c) %age purity of liquid or surface area of liquid.

7. The dependence of vapour pressure with temperature is given by Clausius-Clapeyron equation.

$$\ln\left(\frac{p_2}{p_1}\right) = -\frac{\Delta Hv}{R}\left(\frac{1}{T_2}-\frac{1}{T_1}\right),$$

where ΔHv = molar enthalpy of vapourisation of the given liquid, p_2 =vapour pressure of the liquid at T_2, and p_1 = vapour pressure of the liquid at T_1.

8. Vapour pressure of a liquid does not depend on :

(i) On the amount of liquid taken.

(ii) On surface area of the liquid

(iii) On volume or shape of the container

9. **Saturation :** A gas or gaseous mixture is said to be saturated with the vapours of a liquid if the partial pressure of the liquid vapours is equal to its (saturated) vapour pressure.

(a) Saturated (Equillibrium) Vapour pressure of water, at a given temprature, is called aqueous tension.
The value of aqueous tension is different at different temprature.

(b) Relative Humidity (R.H.)

$$= \frac{\text{Partial pressure of water vapour at given temp.}}{\text{Vapour pressure of water at the same temp.}} \times 100\%$$

10. Vapoure pressure of liquid

$$\propto \frac{1}{\text{The strength of intermolecular forces acting between molecules}}$$

For example CCl_4 has higher vapour pressure because of the weak intermolecular forces acting between its molecules than water which has stronger intermolecular forces acting between water molecules of volatile liquid has lower boiling point than a non-volatile liquid.

Example 15 :

The vapor pressure of water at 80°C is 355 torr. A 100 ml vessel contained water-saturated oxygen at 80°C, the total gas pressure being 760 torr. The contents of the vessel were pumped into a 50.0 ml vessel at the same temperature. What were the partial pressures of oxygen and of water vapor, what was the total pressure in the final equilibrated state? Neglect the volume of any water which might condense.

Sol. In 100 ml vessel which contained water - saturated oxygen, the pressure of O_2 gas = 760 – 355 = 405 torr when the contents of this vessel were pumped into 50 ml vessel at the same temperature, the pressure of oxygen gets doubled

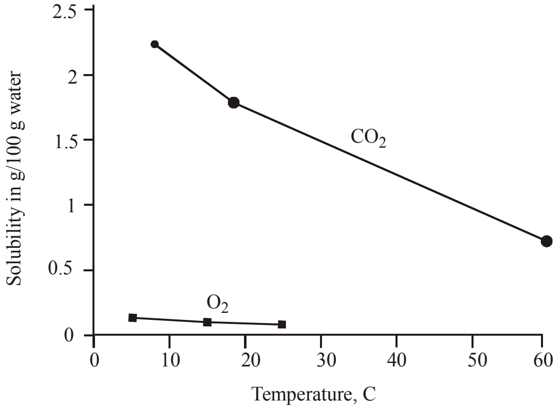
i.e. $P_{O_2} = 810$ torr.

But pressure of water vapour will remain constant, as some vapour in this 50 ml vessel, gets condensed.

So, $P_{H_2O} = 355$ torr & Total pressure = 810+ 355 = 1165 torr.

SOLUBILITY OF A GAS IN A LIQUID

(a) **Effect of Temperature:** The variation of solubility for a gas with temperature can be determined by examining the graph.



Solubility of Gases Vs. Temperature

As the temperature increases, the solubility of a gas decrease as shown by the downward trend in the graph More gas is present in a solution with a lower temperature compared to a solution with a higher temperature.

The reason for this gas solubility relationship with temperature is very similar to the reason that vapor pressure increases with temperature. Increased temperature causes an increase in kinetic energy. The higher kinetic energy causes more motion in molecules which break intermolecular bonds and escape from solution.

This gas solubility relationship can be remembered if you think about what happens to a "soda pop" as it stands around for awhile at room temperature. The taste is very "flat" since more of the "tangy" carbon dioxide bubbles have escaped. Boiled water also tastes "flat" because all of the oxygen gas has been removed by heating.

(b) **Nature of the gas and the solvent :** Solubility of gas in a solvent is due to the chemical similarity between the gas and the solvent.

For example, Gases like hydrogen, oxygen, nitrogen etc. dissolve in water only to a small extent whereas gases like CO_2, HCl, NH_3 etc. are highly soluble.

(c) **Effect of pressure (HENRY LAW) :**

“The partial pressure of the gas in the vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution” and is expressed as : $p = K_H x$. Here K_H is the Henry’s law constant is unique to each gas. (Notice that constant temperature is assumed.) The equation is true only at low concentrations and pressures and for gases that do not react with the solvent. An alternate (and commonly used) expression of Henry's law is $\frac{C_1}{P_1} = \frac{C_2}{P_2}$; where C_1 and P_1 refer to initial conditions and C_2 and P_2 to final conditions.

Note :

- * The K_H value of a gas is different in different solvents and it increase with the increase in temperature.
- * Higher the value of K_H of a gas, lower will be its solubility. Since, $X = p/K_H$.
- * Plot of p Vs X is a straight line passing through the origin with slope equal to K_H.

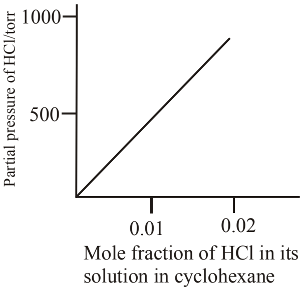


Figure : Plot of P Vs X for solution of HCl in cyc!ohexane.

- * If a mixture of gases is brought in contact with solvent each constituent gas dissolves in proportion to its partial pressure. It means Henry's law applies to each gas independent of the pressure of other gas.

Limitation of Henry's law:

Henry's law is valid only under following condition.

(i) The pressure of gas is not too high.
(ii) The temperature is not too low.
(iii) The gas should not undergo any chemical reaction with the solvent.
(iv) The gas should not undergo dissociation in solution.

Example 16 :

The Henry's law constant for the solubility of N_2 gas in water at 298 K is 1.0×10^5atm. The mole fraction of N_2 in air is 0.8. The number of moles of N_2 from air dissolved in 10moles of water of 298 K and 5atm pressure is –

(A) 4×10^{-4}
(B) 4.0×10^{-5}
(C) 5.0×10^{-4}
(D) 4.0×10^{-6}

Sol. **(A).** $P_{N_2} = K_H \times x_{N_2}$

$$x_{N_2} = \frac{1}{10^5} \times 0.8 \times 5 = 4 \times 10^{-5} \text{ per mole}$$

In 10 mole solubility is 4×10^{-4}

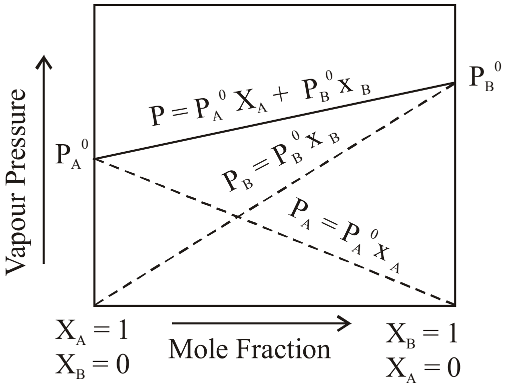
RAOULT'S LAW

The partial pressure of any volatile constituent of a solution at a constant temperature is equal to the vapour pressure of pure constituent multiplied by the mole fraction of that constituent in the solution.

(i) For liquid - liquid solution :

In the case of binary solutions of two volatile liquids, Raoult's law states that at a given temperature, the partial vapour pressure of any component of the solution is equal to the product of the vapour pressure of the pure component and its mole fraction in the solution.

Let a mixture (solution) be prepared by mixing n_A moles of liquid A and n_B moles of liquid B. Let P_A and P_B be the partial pressure of two constituents A & B in solution and P_A^0 & P_B^0 the vapour pressure in pure state respectively.



Thus, according Raoult's law

Partial pressure of A = mole fraction of A x $P_A^0 = X_A P_A^0$

$$P_A = \frac{n_A}{n_A + n_B} P_A^0 \qquad \text{..... (1)}$$

partial pressure of B = mole fraction of B x $P_B^0 = X_A P_B^0$

and $P_B = \dfrac{n_B}{n_A + n_B} P_B^0$ ...... (2)

If total pressure be P_S, then

$$P_S = P_A + P_B = \frac{n_A}{n_A + n_B} P_A^0 + \frac{n_B}{n_A + n_B} P_B^0$$

$$= X_A P_A{}^0 + X_B P_B{}^0 \qquad \text{...... (3)}$$

$$P_S = X_A P_A^0 + (1 - X_A)\, P_B^0 \qquad [\because X_A + X_B = 1]$$

$$P_S = X_A P_A^0 - X_A P_B^0 + P_B^0$$

$$P_S = X_A [P_A^0 - P_B^0] + P_B^0 \qquad \text{....... (4)}$$

Eq. (1), (2) and (3) are the straight line.

(ii) Solid-liquid solution : Raoult proposed a law which states that at a given temperature, the vapour pressure of a solvent in a solution containing non-volatile solute is directly proportional to its mole fraction.

$P = P^0 \times$ mole fraction of solvent

A = non volatile solids, B = volatile liquid

According to Raoult's law , $P = X_A P_A^0 + X_B P_B^0$

for A, $P_A^0 = 0 \therefore P = X_B P_B^0$ .... (5)

Let $P_B{}^0 = P^0$ = Vapour pressure of pure state of solvent here X_B is mole fraction of solvent

$$P_S = \frac{n_B}{n_A + n_B} P^0 \qquad \text{........ (6) ;} \quad P_S \propto \frac{n_B}{n_A + n_B}$$

i.e. vapour pressure of solution $\propto$ mole fraction of solvent

$$\Rightarrow P_S = X_B P_B^0 \Rightarrow P_S = (1-X_A)P_B^0 \Rightarrow P_S = P_B^0 - X_A P_B^0$$

$$\frac{P_B^0 - P_S}{P_B^0} = X_A \quad \text{or} \quad \frac{P^0 - P_S}{P^0} = X_A \text{ ..... (7)}$$

$$\text{or} \quad \frac{P^0 - P_S}{P^0} = \frac{n_A}{n_A + n_B} \quad \text{..... (8)}; \quad \frac{\Delta P}{P^0} = \frac{n_A}{n_A + n_B}$$

where $\frac{\Delta P}{P^0}$ = Relative lowering of vapour pressure.

$$\text{or} \quad \frac{P^0}{P^0 - P_S} = \frac{n_A + n_B}{n_A} \quad \text{or} \quad \frac{P^0}{P^0 - P_S} = 1 + \frac{n_B}{n_A}$$

$$\text{or} \quad \frac{P^0}{P^0 - P_S} - 1 = \frac{n_B}{n_A} \quad \text{or} \quad \frac{P_S}{P^0 - P_S} = \frac{n_B}{n_A}$$

$$\frac{P^0 - P_S}{P_S} = \frac{n_A}{n_B} \quad \text{...... (9)}$$

$$\text{or} \quad \frac{P^0 - P_S}{P_S} = \frac{W_A . m_B}{m_A . W_B} \quad \text{or} \quad \frac{w\,M}{m\,W} \quad \text{....... (10)}$$

where, w = wt. of solute dissolved in gram
W = wt. of solvent in grams, m = molecular mass of solute,
M = molecular weight of solvent

This expression (10) can be used for calculating the molecular weight of solutes.

(iii) Limitation of Raoult's law :

(a) Raoult's law is applicable only to very dilute solutions.

(b) Raoult's law is applicable to solutions containing non-volatile solute only.

(c) Raoult's law is not applicable to solutes which dissociates or associate in the particular solution

Example 17 :

An aqueous solution containing 28% be weight of liquid A (mol. wt. 140) has a vapour pressure of 160 mm at 37°C. Find the vapour pressure of the pure liquid A (the vapour pressure of water at 37°C is 150 mm).

Sol. We know that for a mixture of two miscible liquids,

$$P_{total} = P_A^{\circ} . x_A + P_B^{\circ} . x_B$$

where x_A and x_B are mole fraction of liquids A and B, and P_A° and P_B° are their vapour pressure in pure state.

$$\text{Moles of liquid 'A'} = \frac{28}{140} = 0.2$$

$$\text{Moles of water (liquid B)} = \frac{72}{18} = 4$$

Total number of moles in the solution = 4 + 0.2 = 4.2

$$\text{Moles fraction of A} = \frac{0.2}{4.2} = 0.048$$

Mole fraction of water (B) = 1 – 0.048 = 0.952

P_{total} = Vapour pressure of the solution = 160 mm (given)

So, $160 = P^{o}_A \times 0.048 + 150 \times 0.952$

or $P_A^{\circ} \times 0.048 = 160 - 142.8 = 17.2$

$$\text{or} \quad P_A^{\circ} = \frac{17.2}{0.048} = 358.3\,\text{mm}$$

IDEAL & NON IDEAL SOLUTIONS

Ideal solution : A solution which obeys Raoult's law at all concentrations and at all temperature is called an ideal solution. An ideal solution possesses the following characteristics :

(i) Volume change of mixing should be zero.

$\Delta V_{mix} = 0$;

$V_{solvent} + V_{solute} = V_{solution}$

(ii) Heat change on mixing should be zero.

$\Delta H_{mix} = 0$ (heat is neither absorbed nor evolved)

(iii) There should be no chemical reaction between solvent and solute.

(iv) Solute molecules should not dissociate in the ideal solution.

(v) Solute molecules should not associate in ideal solution.

(vi) Ideal solution must obey Raoult's law at all concentrations.

(vii) For ideal solution charge in entropy is not zero.

$\Delta S_{mix} \neq 0$

Example :

(i) Benzene and toluene (ii) n - Hexane and n - heptane
(iii) Carbon tetrachloride and silicon tetra chloride
(iv) Chloro benzene + Bromo benzene
(v) Ethyl Idodide + Ethyl Bromide

Dilute solution can be assumed as ideal solution.

Non Ideal solutions : There are the solutions which do not obey Raoult's law, called non ideal solutions.

For such solutions $P_A \neq P_A^0 . X_A$; $P_A \neq P_B^0 . X_B$

Non ideal solution are formed when the components differ much in their structures and polarities.

$\Delta H_{mixing} \neq$ zero

$\Delta V_{mixing} \neq$ zero

Non ideal solutions show either positive or negative deviation from Raoult's law.

Positive deviation from Raoult's law

This deviation is shown when the forces of attraction between A — B molecules are less than forces of attraction between A — A and B — B molecules in the two liquids forming the solution.

$$P_A > P_A^0 . X_A \, , \; P_B > P_B^0 . X_B$$

The total vapour pressure of the solution will be greater than the corresponding vapour pressure expected in case of ideal, an ideal solution of same composition. i.e.

$$P_{total} > P_A^0 . X_A + P_B^0 . X_B$$

$\Delta H_{mix} > 0$, Endothermic dissolution ; heat is absorbed
$\Delta V_{mix} > 0$, volume is increased after dissolution.

'A' and 'B' escape easily showing higher vapour pressure then the expected value.

Value of observed boiling point is lower than calculate value of boiling point.

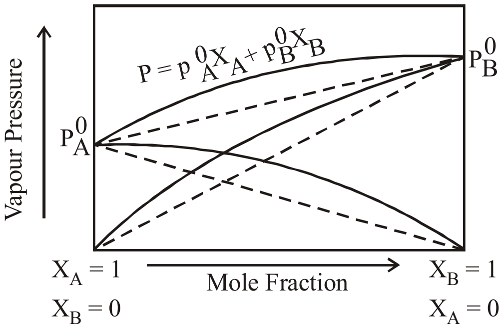
And for negative deviation : $P_A < P^o_A . X_A$; $P_B < P^o_B . X_B$ and $P_{total} < P^o_A . X_A + P^o_B . X_B$

$\Delta H_{mix} < 0$; exothermic dissolution heat is evolved.

$\Delta V_{mix} < 0$; volume is decreased during dissolution.

escaping tendency of both components 'A' and 'B' is lowered showing lower vapour pressure than expected ideally.

Value of observed boiling point is higher than calculate value of boiling point.



Examples :

(i) Acetone + ethyl alcohol	(ii) Water + ethyl alcohol
(iii) $CCl_4 + CHCl_3$	(iv) CCl_4 + toluene
(v) Water and methyl alcohol	(vi) Ethanol and cyclohexane
(vii) Acetone and benzene	(viii) Acetone + CS_2

Negative deviation from Raoult's law :

In these solutions the A—B interaction are stronger than the A—A and B—B molecular interactions present in the two liquids forming the solution. For thus solutions showing – ve deviation.

$P_A < P^o_A . X_A$

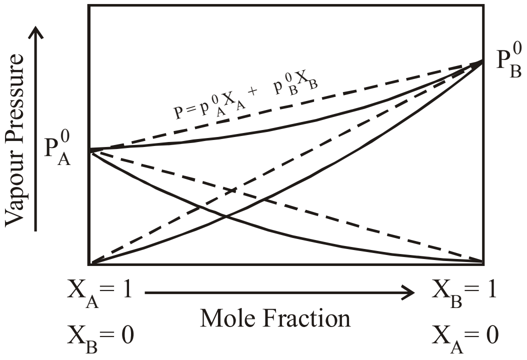
$P_B < P^o_B . X_B$ and $P_{total} < P^o_A . X_A + P^o_B . X_B$

$\Delta H_{mix} < 0$; exothermic dissolution heat is evolved.

$\Delta V_{mix} < 0$; volume is decreased during dissolution.

escaping tendency of both components 'A' and 'B' is lowered showing lower vapour pressure than expected ideally.

Value of observed boiling point is higher than calculate value of boiling point.



Examples : (i) Water + HCl

(ii) $H_2O + HNO_3$

(iii) Nitric acid and chloroform

(iv) $CH_3OH + CH_3COOH$

(v) Acetic acid + pyridine

(vi) Chloroform + diethyl ether

(vii) Chloroform + benzene

(viii) Acetone and chloroform

AZEOTROPIC MIXTURES

Azeotropic mixtures of two liquids which boil at a constant temperature and can be distilled unchanged in their composition. They are formed by non–ideal solutions.

Types of azeotropic mixtures

(a) "Minimum boiling azeotropes" are the mixture of two liquids, whose boiling points is less than either of the two pure components. They are formed by non–ideal solution showing positive deviation.

eg. ethanol (95.5%) + water (4.5%) mixture boiling at 351.15K.

(b) "Maximum boiling azeotropes" are the mixtures of two liquids, whose boiling points are more either of the two components. They are formed by non–ideal solution showing negative deviation.

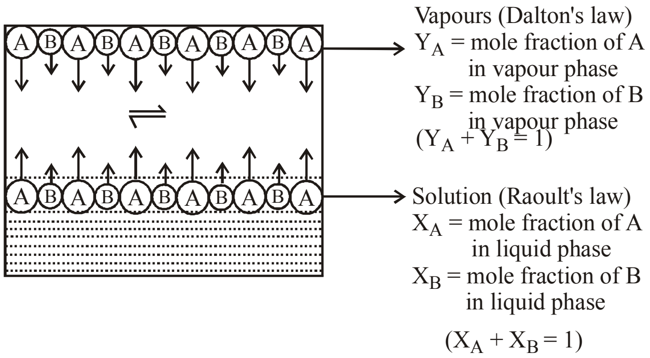
e.g. HNO_3 (68%) + water (32%) mixture boiling at 393.5 K.

Zeotropic Mixture : A mixture in which composition of component in mixture in vapour is different. Its component can be separate by fractional distillation.

Composition in vapour phase :

The composition of the vapour in equilibrium with the solution can be calculated applying Dalton's law of partial pressures.

Let the mole fractions of vapours A and B be Y_A and Y_B respectively. Let p_A and p_B be the partial pressure of vapours A and B respectively and total pressure P.



From Raoult's law $P = P^0_A X_A + P^0_B X_B$

$P_A = P^0_A X_A$ and $P_B = P^0_B X_B$

From Dalton's law,

Partial pressure = Mole fraction × Total pressure

For A : $P_A = y_A \times P = P^0_A X_A \Rightarrow y_A = \frac{P^0_A X_A}{P}$ ....(1)

Similarly, $y_B = \dfrac{P_B^0 X_B}{P}$ .... (2)

Above formula is used for calculation of mole fraction of B in vapour phase

On adding, $X_A + X_B = \dfrac{P \times y_A}{P_A^0} + \dfrac{P \times y_B}{P_B^0} = 1$

$\Rightarrow \quad \dfrac{1}{P} = \dfrac{y_A}{P_A^0} + \dfrac{y_B}{P_B^0}$ .... (3)

Above formula is used to calculate total vapour pressure when mole fractions are given in vapour phase.

$P = P_A^0 X_A + P_B^0 X_B \Rightarrow$ This formula is used to calculate total pressure when mole fraction are given in liquid phase.

$\dfrac{1}{P} = \dfrac{y_A}{P_A^0} + \dfrac{y_B}{P_B^0} \Rightarrow$ This formula is used to calculate total pressure when mole fraction are given in vapour phase.

Thus, in case of ideal solution the vapour phase is phase richer with more volatile component i.e., the one having greater vapour pressure.

Example 18 :

The vapour pressures of ethanol and methanol are 44.5mm and 88.7mm Hg respectively. An ideal solution is formed at the same temperature by mixing 60g of ethanol with 40g of methanol. Calculate the total vapour pressure of the solution and the mole fraction of methanol in the vapour.

Sol. No. of moles of $C_2H_5OH = \dfrac{60}{46} = 1.304$

No. of moles of $CH_3OH = \dfrac{40}{32} = 1.25$

X_A of ethyl alcohol $= \dfrac{1.304}{1.304 + 1.25} = 0.5107$

X_B of ethyl alcohol $= \dfrac{1.25}{1.304 + 1.25} = 0.4893$

Partial pressure of ethyl alcohol

$= X_A . P_A^0 = 0.5107 \times 44.5 = 22.73$ mm Hg

Partial pressure of methyl alcohol

$= X_B . P_B^0 = 0.4893 \times 88.7 = 43.40$ mm Hg

Total vapour pressure of solution

$= 22.73 + 43.40 = 66.13$ mm Hg

Mole fraction of methyl alcohol in the vapour

$$= \frac{\text{Partial pressure of } CH_3OH}{\text{Total vapour pressure}} = \frac{43.40}{66.13} = 0.6563$$

TRY IT YOURSELF - 2

Q.1 H_2S is a toxic gas with rotten egg smell. If the solubility of H_2S in water is 0.20 m calculate Henry's law constant.

Q.2 Henry's law constant for the solubility of methane in benzene at 298K is 4.27×10^5mm Hg. Calculate the solubility of methane in benzene at 298 K under 760mm Hg.

Q.3 Henry's law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. Calculate the quantity of CO_2 in 500 mL of soda water when packed under 2.5 atm CO_2 pressure at 298 K.

Q.4 The vapour pressure of ethanol and methanol are 44.5mm and 88.7 mm of Hg respectively. A solution is prepared by mixing of 60g of ethanol and 40g of methanol. Assuming the solution to be ideal, calculate the vapour pressure of the solution.

Q.5 The vapour pressure of pure liquids A and B are 450 and 700 mm Hg respectively, at 350 K . If total vapour pressure is 600 mm Hg. Find the composition of the vapour phase.

Q.6 Two liquids x and y on mixing form an ideal solution. The vapour pressure of the solution containing 3 mole of x and 1 mole of y is 560 mm Hg. But when 4 mole of x and 1 mole of y are mixed, the vapour pressure of solution thus formed is 570mm Hg. What will be the vapour pressure of pure x and pure y at this temperature?

Q.7 The partial pressure of ethane over a saturated solution containing 6.56×10^{-2} g of ethane is 1 bar. If the solution contains 5.00×10^{-2} g of ethane, then what shall be the partial pressure of the gas.

Q.8 100 g of liquid A (molar mass 140 g mol^{-1}) was dissolved in 1000 g of liquid B (molar mass 180 g mol^{-1}). The vapour pressure of pure liquid B was found to be 500 torr. Calculate the vapour pressure of pure liquid A and its vapour pressure in the solution if the total vapour pressure of the solution is 475 torr.

ANSWERS

(1) 285.71 atm

(2) 1.78×10^{-3}

(3) 1.86g

(4) 66.16mm

(5) A : 0.30, B : 0.70

(6) x = 610mm, y = 410mm.

(7) 0.76 bar

(8) 280.7 torr, 32 torr.

COLLIGATIVE PROPERTIES OF DILUTE SOLUTIONS

(1) A dilute solution is one in which the amount of the solute is very small in comparison to the amount of the solvent.

(2) Dilute solutions containing non-volatile solute exhibit some special properties which depends only upon the number of solute particles present in the solution irrespective of their nature. These properties are termed as colligative properties.

(3) The colligative properties are -

(a) Relative lowering of vapour pressure
(b) Elevation in boiling point
(c) Depression in freezing point
(d) Osmotic pressure

Colligative properties $\propto$ No. of particles

$\propto$ No. of molecules (In the solution of non electrolyte)

$\propto$ No. of ions (In the solution of electrolytes)

$\propto$ No. of moles of solute

$\propto$ Mole fraction of solute

Colligative properties are the properties of dilute solution. Equimolar solutions of different substances (non volatile, non electrolyte) have the same values of colligative properties.

Lowering of vapour pressure : When a non-volatile solute is dissolved in a pure solvents, the vapour pressure of the solvent is lowered i.e. the vapour pressure of a solution is always lower than that of pure solvents, because the escaping tendency of solvents molecules decreases (due to lesser surface area of solutions available for evaporation).

If at a certain temperature P^o is the pressure of pure solvent, and P_S is the vapour pressure of solution then

Lowering of vapour pressure $= P^o - P_S$

Relative lowering of vapour pressure $= \dfrac{P^0 - P_S}{P^0}$

From equation, $\dfrac{P^0 - P_S}{P^0} = \dfrac{n_A}{n_A + n_B}$

for a more dilute solution $n_A <<< n_B$

so $\dfrac{P^0 - P_S}{P^0} = \dfrac{n_A}{n_B}$; $\dfrac{\Delta P}{P^0} = \dfrac{P^0 - P_S}{P^0} = \dfrac{n_A}{n_B}$; $\dfrac{\Delta P}{P^0} = \dfrac{n_A}{n_B}$

or relating lowering of vapour pressure $= \dfrac{P^0 - P_S}{P^0} = \dfrac{n_A}{n_B}$

Method of measuring the relative lowering in vapour pressure : Ostwald & Walker's Method.

Example 19 :

One mole of a non-volatile solute is dissolved in two moles of water. Find the vapour pressure of the solution relative to that of water.

Sol. $\dfrac{P^0_{\text{solvent}} - P_{\text{solution}}}{P^0_{\text{solvent}}} = \dfrac{1}{1+2} = \dfrac{1}{3}$ or $\dfrac{P_{\text{solution}}}{P^0_{\text{solvent}}} = 1 - \dfrac{1}{3} = \dfrac{2}{3}$

Elevation in boiling point : The boiling point of a liquid is that temperature at which its vapour pressure becomes equal to the atmospheric pressure i.e. 760 mm of Hg.

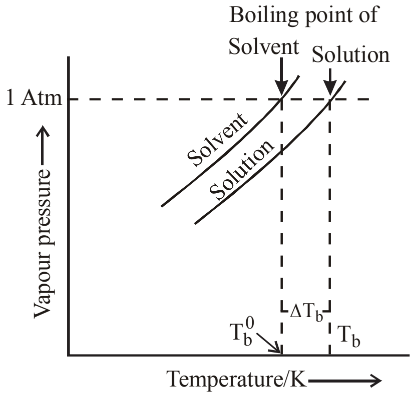


Figure : The vapour pressure curve for solution lies below the curve for pure water. ΔT_b denotes the elevation of boiling point of a solvent in solution.

When a non-volatile solute is dissolved in a pure solvent, its vapour pressure is decreased. The difference ΔT_b of boiling point of pure solvent T_b and the boiling point of the solution T_S then, $T_S > T_b$

and the elevation in boiling point $\Delta T_b = T_S - T_b$

The elevation in boiling point (ΔT_b) is directly proportional to lowering of vapour pressure of the solution i.e.

$\Delta T_b \propto P^0 - P_S$

From Raoult's law for dilute solutions.

$$\frac{P^0 - P_s}{P^0} = \frac{w.M}{m.W} = \frac{n_A}{n_B} \; ; \quad P^0 - P_s = \frac{w.M}{m.W} \times P^0$$

For a solvent P^0 & M = constant

$$\therefore \quad \Delta T_b \propto P^0 - P_s \propto \frac{w}{m.W} \; ; \Delta T_b = \frac{Kw}{m.W}$$

where K = elevation constant

If $\dfrac{w}{m} = 1$ mole and $W = 1$ gm then $\Delta T_b = K$

If $\dfrac{w}{m} = 1$ and W = 100 grams

$\therefore \quad \Delta T_b = \dfrac{K}{100} = K' =$ molecular elevation constant

$\therefore \quad K = 100\,K'$

$$\Delta T_b = \frac{100K' \times w}{m \times W}$$

If $\dfrac{w}{m} = 1$ and W = 1000 gram

$\therefore \quad \Delta T_b = \dfrac{K}{1000} = K_b =$ molal elevation constant

$K_b = \dfrac{RT_b^2}{1000\,\ell_v}$ [ℓ_v = latent heat of vapourisation;

T_b = Boiling point of solvent]

$$\Delta T_b = \frac{K_b \times w \times 1000}{m \times W} \; ; \; \Delta T_b = \frac{w}{m} \times \frac{1000}{W} \times K_b$$

$\therefore \quad \Delta T_b =$ molality x K_b

$\therefore \quad \Delta T_b \propto$ molality

The molal elevation constant for some common solvents are given in the following table :

S.N.	Solvent	B.P.(^{0}C)	Molal elevation constant
(i)	Water	100.0	0.52
(ii)	Ethyl alcohol	78.4	1.15
(iii)	Chloroform	61.2	3.67
(iv)	Carbon tetra chloride	76.8	5.02
(v)	Acetone	56.0	1.70
(vi)	Benzene	80.0	2.70

Example 20 :

An aqueous solution of glucose boils at 100.01°C. The molal elevation constant for water is 0.5 K mol^{-1} Kg. The number of molecules of glucose in the solution containing 100g of water is –

(A) 6.023×10^{23}
(B) 6.023×10^{22}
(C) 12.046×10^{20}
(D) 12.046×10^{23}

Sol. **(C).** $\Delta T_b = K_b.m$

or $m = \frac{\Delta T_b}{K_b} = \frac{0.01}{0.5} = 0.02$ mole Kg^{-1} of water

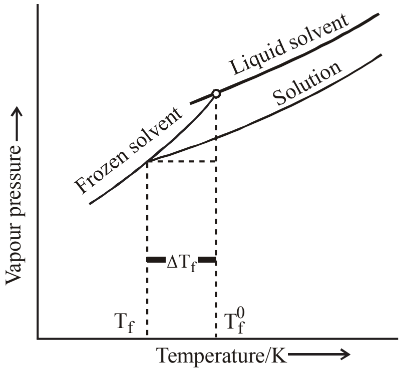
So, the number of moles of glucose in 100g of water

$= \frac{0.02 \times 100}{1000} = 0.002$ moles of glucose

$= 0.002 \times 6.023 \times 10^{23} = 2 \times 6.023 \times 10^{20}$

Depression in freezing point :

The freezing point of a liquid is that temperature at which the liquid and its state exist in equilibrium with each other. It may be defined as the temperature at which the liquid and solid states of a substance have the same vapour pressure.



Depression of the freezing point of a solvent in a solution.

When a non-volatile non-electrolyte is dissolved in a pure solvents the vapour pressure of the solvent is lowered If T_f is the freezing point of pure solvent and T_S is the freezing point of its solution then, $T_S < T_f$

The difference in the freezing point of pure solvent and solution it the depression of freezing point (ΔT_f) Thus,

$T_f - T_s = \Delta T_f$

Depression in freezing point is directly proportional to the lowering of vapour pressure of solution.

$\Delta T_f \propto P^0 - P_S$

From Raoult's law for dilute solution :

$$\frac{P^0 - P_S}{P^0} = \frac{w}{m} . \frac{M}{W} \quad \text{or} \quad P^0 - P_S = \frac{w}{m} . \frac{M}{W} . P^0$$

For the pure solvent, P^0 and M are constant, therefore –

$$P^0 - P_S \propto \frac{w}{mW} \quad \text{or} \quad \Delta P \propto \frac{w}{mW} \propto \Delta T$$

$$\Delta T_f = K . \frac{w}{mW}$$

Where K is a constant, called depression constant.

If $\frac{w}{m} = 1$ (one mole of solute) and W = 1g then $\Delta T_f = K$

If $\frac{w}{m} = 1$ and W = 100 g then $\Delta T_f = \frac{K}{100} = K'$

K' is called molecular depression constant.

It is defined as the depression of freezing point produced when 1mole of the solute is dissolved in 100g of the solvent.

Thus K' = 100 K. So $\Delta T_f = \frac{100K' \times w}{m \times W}$

If $\frac{w}{m} = 1$ and W = 1000 g ; $\Delta T_f = \frac{K}{1000} = K_f$

K_f is called molal depression constant

$$K_f = \frac{RT_f^2}{1000\ell_f} \quad [\ell_f = \text{latent heat of fusion}]$$

or $\Delta T_f = \frac{1000K_f \times w}{m \times W}$ [T_f = Freezing point of solvent]

or ΔT_f = molality × K_f ; $\Delta T_f \propto$ molality

The molal depression constant for some common solvents are given in the following table:

Solvent	F.P.(0C)	Molal Depression Solvents
Water	0.0	1.86
Chloroform	–63.5	4.70
Carbon tetra chloride	–22.8	29.80
Ethyl alcohol	–114.6	1.99
Benzene	5.5	5.12

Example 21 :

What is the percent by mass of iodine needed to reduce the freezing point of benzene to 3.5°C? The freezing point and cryoscopic constant of pure benzene are 5.5°C and 5.12 K/m respectively.

Sol. $\Delta T_f = T_f^\circ - T_f = K_f . m$

$5.5°C - 3.5°C = 5.12 \times m$

$m = \frac{2}{5.12} = 0.39$ molal

∴ Mass of iodine needed for 1000g of benzene

$= m \times$ molecular mass of iodine I_2

$= 0.39$ mole/kg $\times 254$ g/mol $= 99.06$ g/kg

∴ 1000g + 99.06g solution contains 99.06g I_2

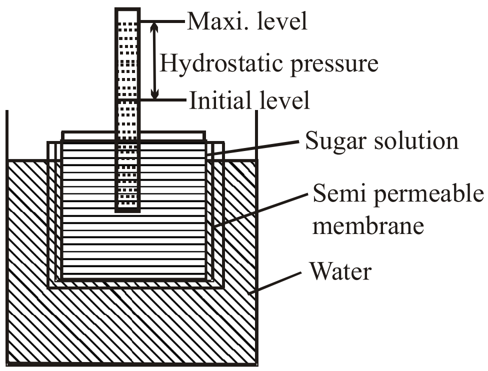
100g solution contains $\frac{99.06g \times 100}{1099.06g} = 9.01\%$

ANTIFREEZE SOLUTIONS

Water is used in radiators of vehicles as cooling liquid. If the vehicle is to be used at high altitudes where temperature is sub-zero, water would freeze in radiators. To avoid this problem, a solution of ethylene glycol in water is used in radiators which will lower the freezing point lower than zero.

OSMOSIS AND OSMOTIC PRESSURE

Osmosis : Osmosis is defined as the spontaneous flow of solvents molecules through semipermeable membrane from a pure solvents to a solution or from a dilute to as concentrated solution.



Osmotic pressure (π) -

(i) Osmotic pressure is the hydrostatic pressure produced when a solution is separated from the solvent by a semipermeable membrane.

(ii) Osmotic pressure may be defined as the excess pressure which must be applied to a solution in order to prevent flow of solvent into the solution through the semipermeable membrane.

d = density of solution

$$\text{Osmotic pressure, } (\pi) = \frac{n}{V}RT = CRT$$

when w gram of solute are dissolved in V litre of solutions and M is the molar mass of the solute, then

$$\pi = \frac{wRT}{MV} \qquad \left[\because n = \frac{w}{M}\right]$$

when height is involved π = hdg

(h = height, d = density, g = gravitational acceleration)

For isotonic or isosmotic solutions $[\because \pi_1 = \pi_2]$

$$\frac{n_1}{V_1} = \frac{n_2}{V_2} \quad \text{or} \quad \frac{w_1}{M_1V_1} = \frac{w_2}{M_2V_2}$$

(iii) The external pressure which must be applied on the solution in order to stop the flow of the solvent into the solution through semipermeable membrane is equal to osmotic pressure.

Van't Hoff law for dilute solution -

The osmotic pressure (P or π) of a solution is directly proportional to its concentration (c) when the temperature is kept constant. The concentration of the solution contain one gram mole in V litres is equal to 1/V.

thus $\pi \propto C$ (when temp. is const.)

or $\pi \propto 1/V$ or πV = constant.

Gaylussac-Van't Hoff law :

$\pi V = nST$, here π = Osmotic pressure

V = Volume of solution (in lit.) containing one gram mole of the solute, n = moles of solute

S = molar solution constant (0.082 lit atm K^{-1} mol^{-1})

T = Temperature (in K)

$$\pi = \frac{n}{V}ST \text{ ; } \pi = CST\left[\because C = \frac{n}{V} \text{ molar concentration of solution}\right]$$

i.e. $\pi \propto C$

Example 22 :

The osmotic pressure of blood is 7.65 atm at 310 K. Find the percentage (wt/volume) for an aqueous solution of glucose which is isotonic with blood.

Sol. Since glucose and blood are isotonic, the osmotic pressure are the same. Therefore, $\pi_{glucose} = \pi_{blood}$.

$$7.65 \times V = \frac{w}{180} \times 0.0821 \times 310$$

[w = amount of glucose present in V litres of solution]

$$7.65 \times 180 = \frac{w}{V} \times 0.0821 \times 310$$

$$\frac{w}{V} = \frac{7.65 \times 180}{0.0821 \times 310} = 54.1 \text{ g } L^{-1} \text{ or } 5.41\%$$

REVERSE OSMOSIS

If a pressure higher than osmotic pressure is applied on the solution, the solvent will flow from the solution into the pure solvent through the semipermeable membrane. Since here the flow of solvent is in the reverse direction to that observed in the usual osmosis, the process is called reverse osmosis.

Use : Reverse osmosis is used for desalination of sea water fro getting fresh drinking water.

TYPES OF SOLUTIONS

(i) Isotonic solutions :

(a) A pair of solution having the same osmotic pressure are known as isosmotic solutions. If two such solutions are separated by a semipermeable membrane there will be no transference of solvent from one solution to be other when Isosmotic solutions separated by a semipermeable membrane are known as isotonic solutions.

(b) isotonic solution have the same molar concentration. $\pi_1 = \pi_2$ i.e., $C_1ST = C_2ST$; $C_1 = C_2$

(c) A solution having lower or higher osmotic pressure than the other is said to be hypotonic hypertonic respectively in respected to other solution.

(d) When a animal cell is placed in hypotonic solutions, cells swell and burst (hemolysis)

(e) When a cell is placed in hypertonic solution, cells contract in size (plasmolysis). When excess of fertilizers (like urea) are applied, plasmolysis takes place and plants dry up (wilt).

(ii) Hypertonic solution : A solution having higher osmotic pressure than some other solution is said to be called hypertonic solution.

(iii) Hypotonic solution : A solution having a lower osmotic pressure relative to some other solution is called hypotonic solution.

ABNORMAL COLLIGATIVE PROPERTIES

It has been observed that difference in the observed and calculated molecular masses of solute is due to association or dissociation of solute molecules is solution. It result in a change in the number of particle in solution

Association of solute particles : The formation of a bigger molecule by the union of two, three or more solute molecules is called association. Let 'n' simple molecule combine to give an associated molecule as :

$$n(X) \underset{\text{Solvent}}{\overset{\text{Non Polar}}{\rightleftharpoons}} (X)_n$$

n single molecule	One bigger molecule.

As a result, the total number of particles in solution becomes less than the number of molecules initially dissolved in the solution and hence the colligative properties will have lower value. As the molar mass of solute is inversely proportional to the colligative properties, so the molar mass of solute will be greater than theoretical value.

Dissociation of solute molecules : Molecules of electrolytes undergo ionization or dissociation in ionizing solvents to give two or more particles in solution.

For example, AB ionizes in solution to give two particles.

$$AB \underset{\text{Solvent}}{\overset{\text{Ionizing}}{\rightleftharpoons}} A^+ + B^-$$

This dissociation result in an increase in the total number of particles and therefore the value of colligative properties of such solution will be higher.

As the colligative properties are inversely related to molecular weight, so the molecular weight of ionizable solute will be less than the theoretical value.

VAN'T HOFF FACTOR (I) :

Certain solutes which undergo dissociation or association in solutions are found to show abnormal molecular mass. Thus, in order to know about the extent of association or dissociation of solutes in solution Vant Hoff. In 1886 introduced a factor (i). It is defined as the ratio of the normal mass to the observed molecular mass of the solute i.e.

$$i = \frac{\text{Normal molar mass}}{\text{Observed molar mass}}$$

$$i = \frac{\text{Observed colligative property}}{\text{Normal colligative property}}$$

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

$$i = \frac{\text{Actual number of particles}}{\text{No.of particles for no ionisation}}$$

Van't Hoff factor and degree of association : If a solute A forms associated molecules $(A)_n$ and α is the degree of association then,

	nA	$\rightleftharpoons$ $(A)_n$
	Initial mole	1 mole
Associated change	$-\alpha$ mole	$+\alpha/n$ mole
Equilibrium mole	$(1-\alpha)$ mole	α/n mole
Equilibrium mole	$(1-\alpha)$ mole	α/n mole

Total number of moles after association of 1 mole of A

$$= (1-\alpha) + (\alpha/n) \text{ mole}$$

$$= (1-\alpha)\,(1 - \frac{1}{n}) \text{ mole}$$

$$\text{Van't Hoff factor (i)} = \frac{\text{Number of moles after association}}{\text{Normal number of mole taken}}$$

$$= 1 - \alpha\left(1 - \frac{1}{n}\right) = 1 - \alpha + \frac{\alpha}{n}$$

$$\therefore \quad \text{degree of association } \alpha = \frac{i-1}{\frac{1}{n}-1}$$

Van't Hoff Factor and degree of dissociation :

If a molecule of solute on dissociation gives n ions and α is the degree of dissociation then,

	$(A)_n$ $\rightleftharpoons$	nA
Initial mole	1 mole	ions
dissociation change	$-\alpha$ mole	$+n\alpha$ mole
Equilibrium mole	$(1-\alpha)$ mole	$n\alpha$ mole

Total number of moles after dissociation of 1 mole of A

$$= [(1-\alpha) + n\alpha] \text{ mole}$$

$$= 1 + \alpha\,(n-1) \text{ mole}$$

$\therefore$ Van't Hoff factor (i)

$$= \frac{\text{Number of moles after dissociation}}{\text{Number of moles takes (normal)}}$$

$$= \frac{1+\alpha(n-1)}{1} = 1 + \alpha\,(n-1) = 1 + n\alpha - \alpha$$

$$\therefore \quad \text{degree of dissociation } (\alpha) = \frac{i-1}{n-1}$$

Observed colligative properties = i × General C. P.

Example 23 :

The freezing point of 0.2 molal K_2SO_4 is –1.1°C. Calculate Van't Haff factor and percentage degree of dissociation of K_2SO_4. Kg for water is 1.86°.

Sol. ΔT_f = freezing point of water – freezing point of solution

$= 0°C - (-1.1°C) = 1.1°$

We know that, $\Delta T_f = i \times K_f \times m$

$$1.1 = i \times 1.86 \times 0.2 \quad \therefore\ i = \frac{1.1}{1.86 \times 0.2} = 2.95$$

But we know, $i = 1 + (n-1)\alpha$

$$2.95 = 1 + (3-1)\alpha = 1 + 2\alpha \Rightarrow \alpha = 0.975$$

Van't hoff factor (i) = 2.95, Degree of dissociation= 0.975, Percentage degree of dissociation = 97.5.

TRY IT YOURSELF - 3

Q.1 10g of non-volatile solute when dissolved in 100g of benzene raises its boiling point by 1°C. Find the molecular mass of the solute? (k_b for benzene = 2.53 K kg mol^{-1})

Q.2 5.0g of a substance with molecular mass 200 have been dissolved in 50g of solvent with molecular mass 60 and vapour pressure 400 torr. Find the vapour pressure of the solution.

Q.3 A decimolar solution of potassium ferrocyanide at 300 K is 50% dissociated. Calculate osmotic pressure.

Q.4 Calculate the vapour pressure of a solution at 100°C containing 3g cane sugar in 70g water.

Q.5 In cold climate, water freezes causing damage of the car radiator. Ethylene glycol is used as an antifreeze agent. Calculate the amount of ethylene glycol to be added to 4kg of water to prevent it from freezing at –8°C ($K_f H_2O$: 1.86 K kg mol^{-1})

Q.6 Calculate the osmotic pressure of a solution containing 0.1 mole of a non-electrolyte solute per litre at 273 K (R = 0.082 L atm mol^{-1} K^{-1})

Q.7 Calculate the amount of NaCl which must be added to 100g water so that the freezing point is depressed by 2K.

Q.8 Osmotic pressure of a solution containing 7g of protein per 100ml of solution is 25mm Hg at 37°C. Calculate the molecular mass of the protein.

Q.9 A solution containing 18g of a non-volatile solute in 200g of water freezes at 272.07 K. Calculate molecular mass of the solute, given K_f = 1.86 K kg^{-1} mol^{-1}.

Q.10 Calcualte boiling point of urea solution obtained by dissolving 12.5g of urea in 170g of water. Molecular mass of urea is 60 and molal elevation constant of water is 0.52 K kg mol^{-1}.

Q.11 The freezing point of a solution containing 0.3g of acetic acid in 30g of benzene is lowered by 0.45°C. Calculate van't Hoff factor. (k_f = benzene = 5.12 K kg mol^{-1})

ANSWERS

(1) 253 g mol^{-1}
(2) 388 torr
(3) 7.38 atms.
(4) 758.29 mm
(5) 1066.6 g
(6) 2.238 atm
(7) 3.145g
(8) 54093
(9) 180
(10) 373.64 K
(11) 0.53

USEFUL TIPS

* The colligative properties are related to molecular masses of solutes by the equations,

(i) $\frac{P_1^0 - P}{P_1^0} = x_2 \simeq \frac{n_2}{n_1} = \frac{W_2M_1}{W_1M_2}$

W_1 and W_2 are masses of solvent and solute in kg., M_1 and M_2 are molar masses of solvent and solute in kg/mol respectively.

(ii) $\Delta T_b = K_b.m = \frac{K_bW_2}{W_1M_2}$

(iii) $\Delta T_f = K_f.m = \frac{K_fW_2}{W_1M_2}$

(iv) $\pi = CRT = \frac{n}{V}RT = \frac{W_2}{M_2V}RT$

* The depression in freezing points are in the order:
Acetic acid < trichloroacetic acid < trifluoroactic acid

* Increasing order of boiling point
0.001 m urea < 0.001m NaCl < 0.001 m $MgCl_2$

* Increasing order of freezing point
0.1M $Ba_3(PO_4)_2$ < 0.1M Na_2SO_4 < 0.1M C_2H_5OH

ADDITIONAL EXAMPLES

Example 1 :

Calculate the molality of 1 litre solution of 93% H_2SO_4 (weight/volume). The density of the solution is 1.84 g/mL.

Sol. Mass of H_2SO_4 in 100ml of 93% H_2SO_4 solution = 93g

$\therefore$ Mass of H_2SO_4 in 1000 ml of the H_2SO_4 sol. = 930g

Mass of 1000 ml H_2SO_4 solution = 1000 × 1.84 = 1840g

Mass of water in 100 ml of solution

= 1840 – 930 = 910g = 0.910 kg

$$\text{Moles of } H_2SO_4 = \frac{\text{Wt. of } H_2SO_4}{\text{Mol Wt. of } H_2SO_4} = \frac{930}{98}$$

$\therefore$ Moles of H_2SO_4 in 1 kg of water

$$= \frac{930}{98} \times \frac{1}{0.910} = 10.43 \text{ mol kg}^{-1}$$

$\therefore$ Molality of 1 litre solution = 10.43

Example 2 :

A bottle of commercial sulphuric acid (density 1.787 gm/ml) is labelled as 86% by weight. What is the molarity of the acid? What volume of the acid has to be used to make 1 litre of 0.2 M H_2SO_4 ?

Sol. Calculation of molarity of acid.

Molarity = No. of moles of solute per litre of the solution

$$= \frac{\text{Wt. of } H_2SO_4 \text{ in one litre of solution}}{\text{Mol. wt. of } H_2SO_4}$$

Wt. of given H_2SO_4 in litre = 1000 × density × strength

$$= 1000 \times 1.787 \times \frac{86}{100} = 1536.82\text{g}$$

Mol wt. of $H_2SO_4 = 2 \times 1 + 32 + 4 \times 16 = 98$

$$\therefore \ \text{Molarity of } H_2SO_4 = \frac{1536.82}{98} = 15.68$$

Calculation of the volume of acid for making 1 litre of 0.2M H_2SO_4.

Applying the formula, $M_1V_1 = M_2V_2$

$15.68 \times V_1 = 0.2 \times 1000$

$$\therefore \quad V_1 = \frac{0.2 \times 1000}{15.68} \text{ml} = 12.75 \text{ ml.}$$

Example 3 :

The vapour pressure of pure benzene at a certain temperature is 640mm Hg. A non-volatile solid weighing 2.175g is added to 39.0g of benzene. The vapour pressure of the solution is 600mm Hg. What is the molecular weight of the solid substance ?

Sol. According to Raoult's law, $\dfrac{p^0 - p}{p^0} = \dfrac{w/m}{w/m + W/M}$

Here, $p^0 = 640\text{mm}$, $p = 600\text{mm}$, $w = 2.175\text{g}$, $W = 39.0\text{g}$, $M = 78$, $m = ?$

Substituting the various values in the above equation,

$$\frac{640 - 600}{640} = \frac{2.175/m}{2.175/m + 39/78}$$

$$\frac{1}{16} = \frac{2.175}{2.175 + 0.5m} \ ; m = 65.25$$

Example 4 :

What mass of the non-volatile solute, urea $(NH_2.CO.NH_2)$ needs to be dissolved in 100g of water in order to decrease the vapour pressure of water by 25%, what will be the molality of the solution ?

Sol. $$\frac{p^0 - p}{p^0} = \frac{w/m}{\frac{w}{m} + \frac{W}{M}}$$

Here, w and m are wt. and molecular wt. of solute.

W and M are wt. and molecular weight of solvent.

p = Pressure of solution, p^0 = Normal vapour pressure

Let the initial (normal) pressure $(p^0) = p$

$$\therefore \quad \text{Pressure of solution} = \frac{75}{100} \times p = \frac{3}{4} p$$

$m = 60, M = 18, W = 100\text{gm}$

$$\therefore \quad \frac{p - \frac{3}{4}p}{p} = \frac{w/60}{\frac{w}{60} + \frac{100}{18}} \ ; \ \frac{1}{4} = \frac{w/60}{(w/60) + 5.55}$$

$$\frac{4w}{60} = \frac{w}{60} + 5.55 \ ; \ \frac{3w}{60} = \frac{w}{20} = 5.55 \ ; \ w = 111\text{g}$$

$$\text{Molality} = \frac{\text{No. of moles of solute}}{\text{Wt. of solvent}} \times 1000 = \frac{111 \times 1000}{60 \times 100}$$

$= 18.52\text{m}$

Example 5 :

The vapour density (hydrogen = 1) of a mixture consisting of NO_2 and N_2O_4 is 38.3 at 2.67°C. Calculate the number of moles of NO_2 in 100g of the mixture.

Sol. Let mole of N_2O_4 taken at start = 1

In case x is the degree of dissociation, the equation is

$$N_2O_4 \rightleftharpoons 2NO_2$$

Initial moles $\quad 1 \qquad 0$

Equ. moles $\quad 1 - x \qquad 2x$

$\therefore$ Total number of moles at equilibrium $= 1 - x + 2x = 1 + x$

Let the volume of 1 mole = V

$\therefore$ Volume of $(1 + x)$ moles $= (1 + x)$ V

Let the density before dissociation = D

and density after dissociation = d

$$\text{Then, } D \propto \frac{1}{V} \text{ and } d \propto \frac{1}{(1+x)V} \quad \therefore \quad \frac{D}{d} = \frac{(1+x)V}{V}$$

$$\text{Also, D, density of } N_2O_4 = \frac{\text{Mol. wt.}}{2} = \frac{92}{2} = 46$$

$$\therefore \quad \frac{46}{38.3} = (1 + x) \ ; \ x = \frac{46 - 38.3}{38.3} = 0.2$$

$\therefore$ At equilibrium, the amount of $N_2O_4 = 1 - 0.2 = 0.8$ mole

and amount of $NO_2 = 2 \times 0.2 = 0.4$ mole

Since, Weight = Amount of moles × Mol. wt.

$\therefore$ Wt. of $N_2O_4 = 0.8 \times 92 = 73.6\text{g}$

and Wt. of $NO_2 = 0.4 \times 46 = 18.4\text{g}$

Total wt. of N_2O_4 and $NO_2 = 73.6 + 18.4\text{g} = 92.0\text{g}$

Since 92.0 of N_2O_4 and NO_2 contain = 18.4g NO_2

$$\text{100g of } N_2O_4 \text{ and } NO_2 \text{ contain} = \frac{18.4 \times 100}{92.0} = 20.0\text{g } NO_2$$

No. of moles of NO_2 in 100gm of the mixture

$$= \frac{\text{Wt. of } NO_2}{\text{Mol. Wt. of } NO_2} = \frac{20}{46} = 0.43 \text{ mole}$$

Example 6 :

In a cold climate, water gets frozen causing damage to the radiator of a car. Ethylene glycol is used as an antifreezing agent. Calculate the amount of ethylene glycol to be added to 4 kg of water to prevent it from freezing at –6°C (K_f for water = 1.85 K mole^{-1} kg)

Sol. $K_f = 1.85 \text{ K mole}^{-1}$ kg), $\Delta T_f = 6\text{K}$, $m = 62$, $W = 4 \text{ kg} = 4 \times 10^3$ g

$$\Delta T_f = \frac{1000 \times K_f \times w}{W \times m} \ ; \quad 6 = \frac{1000 \times 1.85 \times w}{4 \times 10^3 \times 62}$$

On usual calculation, w = 804.32g

Example 7 :

x g of a non-electrolytic compound (molar mass = 200) is dissolved in 1.0L of 0.05M NaCl aqueous solution. The osmotic pressure of this solution is found to be 4.92 atm. at 27°C. Calculate the value of x. Assume complete dissociation of NaCl and ideal behaviour of this solution. ($R = 0.082 \text{L atm. mol}^{-1} \text{K}^{-1}$)

Sol. Effective molarity of solution $= \dfrac{x}{200} + 0.05 \times 2$

Thus, substituting the values in the reaction, $\pi = CRT$

$$4.92 = \left(\frac{x}{200} + 0.10\right)(0.082 \times 300)$$

$$x + 20 = \left(\frac{4.92 \times 200}{0.082 \times 300}\right) = 40 \ ; x = 40 - 20 = 20g$$

Example 8 :

0.85% aqueous solution of $NaNO_3$ is apparently 90% dissociated at 27°C. Calculate its osmotic pressure ($R = 0.082 \text{ L atm K}^{-1} \text{mol}^{-1}$)

Sol. Let vol. of $NaNO_3$ aq. solution $= 100 \text{ cm}^3 = 0.1 \text{ L}$

$\therefore$ Wt. of $NaNO_3 = 0.85g$

Mol. wt. of $NaNO_3 = 23 + 14 + 48 = 85$

Thus, $n = \dfrac{0.85}{85} = 0.01 \text{ mol}$

This is the number of moles of $NaNO_3$ if it were 100% dissociated

Calculation of number of moles for 90% dissociated $NaNO_3$

$$\begin{array}{lcccc} & NaNO_3 \rightleftharpoons & Na^+ + & NO_3^- & + \text{Total} \\ \text{At eq.} & 1-\alpha & \alpha & \alpha & 1+\alpha \end{array}$$

where $\alpha = \dfrac{90}{100} = 0.9 \qquad \therefore \ 1 + \alpha = 1 + 0.9 = 1.9$

$\therefore$ Moles of $NaNO_3$ present $= 1.9 \times 0.01 = 0.019$

Substituting the values in the relation

$$\pi = \frac{n}{V}RT = \frac{0.019 \text{ mol}}{0.1 \text{ L}} \times 0.082 \text{ L atm K}^{-1} \text{mol}^{-1} \times 300 \text{ K}$$

$$= 4.67 \text{ atm}$$

Example 9 :

Calculate the freezing point of an aqueous solution of a non-electrolyte having an osmotic pressure of 2.0 atm at 300K. [$K_f = 186 \text{ K kg mol}^{-1}, R = 0.0821 \text{ L atm K}^{-1} \text{mol}^{-1}$]

Sol. We know that $\pi = CRT$

or $C = \dfrac{\pi}{RT} = \dfrac{2.0}{0.0821 \times 300} = 0.0812 \text{ mol L}^{-1}$

Since density of water can be taken as 1.0 g cm^{-3},

Molarity of the aq. solution = Molality

$0.0812 \text{ mol L}^{-1} = 0.0812 \text{ mol kg}^{-1}$

Now depression in freezing point, ΔT_f is given by

$$\Delta T_f = K_f \times m = 1.86 \times 0.08123 = 0.151 \text{ K}$$

$\therefore$ Freezing point = – 0.151 K

Example 10 :

If latent heat of fusion of ice is 80 cals per g at 0°C, calculate molal depression constant for water.

Sol. $K_f = \dfrac{RT_f}{1000\,\ell_f}$

Here R = 2 cals, $T_f = 0 + 273$ K, $\ell_f = 80$ cals

$$K_f = \frac{272 \times 273}{1000 \times 80} = 1.8564$$

Example 11 :

The vapour pressure of CCl_4(density = 1.58 g cm^{-3}) at 30°C is 143 mm. A 0.5g of a non–volatile solute of molecular weight 65 is dissolved in 100 ml of CCl_4. Calculate the vapour pressure of the solution.

Sol. Here w = 0.5 g, W = 100 × 1.58 = 158 g (since d = W/V), m = 65

M of $CCl_4 = 154$

$$\frac{P^0 - P}{P^0} = \frac{wM}{mW} \text{ or } \frac{143 - P}{143} = \frac{0.5 \times 154}{65 \times 158} \text{ or } P = 141.93 \text{ mm}$$

Example 12 :

A solution of 0.450 gm of urea (mol. wt 60) in 22.5 g of water showed 0.170°C of elevation in boiling point. Calculate the molal elevation constant of water.

Sol.
Wt. of solute w = 0.450 g
Wt. of solvent W = 22.5 g
Mol. wt of solute m = 60
Molal elevation constant K_b = ?
Boiling point elevation ΔT_b = 0.170°C

Substituting these values in the equation –

$$K_b = \frac{m \times W \times \Delta T_b}{1000 \times w} = \frac{60 \times 22.5 \times 0.170}{1000 \times 0.450} = 0.51^\circ \text{ C}$$

Example 13 :

Calculate the vapour pressure of a solution at 100°C containing 3g of cane sugar in 33g of water. (At. wt. C = 12, H = 1, O = 16)

Sol. Vapour pressure of pure water (solvent) at 100°C, $p^\circ = 760$ mm

Vapour pressure of solution, p = ?
Wt. of solvent, W = 33g
Wt. of solute, w = 3g
Mol. wt. of water (H_2O), M = 18
Mol. wt. of sugar ($C_{12}H_{22}O_{11}$), m = 12 × 12 + 22 × 1 + 11 × 16 = 342

According to Raoult's law, $\dfrac{P^0 - P}{P^0} = \dfrac{wM}{Wm}$

$$\therefore \quad P = P^0 - \frac{w \times M}{m \times W} \times P^0 \ ; \ P = 760 - \frac{3 \times 18}{342 \times 33} \times 760$$

($\therefore P^0$ for $H_2O = 760$ mm)

$= 760 - 3.19 = 756.90$ mm

QUESTION BANK

CHAPTER 2 : SOLUTIONS

EXERCISE - 1 [LEVEL-1]

Choose one correct response for each question.

PART 1 : TYPES OF SOLUTIONS

Q.1 On dissolving sugar in water at room temperature solution feels cool to touch. Under which of the following cases dissolution of sugar will be most rapid?
(A) Sugar crystals in cold water.
(B) Sugar crystals in hot water.
(C) Powdered sugar in cold water.
(D) Powdered sugar in hot water.

Q.2 At equilibrium the rate of dissolution of a solid solute in a volatile liquid solvent is –
(A) less than the rate of crystallisation.
(B) greater than the rate of crystallisation.
(C) equal to the rate of crystallisation.
(D) zero

Q.3 Amalgam of mercury with sodium is an example of –
(A) Gaseous solution (B) Liquid solution
(C) Solid solution (D) None of these

Q.4 Which of the following is not an example of a solution?
(A) Air (B) Brass
(C) Amalgam (D) Benzene in water

Q.5 A beaker contains a solution of substance 'A'. Precipitation of substance 'A' takes place when small amount of 'A' is added to the solution. The solution is –
(A) saturated (B) supersaturated
(C) unsaturated (D) concentrated

PART 2 : CONCENTRATION OF SOLUTIONS

Q.6 Express the terms representing the following formulae.

(i) $\frac{\text{No. of moles of solute}}{\text{Volume of solution in litres}} = (W)$

(ii) $\frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}} = (X)$

(iii) $\frac{\text{No. of moles of component}}{\text{Moles in the solution}} = (Y)$

(iv) $\frac{\text{Mass of component}}{\text{Mass of solution}} = (Z)$

(A) W-Molality, X-Molarity, Y-Mass fraction, Z-Mole fraction
(B) W-Molarity, X-Molality, Y-Mass fraction, Z-Mole fraction
(C) W-Molarity, X-Molality, Y-Mole fraction, Z-Mass fraction
(D) W-Molality, X-Molarity, Y-Mole fraction, Z-Mass fraction

Q.7 Which of the following units is useful in relating concentration of solution with its vapour pressure?
(A) Mole fraction (B) Parts per million
(C) Mass percentage (D) Molality

Q.8 When 1.04 g of $BaCl_2$ is present in 10^5g of solution the concentration of solution is
(A) 0.104 ppm (B) 10.4 ppm
(C) 0.0104 ppm (D) 104 ppm

Q.9 What is the volume percentage of the ethanol solution in water if 10 mL of ethanol is dissolved in water and the total volume of the solution is 100mL?
(A) 5% ethanol solution (B) 10% ethanol solution
(C) 15% ethanol solution (D) 20% ethanol solution

Q.10 2.0 molar solution is obtained, when 0.5 mole solute is dissolved in –
(A) 250 ml solvent (B) 250 g solvent
(C) 250 ml solution (D) 1000 ml solvent

Q.11 171 g of cane sugar $(C_{12}H_{22}O_{11})$ is dissolved in 1 litre of water. The molarity of the solution is
(A) 2.0 M (B) 1.0 M
(C) 0.5 M (D) 0.25 M

Q.12 0.5 M of H_2SO_4 is diluted from 1 litre to 10litre, normality of resulting solution is –
(A) 1 N (B) 0.1 N
(C) 10 N (D) 11 N

Q.13 The unit of molality is –
(A) Mole per litre (B) Mole per kilogram
(C) Per mole per litre (D) Mole litre

Q.14 To prepare a solution of concentration of 0.03 g/ml of $AgNO_3$, what amount of $AgNO_3$ should be added in 60 ml of solution –
(A) 1.8 (B) 0.8
(C) 0.18 (D) None of these

Q.15 Concentration terms like mass percentage, ppm, mole fraction and molality do not depend on temperature. However, molarity is a function of temperature because
(A) volume depends on temperature and molarity involves volume.
(B) molarity involves non-volatile solute while all other terms involve volatile solute.
(C) number of moles of solute change with change in temperature.
(D) molarity is used for polar solvents only.

Q.16 A 500g toothpaste sample has 0.2g fluoride concentration. What is the concentration of fluorine in terms of ppm level?
(A) 250 (B) 200
(C) 400 (D) 1000

Q.17 What is the molarity of a solution containing 10 g of NaOH in 500 mL of solution?
(A) 0.25 mol L^{-1} (B) 0.75 mol L^{-1}
(C) 0.5 mol L^{-1} (D) 1.25 mol L^{-1}

Q.18 Suppose 3.50 weight per cent of aqueous solution of NaCl is sea water. What is the molality of sea water?
(A) 6.2 m (B) 0.062 m
(C) 0.62 m (D) 0.0062 m

Q.19 250 mL of sodium carbonate solution contains 2.65g of Na_2CO_3. If 10 mL of this solution is diluted to 500 mL, the concentration of the diluted acid will be –

(A) 0.01 M (B) 0.001 M
(C) 0.05 M (D) 0.002 M

Q.20 The molality of 648 g of pure water is

(A) 36 m (B) 55.5 m
(C) 3.6 m (D) 5.55 m

PART 3 : SOLUBILITY

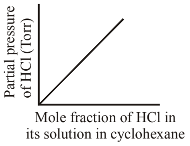
Q.21 Solubility of a substance is its maximum amount that can be dissolved in a specified amount of solvent. It depends upon

(i) nature of solute (ii) nature of solvent
(iii) temperature (iv) pressure
(A) (i), (ii) and (iii) (B) (i), (iii) and (iv)
(C) (i) and (iv) (D) (i), (ii), (iii) and (iv)

Q.22 According to Henry's law 'the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution'. For different gases the correct statement about Henry's constant is –

(A) higher the value of K_H at a given pressure, higher is the solubility of the gas.
(B) higher the value of K_H at a given pressure, lower is the solubility of the gas.
(C) K_H is not a function of nature of gas.
(D) K_H value for all gases is same at a given pressure.

Q.23 In the graph given below, what does the slope of the line represent?



(A) Partial pressure of the gas in vapour phase(p)
(B) Mole fraction of gas in the solution (x)
(C) Henry's law constant (K_H)
(D) All of the above

Q.24 Low concentration of oxygen in the blood and tissues of people living at high altitude is due to –

(A) low temperature
(B) low atmospheric pressure
(C) high atmospheric pressure
(D)both low temperature and high atmospheric pressure.

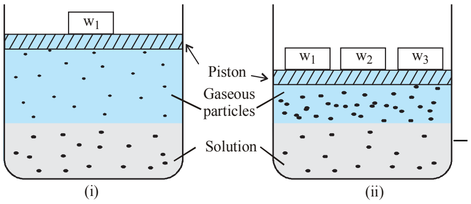
Q.25 Maximum amount of a solid solute that can be dissolved in a specified amount of a given liquid solvent does not depend upon ____.

(A) temperature (B) nature of solute
(C) pressure (D) nature of solvent

Q.26 Henry's law constant for molality of methane in benzene at 298 K is 4.27×10^5 mm Hg. The mole fraction of methane in benzene at 298 K under 760mm Hg is

(A) 1.78×10^{-3} (B) 17.43
(C) 0.114 (D) 2.814

Q.27 Consider the two figures given below.



$w_1 < w_2 < w_3$

Which of the following statements regarding the experiment is true?

(A) The solubility of a gas in liquid in beaker (i) is greater than that in beaker (ii).
(B) The solubility of a gas in beaker (i) is less than that in beaker (ii).
(C) The solubility of a gas is equal in both beakers.
(D) The solubility of a gas remains unaffected by change in weights.

Q.28 Which of the following statement is true about Henry's law?

(A) The solubility of solid in a liquid is directly proportional to the partial pressure of the solid present above the surface of liquid or solution.
(B) The solubility of a gas in a liquid is directly proportional to the partial pressure of gas present above the surface of liquid or solution
(C) The solubility of a liquid in gas is directly proportional to the partial pressure of liquid present above the surface of gas.
(D) The solubility of a gas in solid is directly proportional to the partial pressure of gas present above the surface of solid.

Q.29 Dalton concluded that solubility of gas in a liquid solution is a function of –

(A) partial pressure of the gas.
(B) partial pressure of the liquid.
(C) partial pressure of gas/liquid.
(D) None of the above

Q.30 Why aquatic species are more comfortable in cold water rather than in warm water?

(A) Aquatic species feel hot in cold water rather than in warm water.
(B) Solubility of gas increases with decrease in temperature.
(C) Solubility of gas decreases with decrease in temperature.
(D) None of these

PART 4 : VAPOUR PRESSURE OF LIQUID SOLUTIONS

Q.31 Among the following substances the lowest vapour pressure is exerted by

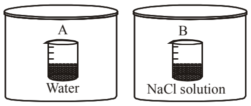
(A) water (B) alcohol
(C) ether (D) mercury.

Q.32 Vapour pressure of a solution is –
(A) Directly proportional to the mole fraction of the solvent
(B) Inversely proportional to the mole fraction of the solute
(C) Inversely proportional to the mole fraction of the solvent
(D) Directly proportional to the mole fraction of the solute.

Q.33 Raoult's law becomes a special case of Henry's law when
(A) $K_H = p_1°$ (B) $K_H > p_1°$
(C) $K_H < p_1°$ (D) $K_H \geq p_1°$

Q.34 Choose the correct option –
(A) For a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction.
(B) Depending on the vapour pressures of the pure components total vapour pressure over the solution decreases or increases with the increase of the mole fraction of any component.
(C) Both (A) and (B)
(D) None of these

Q.35 Two beakers of capacity 500 mL were taken. One of these beakers, labelled as "a", was filled with 400 mL water whereas the beaker labelled "b" was filled with 400 mL of 2 M solution of NaCl. At the same temperature both the beakers were placed in closed containers of same material and same capacity as shown in figure.



At a given temperature, which of the following statements is correct about the vapour pressure of pure water and that of NaCl solution.
(A) Vapour pressure in container (a) is more than that in container (b).
(B) Vapour pressure in container (a) is less than that in container (b).
(C) Vapour pressure is equal in both the containers.
(D) Vapour pressure in container (b) is twice the vapour pressure in container (a).

Q.36 Raoult's law states that –
(A) the partial pressure of the gas in vapour phase is proportional to the mole fraction of gas in the solution.
(B) for solutions of volatile liquids, the partial vapour pressure of each components of the solution is directly proportional to its mole fraction present in the solution.
(C) the solubility of volatile liquid is directly proportional to partial pressure of the gas.
(D) None of the above

Q.37 Which has maximum vapour pressure–
(A) HI (B) HBr
(C) HCl (D) HF

PART 5 : IDEAL AND NON-IDEAL SOLUTIONS

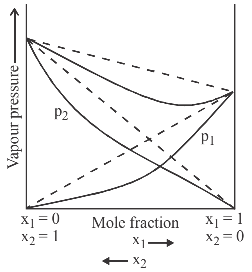
Q.38 Which case is valid for an ideal solution?
(A) $\Delta_{mix}H = 0; \Delta_{mix}V = 0$ (B) $\Delta_{mix}H > 0; \Delta_{mix}V \to 0$
(C) $\Delta_{mix}H < 0; \Delta_{mix}V < 0$ (D) $\Delta_{mix}H > 0; \Delta_{mix}V < 0$

Q.39 Which of the following is not correct for ideal solution
(A) $\Delta S_{mix} = 0$ (B) $\Delta H_{mix} = 0$
(C) It obeys Raoult's law (D) $\Delta V_{mix} = 0$

Q.40 The vapour pressure of the solution of two liquids A ($p°$ = 80mm) and B ($p°$ = 120mm) is found to be 100mm when $x_A = 0.4$. The result shows that
(A) solution exhibits ideal behaviour.
(B) solution shows positive deviations.
(C) solution shows negative deviations.
(D) solution will show positive deviations for lower conc. and negative deviations for higher concentrations.

Q.41 I. n-hexane + n-heptane
II. acetone + ethanol
III. bromoethane + chloroethane
IV. benzene + toluene
Which of the following combination is an example of ideal solutions?
(A) I, II, III (B) II, III, IV
(C) I, III, IV (D) I, II, IV

Q.42 Which of the following statement (s) is/are true the diagram?



(A) The escaping tendency of molecule decrease for component.
(B) Vapour pressure of the solution decreases.
(C) Solution show negative deviation from Raoult's law.
(D) All of the above.

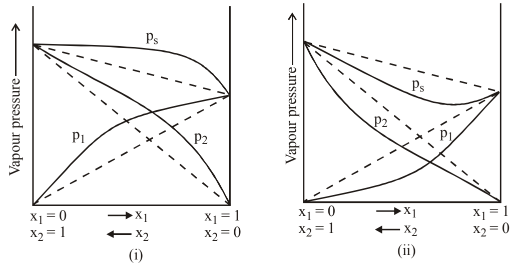
Q.43 The solution which show large positive deviation from Raoult's law form
(A) maximum boiling azeotrope at a specific composition.
(B) maximum freezing azeotrope at a specific composition.
(C) minimum boiling azeotrope at a specific composition.
(D) minimum freezing azeotrope at a specific composition.

Q.44 Which of the following solutions is an example of negative deviation from Raoult's law?
(A) Acetone + Ethanol
(B) Carbon tetrachloride + Chloroform
(C) Acetone + Chloroform
(D) Water + Ethanol

Q.45 Two liquids HNO_3 (A) and water (B) form a maximum boiling azeotrope when mixed in the ratio of 68% and 32% respectively. It means
(A) A – B interactions are stronger than A – A and B – B interactions.
(B) A – B interactions are weaker than A – A and B – B interactions.
(C) vapour pressure of solution is more than the pure components.
(D) vapour pressure of solution is less since only one component vaporises.

Q.46 A binary liquid solution is prepared by mixing n-heptane and ethanol. Which one of the following statements is correct regarding the behaviour of the solution?
(A) The solution formed is an ideal solution.
(B) The solution is non-ideal, showing +ve deviation from Raoult's law.
(C) The solution is non-ideal, showing –ve deviation from Raoult's law.
(D) n-heptane shows +ve deviation while ethanol shows –ve deviation from Raoult's law.

Q.47 Study the figures given below and mark the correct statement.



(A) (a) Graph (i) is for : Nitric acid + Water,
(b) Graph (ii) is for : Acetone + Ethyl alcohol
(B) (a) Graph (i) is for : Water + Ethyl alcohol,
(b) Graph (ii) is for : Acetone + Benzene
(C) (a) Graph (i) is for : Acetone+ Ethyl alcohol
(b) Graph (ii) is for :Acetone + Chloroform
(D) (a) Graph (i) is for : Benzene + Chloroform
(b) Graph (ii) is for : Acetone + Chloroform

Q.48 On the basis of information given below mark the correct option.
(I) In bromoethane and chloroethane mixture intermolecular interactions of A-A and B-B type are nearly same as A-B type interactions.
(II) In ethanol and acetone mixture A-A or B-B type intermolecular interactions are stronger than A-B ype interactions.
(III) In chloroform and acetone mixture A-A or B-B type intermolecular interactions are weaker than A-B type interactions.
(A) Solution (II) & (III) will follow Raoult's law.
(B) Solution (I) will follow Raoult's law.
(C) Solution (II) will show negative deviation from Raoults law.
(D) Solution (III) will show positive deviation from Raoult's law.

Q.49 A solution containing components A and B follows Raoult's law
(A) A - B attraction force is greater than A - A and B - B.
(B) A - B attraction force is less than A - A and B - B.
(C) A - B attraction force remains same as A-A & B - B.
(D) volume of solution is different from sum of volumes of solute and solvent.

Q.50 Intermolecular forces between n-hexane and n-heptane are nearly same as between hexane and heptane individually. When these two are mixed, which of the following is not true about the solution formed?
(A) It obeys Raoult's law, i.e. $p_A = x_A p°_A$ and $p_B = x_B p°_B$
(B) ΔH_{mixing} is zero.
(C) ΔV_{mixing} is zero.
(D) It forms minimum boiling azeotrope.

PART 6 : COLLIGATIVE PROPERTIES

Q.51 Which of the following is not an industrial or biological importance of osmosis?
(A) Movement of water from soil into plant roots and upper portion of plant.
(B) Salting of meat to prevent bacterial action.
(C) Reverse osmosis for desalination of sea water.
(D) Filling of ink in a fountain pen.

Q.52 Mark the correct option for the K_f.
I. K_f depends on nature of solvent.
II. K_f know as freezing point depression constant/molal depression constant.
III. K_f known as cryoscopic constant.
IV. Unit of K_f = K kg mol^{-1}.
V. $M_2 = \dfrac{K_f \times w_1 \times 1000}{\Delta T_f \times w_2}$

where w_2 is the mass of solute having molar mass of M_2 present in w_1 gram of solvent.
(A) I, II, III (B) I, II, III, IV
(C) I, II, III, IV, V (D) II, III, IV, V

Q.53 Solution having same osmotic pressure at a given temperature as that of given solution is called –
(A) Isotonic solution (B) Hypotonic solution
(C) Hypertonic solution (D) None of these

Q.54 The relative lowering of vapour pressure produced by dissolving 71.5 g of a substance in 1000 g of water is 0.00713. The molecular weight of the substance will be
(A) 18.0 (B) 342
(C) 60 (D) 180

Q.55 When mercuric iodide is added to the aqueous solution of potassium iodide, the –
(A) Freezing point is raised
(B) Freezing point is lowered
(C) Freezing point does not change
(D) Boiling point does not change

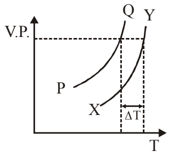
Q.56 The maximum freezing point falls in –
(A) Camphor (B) Naphthalene
(C) Benzene (D) Water

Q.57 The relative lowering of the vapour pressure is equal to the ratio between the number of –
(A) Solute moleules and solvent molecules.
(B) Solute molecules and the total molecules in the solution.
(C) Solvent molecules & the total molecules in the solution.
(D) Solvent molecules & the total number of ions of the solute.

Q.58 Which of the following colligative properties can provide molar mass of proteins (or polymers or colloids) with greater precision –
(A) Relative lowering of vapour pressure
(B) Elevation of boiling point
(C) Depression in freezing point
(D) Osmotic pressure

Q.59 A plant cell shrinks when it is kept in a –
(A) hypotonic solution (B) hypertonic solution
(C) isotonic solution (D) pure water.

Q.60 In the graph plotted between vapour pressure (V.P.) and temperature (ΔT)



(A) PQ is the curve for solvent, XY is the curve of solution and ΔT is depression in freezing point.
(B) PQ is the curve for solution, XY is the curve for solvent & ΔT is elevation in boiling point
(C) PQ is the curve for solvent, XY is the curve for solution and ΔT is molal elevation in boiling point.
(D) PQ is the curve for solvent, XY is the curve for solution and ΔT is elevation in boiling point.

Q.61 A solution whose osmotic pressure is less than that of another is called –
(A) Isotonic solution (B) Hypotonic solution
(C) Hypertonic solution (D) None of these

Q.62 The unit of ebulioscopic constant is –
(A) K kg mol^{-1} or K (molality)$^{-1}$
(B) mol kg K^{-1} or K^{-1} (molality)
(C) kg mol^{-1} K^{-1} or K^{-1} (molality)$^{-1}$
(D) K mol kg^{-1} or K (molality)

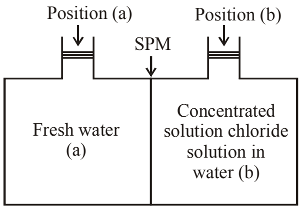
Q.63 If 1g of solute (molar mass = 50 g mol^{-1}) is dissolved in 50g of solvent and the elevation in boiling point is 1 K. The molar boiling constant of the solvent is
(A) 2 (B) 3
(C) 2.5 (D) 5

Q.64 The osmotic pressure of a solution can be increased by
(A) increasing the volume.
(B) increasing the number of solute molecules.
(C) decreasing the temperature.
(D) removing semipermeable membrane.

Q.65 Colligative properties depend on –
(A) the nature of the solute particles dissolved in solution.
(B) the number of solute particles in solution.
(C) the physical properties of the solute particles dissolved in solution.
(D) the nature of solvent particles

Q.66 10% solution of urea is isotonic with 6% solution of a non-volatile solute X. What is the molecular mass of solute X?
(A) 6 g mol^{-1} (B) 60 g mol^{-1}
(C) 36 g mol^{-1} (D) 32 g mol^{-1}

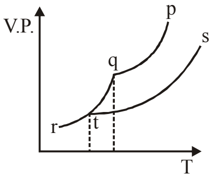
Q.67 Consider the figure and mark the correct option.



(A) Water will move from side (a) to side (b) if a pressure lower than osmotic pressure is applied on piston (b).
(B) Water will move from side (b) to side (a) if a pressure greater than osmotic pressure is applied on piston (b).
(C) Water will move from side (b) to side (a) if a pressure equal to osmotic pressure is applied on piston (b).
(D) Water will move from side (a) to side (b) if pressure equal to osmotic pressure is applied on piston (a).

Q.68 Which of the following is a colligative property?
(A) Surface tension (B) Viscosity
(C) Refractive index (D) Osmotic pressure.

Q.69 In the given graph, pq, qr and st represent



(A) pq – liquid state of solution, qr – solid state of solution, st – liquid state of solvent
(B) pq – liquid state of solvent, qr – solid state of solvent, st – liquid state of solution
(C) pq – liquid state of solvent, qr – solid state of solution, st – liquid state of solution
(D) pq – solid state of solvent, qr – liquid state of solvent, st – solid state of solution.

Q.70 2 g of sugar is added to one litre of water to give sugar solution. What is the effect of addition of sugar on the boiling point and freezing point of water?
(A) Both boiling point and freezing point increases.
(B) Both boiling point and freezing point decreases.
(C) Boiling point increases and freezing point decreases.
(D) Boiling point decreases and freezing point increases.

Q.71 Sprinkling of salt helps in clearing the snow covered in hills. The phenomenon involved in the process is

(A) lowering in vapour pressure of snow.

(B) depression in freezing point of snow.

(C) increase in freezing point of snow.

(D) melting of ice due to increase in temperature by putting salt.

PART 7 : ABNORMAL MOLECULAR MASS

Q.72 Which of the following representations of i (van't Hoff factor) is not correct?

(A) $i = \dfrac{\text{Observed colligative property}}{\text{Expected colligative property}}$

(B) $i = \dfrac{\text{Normal molecular mass}}{\text{Observed molecular mass}}$

(C) $i = \dfrac{\text{Number of molecules actually present}}{\text{Number of molecules expected to be present}}$

(D) $i = \dfrac{\text{Total number of particles taken before association/dissociation}}{\text{Number of particles after association/dissociation}}$

Q.73 A solute X when dissolved in a solvent associates to form a pentamer. The value of van't Hoff factor(i) for the solute will be

(A) 0.5 (B) 5

(C) 0.2 (D) 0.1

Q.74 If an equimolar solution of $CaCl_2$ and $AlCl_3$ in water have boiling point of T_1 and T_2 respectively then

(A) $T_1 > T_2$ (B) $T_2 > T_1$

(C) $T_1 = T_2$ (D) $T_1 \neq T_2$

Q.75 For which of the following van't Hoff factor cannot be greater than unity?

(A) $K_4[Fe(CN)_6]$ (B) $AlCl_3$

(C) NH_2CONH_2 (D) KNO_3

Q.76 Which of the following relations is not correctly matched with the formula?

(A) In case of association, $\alpha = \dfrac{i-1}{\dfrac{1}{n}-1}$

(B) In case of dissociation, $\alpha = \dfrac{i-1}{n+1}$

(C) Relative lowering of vapour pressure

$$= \frac{p_A^0 - p_A}{p_A^0} = i\frac{n_B}{n_A + n_B}$$

(D) Elevation in boiling point,

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

Q.77 The aqueous solution that has the highest value of lowering of vapour pressure at a given temperature is –

(A) 0.1 molal sodium phosphate.

(B) 0.1 molal barium chloride.

(C) 0.1 molal sodium chloride.

(D) 0.1 molal glucose.

Q.78 Why is the molecular mass determined by measuring colligative property in case of some solutes is abnormal?

(A) Due to association or dissociation of solute molecules

(B) Due to insolubility of solute molecules

(C) Due to decomposition of solute molecules

(D) Due to large size of solute molecules

Q.79 Which of the following aqueous solutions have higher freezing point?

(A) 0.1 m $Al_2(SO_4)_3$ (B) 0.1 m $BaCl_2$

(C) 0.1 m $AlCl_3$ (D) 0.1 m NH_4Cl

Q.80 Which of the following will have the highest freezing point at one atmosphere?

(A) 0.1 M NaCl solution (B) 0.1 M sugar solution

(C) 0.1 M $BaCl_2$ solution (D) 0.1M $FeCl_3$ solution

EXERCISE - 2 [LEVEL-2]

Choose one correct response for each question.

Q.1 The volumes of 4N HCl and 10N HCl required to make 1litre of 6N HCl are –

(A) 0.75 litre of 10 N HCl and 0.25 litre of 4 N HCl.
(B) 0.25 litre of 4 N HCl and 0.75 litre of 10 N HCl.
(C) 0.66 litre of 4 N HCl and 0.34 litre of 10 N HCl.
(D) 0.80 litre of 4 N HCl and 0.20 litre of 10 N HCl.

Q.2 1.0 gm of pure calcium carbonate was found to require 50ml of dilute HCl for complete reaction. The strength of the HCl solution is given by –

(A) 4 N (B) 2 N
(C) 0.4 N (D) 0.2 N

Q.3 When a substance is dissolved in a solvent, the vapour pressure of the solvent is decreased. This results in –

(A) An increase in the boiling point of the solution.
(B) A decrease in the boiling point of solvent.
(C) The solution having a higher freezing point than the solvent.
(D) The solution having a lower osmotic pressure than the solvent.

Q.4 How many grams of CH_3OH should be added to water to prepare 150ml solution of 2M CH_3OH–

(A) 9.6 (B) 2.4
(C) 9.6×10^3 (D) 2.4×10^3

Q.5 Which one of the following mixtures can be separated into pure components by fractional distillation –

(A) Benzene – toluene (B) Water – ethyl alcohol
(C) Water – nitric acid (D) Water – hydrochloric acid

Q.6 All form ideal solutions except

(A) C_2H_5Br and C_2H_5I (B) C_6H_5Cl and C_6H_5Br
(C) C_6H_6 and $C_2H_5CH_3$ (D) C_2H_5I and C_2H_5OH

Q.7 The azeotropic mixture of water (b.p. 100°C) and HCl (b.p. 85°C) boils at 108.5°C. When this mixture is distilled it is possible to obtain –

(A) Pure HCl
(B) Pure water
(C) Pure water as well as pure HCl
(D) Neither HCl nor H_2O in their pure states

Q.8 The concentration in gms per litre of a solution of cane sugar (M = 342) which is isotonic with a solution containing 6 gms of urea (M = 60) per litre is –

(A) 3.42 (B) 34.2
(C) 5.7 (D) 19

Q.9 Osmotic pressure is 0.0821 atm at temperature of 300K. Find concentration in mole/litre –

(A) 0.033 (B) 0.066
(C) 0.33×10^{-2} (D) 3

Q.10 The amount of urea to be dissolved in 500 ml of water (K =18.6 K mole^{-1} in 100g solvent) to produce a depression of 0.186°C in freezing point is –

(A) 9 g (B) 6 g
(C) 3 g (D) 0.3 g

Q.11 1.00 gm of a non-electrolyte solute dissolved in 50 gm of benzene lowered the freezing point of benzene by 0.40K. K_f for benzene is 5.12 kg mol^{-1}. Molecular mass of the solute will be –

(A) 256 g mol^{-1} (B) 2.56 g mol^{-1}
(C) 512×10^3 g mol^{-1} (D) 2.56×10^4 g mol^{-1}

Q.12 In equimolar solution of glucose, NaCl and $BaCl_2$, the order of osmotic pressure is as follow

(A) Glucose > NaCl > $BaCl_2$ (B) NaCl > $BaCl_2$ > Glucose
(C) $BaCl_2$ > NaCl > Glucose (D) Glucose > $BaCl_2$ > NaCl

Q.13 The osmotic pressure of which solution is maximum(consider that deci-molar solution of each 90% dissociated)

(A) Aluminium sulphate
(B) Barium chloride
(C) Sodium sulphate
(D) A mixture of equal volumes of (B) and (C)

Q.14 At 25°C, the highest osmotic pressure is exhibited by 0.1M solution of –

(A) $CaCl_2$ (B) KCl
(C) Glucose (D) Urea

Q.15 Which of the following has minimum freezing point –

(A) 0.1M $K_2Cr_2O_7$ (B) 0.1 M NH_4Cl
(C) 0.1 M $BaSO_4$ (D) 0.1 M $Al_2(SO_4)_3$

Q.16 If 1 M and 2.5 litre NaOH solution is mixed with another 0.5 M and 3 litre NaOH solution, then molarity of the resultant solution will be –

(A) 1.0 M (B) 0.73 M
(C) 0.80 M (D) 0.50 M

Q.17 Conc. H_2SO_4 has density of 1.9 g mL^{-1} and is 99% by weight. Calculate the molarity of H_2SO_4 (Mol weight of H_2SO_4 = 98 g mol^{-1}).

(A) 2.4 M (B) 24.2 M
(C) 19.1 M (D) 9.8 M

Q.18 What will be the normality of a solution containing 4.9 g. H_3PO_4 dissolved in 500 ml water –

(A) 0.3 (B) 1.0
(C) 3.0 (D) 0.1

Q.19 Which of the following should be done in order to prepare 0.40M NaCl starting with 100ml of 0.30M NaCl (mol.wt. of NaCl = 58.5)

(A) Add 0.585g NaCl (B) Add 20ml water
(C) Add 0.010ml NaCl (D) Evaporate 10ml water

Q.20 If two liquids A and B form minimum boiling azeotrope at some specific composition then –

(A) A-B interactions are stronger than those between A-A or B-B.
(B) vapour pressure of solution increases because more number of molecules of liquids A & B can escape from the solution.
(C) vapour pressure of solution decreases because less number of molecules of only one of the liquids escape from the solution.
(D) A-B interactions are weaker than those between A-A or B-B.

Q.21 The system that forms maximum boiling azeotrope is

(A) acetone - chloroform (B) ethanol - acetone
(C) n-hexane - n-heptane (D) carbon disulphide - acetone

Q.22 If 20ml of 0.4 N NaOH solution completely neutralises 40ml of a dibasic acid. Molarity of the acid solution is
(A) 0.1 M (B) 0.2 M
(C) 0.3 M (D) 0.4 M

Q.23 If 25 ml of 0.25M NaCl solution is diluted with water to a volume of 500 ml the new concentration of the solution is
(A) 0.167 M (B) 0.0125 M
(C) 0.833 M (D) 0.0167 M

Q.24 An aqueous solution of glucose is 10% in strength. The volume in which 1 gm mole of it is dissolved will be –
(A) 18 litre (B) 9 litre
(C) 0.9 litre (D) 1.8 litre

Q.25 A 5 molar solution of H_2SO_4 is diluted from 1 litre to 10 litres. The normality of the solution is
(A) 0.25 N (B) 1 N
(C) 2 N (D) 7 N

Q.26 Normality of 10% (weight/volume)acetic acid is
(A) 1 N (B) 10 N
(C) 1.7 N (D) 0.83 N

Q.27 The normality of 10 litre volume hydrogen peroxide is
(A) 0.176 (B) 3.52
(C) 1.78 (D) 0.88

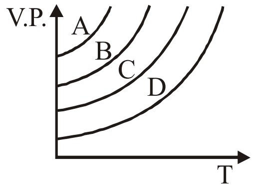
Q.28 If 0.50 mol of $CaCl_2$ is mixed with 0.20 mol of Na_3PO_4, the maximum number of moles of $Ca_3(PO_4)_2$ which can be formed, is –
(A) 0.70 (B) 0.50
(C) 0.20 (D) 0.10

Q.29 How much water is needed to dilute 10 ml of 10N hydrochloric acid to make it exactly decinormal (0.1 N)
(A) 990 ml (B) 1000 ml
(C) 1010 ml (D) 100 ml

Q.30 When 10g of a non-volatile solute is dissolved in 100 g of benzene, it raises boiling point by 1°C then molecular mass of the solute is (K_b for benzene = 2.53k-m^{-1})
(A) 223 g (B) 233 g
(C) 243 g (D) 253 g

Q.31 The vapour pressure of pure liquid A is 0.80 atm. On mixing a non-volatile B to A, its vapour pressure becomes 0.6 atm. The mole fraction of B in the solution is
(A) 0.150 (B) 0.25
(C) 0.50 (D) 0.75

Q.32 The given graph shows the vapour pressure-temperature curves for some liquids,



Liquids A, B, C and D respectively are
(A) diethyl ether, acetone, ethyl alcohol, water
(B) acetone, ethyl alcohol, diethyl ether, water
(C) water, ethyl alcohol, acetone, diethyl ether
(D) ethyl alcohol, acetone, diethyl ether, water,

Q.33 Two liquids A and B have $p_A^\circ > p_B^\circ$. They constitute an ideal binary solution. What is true about the relation between mol fraction of A in liquid phase (x_A) and in vapour phsae (y_A)?
(A) $x_A = y_A$ (B) $x_A > y_A$
(C) $x_A < y_A$ (D) None of these

Q.34 Which solution will have the highest boiling point
(A) 1% solution of glucose in water
(B) 1% solution of sodium chloride in water
(C) 1% solution of zinc sulphate in water
(D) 1% solution of urea in water

Q.35 What amount of $CaCl_2$ (i = 2.47) is dissolved in 2 litres of water so that its osmotic pressure is 0.5atm at 27°C?
(A) 3.42 g (B) 9.24 g
(C) 2.834 g (D) 1.820 g

Q.36 A 0.0020 m aqueous solution of an ionic compound $[Co(NH_3)_5(NO_2)]Cl$ freezes at –0.00732°C. Number of moles of ions in which 1 mol of ionic compound produces on being dissolved in water will be (K_f = –1.86°C/m)
(A) 3 (B) 4
(C) 1 (D) 2

Q.37 When a gas is bubbled through water at 298 K, a very dilute solution of gas is obtained. Henry's law constant for the gas is 100 k bar. If gas exerts a pressure of 1 bar, the number of moles of gas dissolved in 1 litre of water is
(A) 0.555 (B) 55.55×10^{-5}
(C) 55.55×10^{-3} (D) 5.55×10^{-5}

Q.38 What will be the osmotic pressure in pascals exerted by a solution prepared by dissolving 1.0g of polymer of molar mass 150,000 in 500 mL of water at 37°C?
(A) 30.96 Pa (B) 34.36 Pa
(C) 68.72 Pa (D) 48.25 Pa

Q.39 When acetone and chloroform are mixed together, hydrogen bonds are formed between them. Which statement is correct about the solution made by mixing acetone and chloroform?
(A) On mixing acetone and chloroform will form an ideal solution.
(B) On mixing acetone and chloroform positive deviation is shown since the vapour pressure increases.
(C) On mixing acetone and chloroform negative deviation is shown since there is decrease in vapour pressure.
(D) At a specific composition acetone and chloroform will form minimum boiling azeotrope.

Q.40 Which of the following has been arranged in the increasing order of freezing point?
(A) $0.025\ M\ KNO_3 < 0.1\ M\ NH_2CSNH_2 < 0.05\ M\ BaCl_2 < 0.1\ M\ NaCl$
(B) $0.1\ M\ NaCl < 0.05\ M\ BaCl_2 < 0.1\ M\ NH_2CSNH_2 < 0.025\ M\ KNO_3$
(C) $0.1\ M\ NH_2CSNH_2 < 0.1\ M\ NaCl < 0.05\ M\ BaCl_2 < 0.025\ M\ KNO_3$
(D) $0.025\ M\ KNO_3 < 0.05\ M\ BaCl_2 < 0.1\ M\ NaCl < 0.1\ M\ NH_2CSNH_2$

Q.41 Osmotic pressure of a solution containing 2g dissolved protein per 300 cm^3 of solution in 20mm of Hg at 27°C. The molecular mass of protein is

(A) 6239.6 g mol^{-1} (B) 12315.5 g mol^{-1}

(C) 3692.1 g mol^{-1} (D) 7368.4 g mol^{-1}

Q.42 The elevation in boiling point of a solution of 9.43g of $MgCl_2$ in 1 kg of water is ($K_b = 0.52$ K kg mol^{-1},

Molar mass of $MgCl_2 = 94.3$ g mol^{-1})

(A) 0.156 (B) 0.52

(C) 0.17 (D) 0.94

Q.43 For an ideal binary liquid solution with

$P°_A > P°_B$ in which relation between X_A (mole fraction of A in liquid phase) and Y_A (mole fraction of A in vapour phase) is correct, X_B and Y_B are mole fraction of B in liquid and vapour phase respectively

(A) $X_A = Y_A$ (B) $X_A > Y_A$

(C) $\frac{X_A}{X_B} < \frac{Y_A}{Y_B}$ (D) None of these

Q.44 Calculate the osmotic pressure at temperature 37°C of an aqueous solution of urea which freezes at –0.52°C. Assume molality and molarity be numerically equal.

($K_f = 1.86°\ Cm^{-1}$).

(A) 720.5 atm (B) 7.1 atm

(C) 71.1 atm (D) 0.85 atm

Q.45 What will be the molarity of 30 mL of 0.5 M H_2SO_4 solution diluted to 500 mL?

(A) 0.3 M (B) 0.03 M

(C) 3 M (D) 0.103 M

Q.46 Calculate the freezing point of an aqueous solution containing 10% by mass of glucose, 5% by mass of urea and 1% by mass of KCI. $K_f(H_2O) = 1.86$ K kg mol^{-1}.

(A) –2.25°C (B) 0°C

(C) –3.67°C (D) –1.63°C

Q.47 Which of the following-will have same value of van't Hoff factor as that of $K_4[Fe(CN)_6]$?

(A) $Al_2(SO_4)_3$ (B) $AlCl_3$

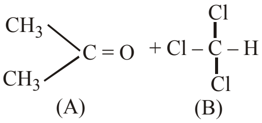
(C) $Al(NO_3)_3$ (D) $Al(OH)_3$

Q.48 A sample of drinking water severely contaminated with chloroform, $CHCl_3$, is supposed to be carcinogenic in nature. The level of contamination was 15 ppm (by mass). What is the molality of chloroform in the water sample?

(A) 2.25×10^{-5} m (B) 1.25×10^{-4} m

(C) 1.85×10^{-6} m (D) 1.72×10^{-5} m

Q.49 When acetone and chloroform are mixed together, which of the following observations is correct?



(A) A – A and B – B interactions are stronger than A – B interactions.

(B) A – A and B – B interactions are weaker than A – B interactions.

(C) A – A, B – B and A – B interactions are equal.

(D) The liquids form separate layers and are immiscible.

Q.50 What weight of glycerol should be added to 600 g of water in order to lower its freezing point by 10°C?

($K_f = 1.86°\ C\ m^{-1}$)

(A) 496g (B) 297 g

(C) 310 g (D) 426 g

Q.51 Calculate the freezing point of a solution of urea in water which boils at 100.18°C.

($K_f = 1.86°\ C\ m^{-1}$, $K_b = 0.512°Cm^{-1}$)

(A) –0.18°C (B) 0.65°C

(C) –0.65°C (D) 0.18°C

EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)

NOTE : The answer to each question is a NUMERICAL VALUE.

Q.1 If N_2 gas is bubbled through water at 293 K, if 7.16×10^{-A} millimoles of N_2 gas would dissolve in 1 litre of water. Assume that N_2 exerts a partial pressure of 0.987 bar. Find the value of A. Given that Henry's law constant for N_2 at 293 K is 76.48 kbar.

Q.2 Calculate the integral part of boiling point of a solution containing 0.61 g of benzoic acid in 50 g of $CS_2(l)$ assuming 84% dimerisation of the acid. The boiling point and K_b of CS_2 are 46.2ºC and 2.3 K kg mol^{-1} respectively.

Q.3 A solution is prepared by dissolving 1.00 g of a nonvolatile solute in 15.0 g of acetic acid. The boiling point of this solution is 120.17°C. Find the approximate molar mass of the solute. [k_b = 3.07°C/molal]

Q.4 The molal concentration of oxygen in water at 20°C is 3.0×10^{-A} molal such that it saturates with air at 1.00 atm? Assume that the mole fraction of oxygen in air is 0.21, and that of nitrogen is 0.79. Find the value of A.

Q.5 A solution was prepared by dissolving 18.00g of glucose in 150.0g of water. The resulting solution was found to have a boiling point of 100.34°C. Calculate the molecular weight of glucose. Glucose is a molecular solid that is present as individual molecules in solution.

Q.6 MX_2 dissociates into M^{2+} and X^- ions in an aqueous solution, with a degree of dissociation (α) of 0.5. The ratio of the observed depression of freezing point of the aqueous solution to the value of the depression of freezing point in the absence of ionic dissociation is –

Q.7 If the freezing point of a 0.01 molal aqueous solution of a cobalt(III) chloride-ammonia complex (which behaves as a strong electrolyte) is –0.0558ºC, the number of chloride(s) in the coordination sphere of the complex is

[K_f of water = 1.86 K kg mol^{-1}]

Q.8 The mole fraction of a solute in a solution is 0.1. At 298 K, molarity of this solution is the same as its molality. Density of this solution at 298 K is 2.0 g cm^{-3}. The ratio of the molecular weights of the solute and solvent,

$\left(\frac{MW_{solute}}{MW_{solvent}}\right)$ is ___

Q.9 The vapour pressure of pure water at 298 K is 23.76 mm. The vapour pressure of a solution of sucrose ($C_{12}H_{22}O_{11}$) in 5.56 moles of water is 23.392 mmHg. The mass of sucrose in the solution is

EXERCISE - 4 [PREVIOUS YEARS JEE MAIN QUESTIONS]

Q.1 Which of the following concentration factor is affected by change in temperature ? **[AIEEE-2002]**

(A) Molarity
(B) Molality
(C) Mol fraction
(D) Weight fraction

Q.2 For an aqueous solution, freezing point is –0.186ºC . Elevation of the boiling point of the same solution is ($K_f = 1.86^\circ\ mol^{-1}\ kg$) and $K_b = 0.512^\circ\ mol^{-1}\ kg$)

(A) 0.186º
(B) 0.0512º **[AIEEE-2002]**
(C) 1.86º
(D) 5.12º

Q.3 In a mixture of A and B, components show negative deviation when – **[AIEEE-2002]**

(A) A – B interaction is stronger than A – A and B – B interaction.
(B) A – B interaction is weaker than A – A and B – B interaction.
(C) $\Delta V_{mix} > 0$, $\Delta S_{mix} > 0$
(D) $\Delta V_{mix} = 0$, $\Delta S_{mix} > 0$

Q.4 A pressure cooker reduces cooking time for food because **[AIEEE-2003]**

(A) The higher pressure inside the cooker crushes the food material.
(B) Cooking involves chemical changes helped by a rise in temperature,
(C) Heat is more evenly distributed in the cooking space.
(D) Boiling point of water involved in cooking is increased

Q.5 If liquids A and B form an ideal solution –**[AIEEE-2003]**

(A) The free energy of mixing is zero.
(B) The free energy as well as the entropy of mixing are each zero.
(C) The enthalpy of mixing is zero.
(D) The entropy of mixing is zero.

Q.6 In a 0.2 molal aqueous solution of a weak acid HX the degree of ionization is 0.3 . Taking k_f for water as 1.85, the freezing point of the solution will be nearest to –

(A) –0.260ºC
(B) +0.480ºC **[AIEEE-2003]**
(C) –0.480ºC
(D) –0.360ºC

Q.7 25 ml of a solution of barium hydroxide required 35 ml on titration with a 0.1 molar solution of hydrochloric acid. Molarity of barium hydroxide solution was **[AIEEE-2003]**

(A) 0.28
(B) 0.35
(C) 0.07
(D) 0.14

Q.8 Which one of the following aqueous solutions will exhibit highest boiling point ? **[AIEEE-2004]**

(A) 0.01 M Na_2SO_4
(B) 0.01 M KNO_3
(C) 0.015 M urea
(D) 0.015 M glucose

Q.9 To neutralise completely 20 mL of 0.1 M aqueous solution of phosphorous acid (H_3PO_3), the volume of 0.1 M aqueous KOH solution required is - **[AIEEE-2004]**

(A) 10 mL
(B) 20 mL
(C) 40 mL
(D) 60 mL

Q.10 Which of the following liquid pairs shows a positive deviation from Raoult's law ? **[AIEEE-2004]**

(A) Water - hydrochloric acid
(B) Benzene - methanol
(C) Water - nitric acid
(D) Acetone - chloroform

Q.11 Which one of the following statement is false **[AIEEE-2004]**

(A) Raoult's law states that the vapour pressure of a component over a solution is proportional to its mole fraction.
(B) The osmotic pressure (π) of a solution is given by the equation $\pi = MRT$ where M is the molarity of the solution.
(C) The correct order of osmotic pressure for 0.01 M aqueous solution of each compound is $BaCl_2 > KCl > CH_3COOH >$ sucrose.
(D) Two sucrose solutions of same molality prepared in different solvents will have the same freezing point depression.

Q.12 If α is the degree of dissociation of Na_2SO_4, the vant Hoff's factor (i) used for calculating the molecular mass is **[AIEEE-2005]**

(A) $1 - \alpha$
(B) $1 + \alpha$
(C) $1 - 2\alpha$
(D) $1 + 2\alpha$

Q.13 Benzene and toluene form nearly ideal solutions. At 20ºC, the vapour pressure of benzene is 75 torr and that of toluene is 22 torr. The partial vapour pressure of benzene at 20ºC for a solution containing 78 g of benzene and 46 g of toluene in torr is – **[AIEEE-2005]**

(A) 25
(B) 50
(C) 53.5
(D) 37.5

Q.14 Two solutions of a substance (non electrolyte) are mixed in the following manner. 480 ml of 1.5 M first solution +520mL of 1.2M second solution. What is the molarity of the final mixture ? **[AIEEE-2005]**

(A) 1.50 M
(B) 1.20 M
(C) 2.70 M
(D) 1.344 M

Q.15 Equimolal solutions in the same solvent have **[AIEEE-2005]**

(A) Same freezing point but different boiling point
(B) Same boling point but different freezing point
(C) Different boiling and different freezing point
(D) Same boiling and same freezing points

Q.16 18 g of glucose ($C_6H_{12}O_6$) is added to 178.2 g of water. The vapour pressure of water for this aqueous solution at 100º C is - **[AIEEE 2006]**

(A) 7.60 Torr
(B) 76.00 Torr
(C) 752.40 Torr
(D) 759.00 Torr

Q.17 Density of a 2.05 M solution of acetic acid in water is 1.02 g/mL. The molality of the solution is -**[AIEEE 2006]**

(A) 3.28 mol kg^{-1}
(B) 2.28 mol kg^{-1}
(C) 0.44 mol kg^{-1}
(D) 1.14 mol kg^{-1}

Q.18 A mixture of ethyl alcohol and propyl alcohol has a vapour pressure of 290 mm at 300 K. The vapour pressure of propyl alcohol is 200 mm. If the mole fraction of ethyl alcohol is 0.6, its vapour pressure (in mm) at the same temperature will be - **[AIEEE 2007]**

(A) 350
(B) 300
(C) 700
(D) 360

Q.19 A 5.25% solution of a substance is isotonic with a 1.5% solution of urea (molar mass = 60 g mol^{-1}) in the same solvent. If the densities of both the solutions are assumed to be equal to 1.0 gcm^{-3}, molar mass of the substance will be - **[AIEEE 2007]**

(A) 90.0g mol^{-1} (B) 115.0g mol^{-1}

(C) 105.0g mol^{-1} (D) 210.0 g mol^{-1}

Q.20 The density (in g mL^{-1}) of a 3.60 M sulphuric acid solution that is 29% H_2SO_4 (Molar mass = 98 g mol^{-1}) by mass will be - **[AIEEE 2007]**

(A) 1.64 (B) 1.88

(C) 1.22 (D) 1.45

Q.21 The vapour pressure of water at 20º C is 17.5 mm Hg. If 18g of glucose ($C_6H_{12}O_6$) is added to 178.2 g of water at 20° C, the vapour pressure of the resulting solution will be - **[AIEEE 2008]**

(A) 15.750 mm Hg (B) 16.500 mm Hg

(C) 17.325 mm Hg (D) 17.675 mm Hg

Q.22 At 80º C , the vapour pressure of pure liquid 'A' is 520 mm Hg and that of pure liquid 'B' is 1000 mm Hg. If a mixture solution of 'A' and 'B' boils at 80º C and 1 atm pressure, the amount of 'A' in the mixture is (1 atm = 760 mm Hg) **[AIEEE 2008]**

(A) 34 mol percent (B) 48 mol percent

(C) 50 mol percent (D) 52 mol percent

Q.23 A binary liquid solution is prepared by mixing n-heptane and ethanol. Which one of the following statements is correct regarding the behaviour of the solution ?

(A) The solution is non-ideal, showing +ve deviation form Raoult's Law. **[AIEEE 2009]**

(B) The solution is non-ideal, showing –ve deviation from Raoult's Law.

(C) n-heptane shows +ve deviation while ethanol shows – ve deviation from Raoult's Law.

(D) The solution formed is an ideal solution.

Q.24 Two liquids X and Y form an ideal solution. At 300 K, vapour pressure of the solution containing 1 mol of X and 3 mol of Y is 550 mmHg. At the same temperature, if 1 mol of Y is further added to this solution, vapour pressure of the solution increases by 10 mmHg. Vapour pressure (in mmHg) of X and Y in their pure states will be, respectively - **[AIEEE 2009]**

(A) 300 and 400 (B) 500 and 600

(C) 400 and 600 (D) 200 and 300

Q.25 If sodium sulphate is considered to be completely dissociated into cations and anions in aqueous solution, the change in freezing point of water (ΔT_f), when 0.01 mol of sodium sulphate is dissolved in 1 kg of water, is (K_f = 1.86 K kg mol^{-1}) **[AIEEE 2010]**

(A) 0.0372 K (B) 0.0558 K

(C) 0.0744 K (D) 0.0186 K

Q.26 On mixing, heptane and octane form an ideal solution. At 373 K, the vapour pressures of the two liquid components (heptane and octane) are 105 kPa and 45 kPa respectively. Vapour pressure of the solution obtained by mixing 25.0g of heptane and 35 g of octane will be (Molar mass of heptane = 100 g mol^{-1} and of octane = 114 g mol^{-1}). **[AIEEE 2010]**

(A) 72.0 kPa (B) 36.1 kPa

(C) 96.2 kPa (D) 144.5 kPa

Q.27 Ethylene glycol is used as an antifreeze in a cold climate. Mass of ethylene glycol which should be added to 4 kg of water to prevent it form freezing at –6°C will be : (K_f for water = 1.86 K kg mol^{-1}, and molar mass of ethylene glycol = 62g mol^{-1}) : **[AIEEE 2011]**

(A) 804.32 g (B) 204.30 g

(C) 400.00 g (D) 304.60 g

Q.28 The density of a solution prepared by dissolving 120 g of urea (mol. mass = 60 u) in 1000 g of water is 1.15 g/mL. The molarity of this solution is : **[AIEEE 2012]**

(A) 0.50 M (B) 1.78 M

(C) 1.02 M (D) 2.05 M

Q.29 K_f for water is 1.86 K kg mol^{-1}. If your automobile radiator holds 1.0 kg of water, how many grams of ethylene glycol ($C_2H_6O_2$) must you add to get the freezing point of the solution lowered to –2.8ºC ? **[AIEEE 2012]**

(A) 72 g (B) 93 g

(C) 39 g (D) 27 g

Q.30 The molarity of a solution obtained bymixing 750 mL of 0.5(M) HCl with 250 mL of 2(M)HCl will be – **[JEE MAIN 2013]**

(A) 0.875 M (B) 1.00 M

(C) 1.75 M (D) 0.975 M

Q.31 Consider separate solutions of 0.500 M C_2H_5OH(aq), 0.100M $Mg_3(PO_4)_2$(aq), 0.250 M KBr (aq) and 0.125M Na_3PO_4(aq) at 25°C. Which statement is true about these solutions, assuming all salts to be strong electrolytes?

(A) 0.125 M Na_3PO_4(aq) has the highest osmotic pressure. **[JEE MAIN 2014]**

(B) 0.500 M C_2H_5OH (aq) has the highest osmotic pressure.

(C) They all have the same osmotic pressure.

(D) 0.100M $Mg_3(PO_4)_2$(aq) has the highest osmotic pressure.

Q.32 The vapour pressure of acetone at 20°C is 185 torr. When 1.2 g of a non-volatile substance was dissolved in 100 g of acetone at 20°C, its vapour pressure was 183 torr. The molar mass (g mol^{-1}) of the substance is **[JEE MAIN 2015]**

(A) 64 (B) 128

(C) 488 (D) 32

Q.33 18 g glucose ($C_6H_{12}O_6$) is added to 178.2 g water. The vapour pressure of water (in torr) for this aqueous solution is: **[JEE MAIN 2016]**

(A) 76.0 (B) 752.4

(C) 759.0 (D) 7.6

Q.34 The freezing point of benzene decreases by 0.45°C when 0.2 g of acetic acid is added to 20 g of benzene. If acetic acid associates to form a dimer in benzene, percentage association of acetic acid in benzene will be :

(K_f for benzene = 5.12 K kg mol^{-1}) **[JEE MAIN 2017]**

(A) 94.6 % (B) 64.6 %
(C) 80.4% (D) 74.6%

Q.35 For 1 molal aqueous solution of the following compounds, which one will show the highest freezing point? **[JEE MAIN 2018]**

(A) $[Co(H_2O)_4Cl_2]Cl.2H_2O$ (B) $[Co(H_2O)_3Cl_3].3H_2O$
(C) $[Co(H_2O)_6]Cl_3$ (D) $[Co(H_2O)_5Cl]Cl_2.H_2O$

Q.36 Which one of the following statements regarding Henry's law **not correct** ? **[JEE MAIN 2019 (Jan)]**

(A) The value of K_H increases with function of the nature of the gas.
(B) Higher the value of K_H at a given pressure, higher is the solubility of the gas in the liquids.
(C) The partial of the gas in vapour phase is proportional to the mole fraction of the gas in the solution.
(D) Different gases have different K_H (Henry's law constant) values at the same temperature.

Q.37 The vapour pressures of pure liquids A and B are 400 and 600 mmHg, respectively at 298K. On mixing the two liquids, the sum of their initial volumes is equal to the volume of the final mixture. The mole fraction of liquid B is 0.5 in the mixture. The vapour pressure of the final solution, the mole fraction of components A and B in vapour phase, respectively are- **[JEE MAIN 2019 (April)]**

(A) 500 mmHg, 0.5, 0.5 (B) 450 mmHg, 0.4, 0.6
(C) 450 mmHg, 0.5, 0.5 (D) 500 mmHg, 0.4, 0.6

Q.38 Liquid 'M' and liquid 'N' form an ideal solution. The vapour pressures of pure liquids 'M' and 'N' are 450 and 700 mmHg, respectively, at the same temperature. Then correct statement is: **[JEE MAIN 2019 (APRIL)]**

(x_M = Mole fraction of 'M' in solution ;
x_N = Mole fraction of 'N' in solution ;
y_M = Mole fraction of 'M' in vapour phase ;
y_N = Mole fraction of 'N' in vapour phase)

(A) $(x_M - y_M) < (x_N - y_N)$ (B) $\frac{x_M}{x_N} < \frac{y_M}{y_N}$
(C) $\frac{x_M}{x_N} > \frac{y_M}{y_N}$ (D) $\frac{x_M}{x_N} = \frac{y_M}{y_N}$

Q.39 Molal depression constant for a solvent is 4.0 kg mol^{-1}. The depression in the freezing point of the solvent for 0.03 mol kg^{-1} solution of K_2SO_4 is :
(Assume complete dissociation of the electrolyte) **[JEE MAIN 2019 (APRIL)]**

(A) 0.12 K (B) 0.36 K
(C) 0.18 K (D) 0.24 K

Q.40 At room temperature, a dilute soluton of urea is prepared by dissolving 0.60 g of urea in 360 g of water. If the vapour pressure of pure water at this temperature is 35 mmHg, lowering of vapour pressure will be (molar mass of urea = 60 g mol^{-1}) **[JEE MAIN 2019 (APRIL)]**

(A) 0.027 mmHg (B) 0.028 mmHg
(C) 0.017 mmHg (D) 0.031 mmHg

Q.41 The osmotic pressure of a dilute solution of an ionic compound XY in water is four times that of a solution of 0.01 M $BaCl_2$ in water. Assuming complete dissociation of the given ionic compounds in water, the concentration of XY (in mol L^{-1}) in solution is : **[JEE MAIN 2019 (APRIL)]**

(A) 6×10^{-2} (B) 4×10^{-4}
(C) 16×10^{-4} (D) 4×10^{-2}

Q.42 At 35°C, the vapour pressure of CS_2 is 512 mm Hg and that of acetone is 344 mm Hg. A solution of CS_2 in acetone has a total vapour pressure of 600 mm Hg. The false statement amongst the following is : **[JEE MAIN 2020 (JAN)]**

(A) Heat must be absorbed in order to produce the solution at 35°C.
(B) Raoult's law is not obeyed by this system .
(C) A mixture of 100 mL CS_2 and 100 mL acetone has a volume < 200 mL.
(D) CS_2 and acetone are less attracted to each other than to themselves.

Q.43 Two open beakers one containing a solvent and the other containing a mixture of that solvent with a non volatile solute are together sealed in a container. Over time - **[JEE MAIN 2020 (JAN)]**

(A) The volume of the solution does not change and the volume of the solvent decreases.
(B) The volume of the solution decrease and the volume of the solvent increases.
(C) The volume of the solution increase and the volume of the solvent decreases.
(D) The volume of the solution and the solvent does not change.

Q.44 How much amount of NaCl should be added to 600 g of water (r = 1.00 g/mL) to decrease the freezing point of water to – 0.2 °C ? ______. (The freezing point depression constant for water = 2K kg mol^{-1}) **[JEE MAIN 2020 (JAN)]**

EXERCISE - 5 [PREVIOUS YEARS AIPMT / NEET QUESTIONS]

Q.1 The vapour pressure of two liquids P and Q are 80 and 60 torr, respectively. The total vapour pressure of solution obtained by mixing 3 mole of P and 2 mole of Q would be **[AIPMT 2005]**
(A) 72 torr (B) 140 torr
(C) 68 torr (D) 20 torr

Q.2 A solution of urea (mol. mass 56 g mol^{-1}) boils at 100.18°C at the atmospheric pressure. If K_f and K_b for water are 1.86 and 0.512Kkgmol^{-1} respectively, the above solution will freeze at – **[AIPMT 2005]**
(A) 0.654°C (B) – 0.654°C
(C) 6.54°C (D) – 6.54°C

Q.3 The mole fraction of the solute in one mol molal aqueous solution is – **[AIPMT 2005]**
(A) 0.009 (B) 0.018
(C) 0.027 (D) 0.036

Q.4 A solution has a 1 : 4 mole ratio of pentane to hexane. The vapour pressures of the pure hydrocarbons at 20ºC are 440 mm Hg for pentane and 120 mm Hg for hexane. The mole fraction of pentane in the vapour phase would be –
(A) 0.549 (B) 0.200 **[AIPMT 2005]**
(C) 0.786 (D) 0.478

Q.5 A solution containing 10g per dm^3 of urea (molecular mass = 60g mol^{-1}) is isotonic with a 5% solution of a non-voltatile solute. The molecular mass of this nonvolatile solute is – **[AIPMT 2006]**
(A) 300g mol^{-1} (B) 350 g mol^{-1}
(C) 200g mol^{-1} (D) 250g mol^{-1}

Q.6 1.00g of a non-electrolyte solute (molar mass 250g mol^{-1}) was dissolved in 51.2g of benzene. If the freezing point depression constant K_f of benzene is 5.12 K kg mol^{-1}, the freezing point of benzene will be lowered by **[AIPMT 2006]**
(A) 0.3 K (B) 0.5 K
(C) 0.4 K (D) 0.2 K

Q.7 A solution of acetone in ethanol – **[AIPMT 2006]**
(A) shows a positive deviation from Raoult's law
(B) behaves like a non ideal solution
(C) obeys Raoult's law
(D) shows a negative deviation from Raoult's law

Q.8 During osmosis, flow of water through a semipermeable membrane is – **[AIPMT 2006]**
(A) from both sides of semipermeable membrane with equal flow rates.
(B) from both sides of semipermeable membrane with unequal flow rates.
(C) from solution having lower concentration only.
(D) from solution having higher concentration only.

Q.9 Concentrated aqueous sulphuric acid is 98% H_2SO_4 by mass and has a density of 1.80 gm L^{-1}. Volume of acid required to make one litre of 0.1 H_2SO_4 solution is – **[AIPMT 2007]**
(A) 16.65 mL (B) 22.20 mL
(C) 5.55 mL (D) 11.10 mL

Q.10 0.5 molal aqueous solution of a weak acid (HX) is 20% ionised. If K_f for water is 1.86 K kg mol^{-1}, the lowering in freezing point of the solution is – **[AIPMT 2007]**
(A) 0.56 K (B) 1.12 K
(C) – 0.56 K (D) – 1.12 K

Q.11 A 0.0020m aqueous solution of an ionic compound $Co(NH_3)_5(NO_2)Cl$ freezes at –0.00732°C. Number of moles of ions which 1 mol of ionic compound produces on being dissolved in water will be (K_f = – 1.86°C/m)
(A) 3 (B) 4 **[AIPMT 2009]**
(C) 1 (D) 2

Q.12 An aqueous solution is 1.00 molal in KI. Which change will cause the vapour pressure of the solution to increase? **[AIPMT (PRE) 2010]**
(A) Addition of NaCl (B) Addition of Na_2SO_4
(C) Addition of 1.00 molal KI (D) Addition of water

Q.13 A solution of sucrose (molar mass=342 gmol^{-1}) has been prepared by dissolving 68.5 g of sucrose in 1000g of water. The freezing point of the solution obtained will be (K_f for water = 1.86 K kg mol^{-1}) **[AIPMT (PRE) 2010]**
(A) – 0.372ºC (B) – 0.520ºC
(C) + 0.372ºC (D) – 0.570ºC

Q.14 The freezing point depression constant for water is – 1.86°Cm^{-1}. If 5.00g Na_2SO_4 is dissolved in 45.0 g H_2O, the freezing point is changed by –3.82°C. Calculate the van't Hoff factor for Na_2SO_4 **[AIPMT (PRE) 2011]**
(A) 0.381 (B) 2.05
(C) 2.63 (D) 3.11

Q.15 The van't Hoff factor i for a compound which undergoes dissociation in one solvent and association in other solvent is respectively – **[AIPMT (PRE) 2011]**
(A) Greater than one and greater than one
(B) Less than one and greater than one
(C) Less than one and less than one
(D) Greater than one and less than one

Q.16 Mole fraction of the solute in a 1.00 molal aqueous solution is – **[AIPMT (PRE) 2011]**
(A) 1.7700 (B) 0.1770
(C) 0.0177 (D) 0.0344

Q.17 A 0.1 molal aqueous solution of a weak acid is 30%ionized. If K_f for water is 1.86ºC/m, the freezing point of the solution will be : **[AIPMT (MAINS) 2011]**
(A) –0.18ºC (B) –0.54ºC
(C) –0.36ºC (D) –0.24ºC

Q.18 200mL of an aqueous solution of a protein contains its 1.26g. The osmotic pressure of this solution at 300K is found to be 2.57 × 10^{-3} bar. The molar mass of protein will be (R = 0.083 L bar mol^{-1} K^{-1}) : **[AIPMT (MAINS) 2011]**
(A) 51022 g mol^{-1} (B) 122044 g mol^{-1}
(C) 61038 g mol^{-1} (D) 31011 g mol^{-1}

Q.19 P_A & P_B are the vapour pressure of pure liquid components, A&B, respectively of an ideal binary solution. If X_A represents the mole fraction of component A, the total pressure of the solution will be – **[AIPMT (PRE) 2012]**

(A) $P_A + X_A (P_B - P_A)$
(B) $P_A + X_A (P_A - P_B)$
(C) $P_B + X_A (P_B - P_A)$
(D) $P_B + X_A (P_A - P_B)$

Q.20 Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 25°C are 200 mm Hg and 41.5mm Hg respectively. Vapour pressure of the solution obtained by mixing 25.5 g of $CHCl_3$ and 40 g of CH_2Cl_2 at the same temperature will be : (Molecular mass of $CHCl_3$ = 119.5 u and molecular mass of CH_2Cl_2 = 85 u). **[AIPMT (MAINS) 2012]**

(A) 173.9 mm Hg
(B) 615.0 mm Hg
(C) 347.9 mm Hg
(D) 90.92 mm Hg

Q.21 How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2.0 M HNO_3? **[NEET 2013]**

(A) 54.0 conc. HNO_3
(B) 45.0 conc. HNO_3
(C) 90.0 conc. HNO_3
(D) 70.0 conc. HNO_3

Q.22 Of the following 0.10 m aqueous solutions, which one will exhibit the largest freezing point depression? **[AIPMT 2014]**

(A) KCl
(B) $C_6H_{12}O_6$
(C) $Al_2(SO_4)_3$
(D) K_2SO_4

Q.23 The boiling point of 0.2 mol kg^{-1} solution of X in water is greater than equimolal solution of Y in water. Which one of the following statements is true in this case ?

(A) Molecular mass of X is greater than the molecular mass of Y. **[AIPMT 2015]**
(B) Molecular mass of X is less than the molecular mass of Y.
(C) Y is undergoing dissociation in water while X undergoes no change.
(D) X is undergoing dissociation in water.

Q.24 Which one of the following electrolytes has the same value of van't Hoff's factor (i) as that of $Al_2(SO_4)_3$ (if all are 100% ionised) ? **[AIPMT 2015]**

(A) $K_3[Fe(CN)_6]$
(B) $Al(NO_3)_3$
(C) $K_4[Fe(CN)_6]$
(D) K_2SO_4

Q.25 Which one is not equal to zero for an ideal solution ? **[AIPMT 2015]**

(A) ΔS_{mix}
(B) ΔV_{mix}
(C) $\Delta P = P_{observed} - P_{Raoult}$
(D) ΔH_{mix}

Q.26 What is the mole fraction of the solute in a 1.00 m aqueous solution ? **[RE-AIPMT 2015]**

(A) 0.0354
(B) 0.0177
(C) 0.177
(D) 1.770

Q.27 Which of the following statements about the composition of the vapour over an ideal 1 : 1 molar mixture of benzene and toluene is correct? Assume that the temperature is constant at 25°C. (Given, Vapour Pressure Data at 25°C, benzene = 12.8 kPa, toluene = 3.85 kPa) **[NEET 2016 PHASE 1]**

(A) The vapour will contain a higher percentage of benzene.
(B) The vapour will contain a higher percentage of toluene.
(C) The vapour will contain equal amounts of benzene and toluene.
(D) Not enough information is given to make a prediction.

Q.28 At 100°C the vapour pressure of a solution of 6.5 g of a solute in 100 g water is 732 mm. If K_b = 0.52, the boiling point of this solution will be **[NEET 2016 PHASE 1]**

(A) 101°C
(B) 100°C
(C) 102°C
(D) 103°C

Q.29 Which one of the following is INCORRECT for ideal solution ? **[NEET 2016 PHASE 2]**

(A) $\Delta H_{mix} = 0$
(B) $\Delta U_{mix} = 0$
(C) $\Delta P = P_{obs} - P_{\text{calculated by Rauoult's law}} = 0$
(D) $\Delta G_{mix} = 0$

Q.30 If molality of the dilute solutions is doubled of molal depression constant (K_f) will be – **[NEET 2017]**

(A) halved
(B) tripled
(C) unchanged
(D) doubled

Q.31 The mixture that forms maximum boiling azeotrope is:

(A) Water + Nitric acid **[NEET 2019]**
(B) Ethanol + Water
(C) Acetone + Carbon disulphide
(D) Heptane + Octane

Q.32 For an ideal solution, the correct option is :

(A) $\Delta_{mix} S = 0$ at constant T and P. **[NEET 2019]**
(B) $\Delta_{mix} V \neq 0$ at constant T and P.
(C) $\Delta_{mix} H = 0$ at constant T and P.
(D) $\Delta_{mix} G = 0$ at constant T and P.

ANSWER KEY

EXERCISE - 1

Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
A	D	C	C	D	B	C	A	B	B	C	C	B	B	A	A	C	C	C	D	B	D	B	C	B	C
Q	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
A	A	B	B	A	B	D	A	A	C	A	B	C	A	A	C	C	D	C	C	A	B	C	B	C	D
Q	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
A	D	B	A	D	B	A	B	D	B	D	B	A	C	B	B	C	B	D	B	C	B	D	C	B	C
Q	**76**	**77**	**78**	**79**	**80**																				
A	B	A	A	D	B																				

EXERCISE - 2

Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
A	C	C	A	A	A	D	D	B	C	C	A	C	A	A	D	B	C	A	A	D	A	A	B	D	A	C
Q	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	
A	C	D	A	D	B	A	C	B	D	D	B	B	C	B	A	A	C	B	B	C	A	B	B	B	C	

EXERCISE - 3

Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
A	1	46	90	4	180	2	1	9	30	

EXERCISE - 4

Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
A	A	B	A	D	C	B	C	A	C	B	D	D	B	D	D	C	B	A	D	C	C	C	A	C	B
Q	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**						
A	A	A	D	B	A	C	A	B	A	B	B	D	C	B	C	A	C	C	1.75						

EXERCISE - 5

Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
A	A	B	B	D	A	C	A	C	C	B	D	D	C	C	D	C	D	C	D	D	B	C	D	C	A
Q	**26**	**27**	**28**	**29**	**30**	**31**	**32**																		
A	B	A	A	D	C	A	C																		

CHAPTER - 2 SOLUTIONS

TRY IT YOURSELF - 1

(1) Mass of sugar = 34.2g

Mass of water = 180.0g

$$\text{Molality} = \frac{34.2 \times 1000}{342 \times 180} = 0.56\ \text{M}$$

$$\text{No. of moles of sugar} = \frac{34.2}{342} = 0.1$$

$$\text{No. of moles of water} = \frac{180}{18} = 10$$

Mole fraction of sugar

$$= \frac{n_A}{n_A + n_B} = \frac{0.1}{0.1+10} = \frac{0.1}{10.1} = 0.0099$$

(2) $\text{Strength of solution in gL}^{-1} = \frac{1}{100} \times 1000 = 10\text{g L}^{-1}$

$$\text{Molarity} = \frac{\text{Strength in gL}^{-1}}{\text{Molecular weight}} = \frac{10}{40} = 0.25\ \text{M}$$

$$\text{Normality} = \frac{\text{Strength in gL}^{-1}}{\text{Equivalent weight}} = \frac{10}{40} = 0.25\ \text{N}$$

(3) **(A).** Equivalent weight of oxalic acid = 126/2 = 63

Weight dissolved to get 1L of N/2 solution

$= 63 \times (1/2) = 31.5\text{g}$

Weight required to get only 250 mL of solution

$= 31.5 \times (1/4) = 7.875\text{g}$

(4) Weight of 1L solution = 1000 × 1.25 = 1250g

Weight of solute = 3 × 248 = 744 g

Molecular weight of hypo $Na_2S_2O_3.5H_2O = 248$

Weight of water = 1250 – 744 = 506 g

$$\text{No. of moles of } H_2O = \frac{506}{18} = 28$$

$$\text{Mole fraction of solute} = \frac{3}{3+28} = \frac{3}{31} = 0.097$$

Number of moles of Na^+ in 3M sodium thiosulphate solution = 6

$$\text{Molality of } Na^+ = \frac{6 \times 1000}{506} = 11.86$$

$$\text{Molality of } S_2O_3^{--} = \frac{3 \times 1000}{506} = 5.93$$

(5) $$\text{Mole fraction} = \frac{\text{No. of moles of solute}}{\text{Total No. of moles of solute \& solvent}}$$

In an aqueous solution no. of moles of water

$= 1000/18 = 55.55$

(Since molality of solution is one. So one mole solute is dissolved in 1000g of water) $= \frac{1}{1+55.55} = \frac{1}{56.55} = 0.018$

(6) $$\text{Molarity} = \frac{W_{\text{solute}}}{\text{Mol. wt.}} \times \frac{1000}{V}$$

49% by weight means 49g H_2SO_4 in 100g solution

$$M = \frac{49}{98} \times \frac{1000}{100/1.5} = 7.5$$

Normality = 7.5× 2 (Normality = molarity × basicity of acid)

= 15 N

(7) **(C).** 0.25 molal aqueous soltuion means that

Moles of urea = 0.25 mole

Mass of solvent (water) = 1 Kg = 1000g

Molar mass of urea = 14 + 2 + 12 + 16 + 14 + 2 = 60g mol^{-1}

∴ 0.25 mole of urea = 60 × 0.25 mole = 15g

Total mass of the solution = 1000 + 15g = 1015g = 1.015g

Thus, 1.015 kg of solution contain urea = 15g

∴ 2.5 kg of solution will require area

$$= \frac{15}{1.015} \times 2.5\ \text{kg} = 37.5\ \text{g}$$

(8) **(B).** Let, mass of the solution = 100 g

So mass of glucose in the solution, w_g = 10 g

and mass of water in the solution, w_w = 100g – 10g = 90g

Molar mass of glucose, $M_g = 180\ \text{g mol}^{-1}$

Density of the solution, $\rho = 1.2\ \text{g m L}^{-1}$

So amount of glucose in the solution,

$$n_g = \frac{w_g}{M_g} = \frac{10\text{g}}{180\text{g mol}^{-1}} = 0.0556\ \text{mol}$$

Molarity of the solution,

$$M = \frac{n_g}{\text{Volume of the solution in L}}$$

$$= \frac{0.0556\,\text{mol}}{(100\text{g}/1.2\text{g mL}^{-1})/1000\,\text{mL}/\text{L}} = 0.67\ \text{mol L}^{-1}$$

(9)

	Ca	+	$\frac{1}{2}O_2$	→	CaO
Equivalent taken	1/20		excess		
Equivalent after reaction	0		——		1/20

$(\because \text{Eq.} = w/E)$

$$N_{CaO} = \frac{1}{20 \times 1} = 0.05 \qquad \left(\because N = \frac{\text{Eq.}}{\text{V in litre}}\right)$$

(10) Normality of 1M H_2SO_4 = 2N

$N_1V_1 = N_2V_2$; 1N × 10 = 2N × V_2 ; 5ml = V_2

TRY IT YOURSELF - 2

(1) By definition 0.2 mole of the gas dissolved in 1000g of water.

$$\text{No. of moles of water in 1000g} = \frac{1000}{18} = 55.55$$

Mole fraction of H_2S

$$= \frac{n_{H_2S}}{n_{H_2S} + n_{H_2O}} = \frac{0.2}{0.2+55.55} = \frac{0.2}{55.75} = 0.00358$$

$$\chi_{H_2S} = \frac{\text{Partial pressure of } H_2S}{K_H}$$

$$K_H = \frac{1 \text{ atm}}{0.00358} = 285.71 \text{ atm}$$

(2) Here, $K_H = 4.27 \times 10^5$ mm, $P = 760$mm

Applying Henry's law, $P = K_H x$

$$x = \frac{P}{K_H} = \frac{760\text{m}}{4.27 \times 10^5 \text{mm}} = 1.78 \times 10^{-3}$$

i.e. mole fraction of methane in benzene = 1.78×10^{-3}

(3) $K_H = 1.67 \times 10^8$ Pa

$P_{CO_2} = 2.5 \text{ atm} = 2.5 \times 101325$ Pa

Applying Henry's law, $P_{CO_2} = K_H \times x_{CO_2}$

$$x_{CO_2} = \frac{P_{CO_2}}{K_H} = \frac{2.5 \times 101325\text{Pa}}{1.67 \times 10^8 \text{Pa}} = 1.517 \times 10^{-3}$$

$$\text{i.e.,} \quad \frac{nCO_2}{nH_2O + nCO_2} = \frac{nCO_2}{nH_2O} = 1.517 \times 10^{-3}$$

For 500mL of soda water, water present = 500mL = 500g

$$= \frac{500\text{g}}{18\text{g mol}^{-1}} = 27.78 \text{ moles}$$

$$\therefore \frac{nCO_2}{nH_2O} = 1.517 \times 10^{-3}$$

$$\frac{nCO_2}{27.78} = 1.517 \times 10^{-3}$$

$nCO_2 = 1.517 \times 10^{-3} \times 27.78 = 42.14 \times 10^{-3}$ mole

$= 42.14$ m mol $= 42.14 \times 10^{-3} \times 44\text{g} = 1.86$g

(4) No. of moles of methanol $= \frac{40}{32} = 1.25$

No. of moles of ethanol $= \frac{60}{46} = 1.30$

Mole fraction of methanol $= \frac{1.25}{1.25 + 1.30} = 0.49$

Mole fraction of ethanol $= \frac{1.30}{1.30 + 1.25} = 0.51$

Vapour pressure of pure methanol = 88.7 mm

Vapour pressure of pure ethanol = 44.5 mm

Partial vapour pressure of methanol

$= 88.7 \text{ mm} \times 0.49 = 43.46$ mm

Partial vapour pressure of ethanol

$= 44.5 \text{ mm} \times 0.51 = 22.70$ mm

$\therefore$ Total vapour pressure of solution

$= 43.46 + 22.70 = 66.16$mm

(5) Here, $P_A^\circ = 450$mm, $P_B^\circ = 700$mm, $P_{Total} = 600$mm

Applying Raoult's law,

$$P_A = x_A \times P_A^\circ$$

$$P_B = x_B \times P_B^\circ = (1 - x_A) P_B^\circ$$

$$P_{total} = P_A + P_B = x_A P_A^\circ + (1 - x_A) P_B^\circ$$

$$= P_B^\circ + (P_A^\circ - P_B^\circ) x_A$$

Substituting the given values we get

$600 = 700 + (450 - 700) x_A$ or $250 x_A = 100$

or $x_A = \frac{100}{250} = 0.40$

Thus, composition of the liquid mixture will be

x_A (mole fraction of A) = 0.40

x_B (mole fraction of B) = 1 – 0.40 = 0.60

$$P_A = x_A \times P_A^\circ = 0.40 \times 450 \text{ mm} = 180 \text{ mm}$$

$$P_B = x_B \times P_B^\circ = 0.60 \times 700 \text{ mm} = 420 \text{ mm}$$

Mole fraction of A in the vapour phase

$$= \frac{P_A}{P_A + P_B} = \frac{180}{180 + 420} = 0.30$$

Mole fraction of B in the vapour phase = 1 – 0.30 = 0.70

(6) Let the vapour pressure of pure x and y be p°_x and p°_y respectively.

In first solution : Mole fraction of x $= \frac{3}{3+1} = 0.75$

Mole fraction of y $= \frac{1}{3+1} = 0.25$

According to Raoult's law :

$p^\circ_x \times 0.75 + p^\circ_y \times 0.25 = 500$nm .... (1)

In second solution, Mole fraction of x $= \frac{4}{4+1} = 0.8$

Mole fraction of y = 1/5 = 0.2

According to Raoult's law :

$p^\circ_x \times 0.8 + p^\circ_y \times 0.2 = 600$nm .... (2)

Multiply eq. (1) by 4 and eq. (2) by 5

$3p^\circ_x + p^\circ_y = 2240$ .... (3)

$4p^\circ_x + p^\circ_y = 2850$ .... (4)

$-p^\circ_x = -610$ mm

$\therefore$ $p_x = 610$ mm

Substitute the value of p_x in eq. (3)

$3 \times 610 + p^\circ_y = 2240$

$p^\circ_y = 410$

$\therefore$ Vapour pressure of pure liquid x = 610mm, y = 410mm.

(7) Partial pressure of ethane over a saturated solution = 1 bar.

Mass of ethane in the saturated solution at 1 bar

$= 6.56 \times 10^{-2}$ g

Mass of ethane in the solution = 5.00×10^{-2} g

Partial pressure of ethane gas = ?

According to the Henry's law,

Partial pressure of the gas = $K_H \times$ Molefraction of the gas in solution

So, $1 \text{ bar} \propto K_H \times 6.56 \times 10^{-2}$ g and $p \propto K_H \times 5.00 \times 10^{-2}$ g

$$\text{So, } \frac{p}{1\,\text{bar}} = \frac{K_H \times 5.00 \times 10^{-2}\,g}{K_H \times 6.56 \times 10^{-2}\,g}$$

$$\text{or } p = \frac{5.00}{6.56} \times 1 \text{ bar} = 0.76 \text{ bar}$$

(8) From Raoult's law

$$X_A = \frac{n_A}{n_A + n_B} = \frac{100g/140g\ mol^{-1}}{(100g/140gmol^{-1}) + (1000g/180gmol^{-1})}$$

$= 0.114$

$p = p^o_B + (p^o_A - p^o_B)\,X_A$

$475 \text{ torr} = 500 \text{ torr} + (p^o_A - 500 \text{ torr}) \times 0.114$

This gives, $p^o_A = 500 \text{ torr} - \dfrac{25 \text{ torr}}{0.114} = 280.7 \text{ torr}$

We also know, $p_A = p^o_A X_A = (280.7 \text{ torr} \times 0.114) = 32$ torr.

TRY IT YOURSELF - 3

(1) $M_B = \dfrac{K_b \times W_B}{\Delta T_b \times W_A}$

Mass of solute = 10g, Mass of benzene = 100g = 0.1 kg

$\Delta T_b = 1$ K ; $K_b = 2.53$ K kg mol^{-1}

$$M_B = \frac{2.53 \times 10}{1 \times 0.1} = 253 \text{ g mol}^{-1}$$

(2) $\dfrac{P_A^0 - P_S}{P_A^0} = \dfrac{W_{solute}}{M_{solute}} \times \dfrac{M_{solute}}{W_{solvent}}$

$$\frac{400 - P_S}{400} = \frac{5}{200} \times \frac{60}{50} \;;\; P_s = 388 \text{ torr}$$

(3) $K_4Fe(CN)_6 \rightleftharpoons 4K^+ + [Fe(CN)_6]^{4-}$

$$i = \frac{1 + (n-1)\,\alpha}{1} = \frac{1 + (5-1) \times 0.5}{1} = 3$$

$\pi = i.CRT$

$\pi = 3 \times 0.1 \times 0.082 \times 300 = 7.38$ atm

Osmotic pressure of the solution is 7.38 atms.

(4) $p^o_A = 760$ mm at 100°C

$$\frac{\Delta p}{p_A^0} = \frac{W_B}{M_B} \times \frac{M_A}{W_A} \;;\; \frac{\Delta p}{760} = \frac{3}{342} \times \frac{18}{70}$$

$$\Delta p = \frac{760 \times 3 \times 18}{342 \times 70} = 1.71 \text{ mm}$$

$p_A = p^o_A - \Delta p = 760 - 1.71 = 758.29$ mm

Vapour pressure of solution is 758.29mm

(5) $W_B = \dfrac{M_B \times \Delta T_f \times W_A}{K_f}$

Molar mass of ethylene glycol = 62 g mol^{-1}

$\Delta T_f = 0° - (-8°C) = 8°C = 8K$

$K_f = 1.86$ K kg mol^{-1}

$$W_A = 4 \text{ kg} ; W_B = \frac{62 \times 8 \times 4}{1.86} = 1066.6g$$

(6) $\pi = CRT = 0.1 \times 0.082 \times 273 = 2.238$ atm

(7) Value of i for NaCl is 2 as NaCl is strong electrolyte and is completely ionised.

$\Delta T_f = i\,K_f . m$

$2 = 2 \times 1.86 \times m$

$m = 1/1.86$

Amount of NaCl dissolved per kilogram of solvent

$= 1/1.86 \times 58.5 = 31.45$ g

Amount of NaCl dissolved is 100g of solvent

$$= \frac{31.45}{10} = 3.145g$$

(8) $\pi = \dfrac{W_B}{M_B} \times \dfrac{RT}{V} \;;\; M_B = \dfrac{W_B \times RT}{\pi \times V}$

$$M_B = \frac{7 \times 0.082 \times 310}{(25/760) \times (100/1000)}$$

$$M_B = \frac{7 \times 0.082 \times 310 \times 760}{25 \times 100} \times 1000 = 54093$$

(9) $\Delta T_f = 273 - 272.07 = 0.93$ K

$$M_B = \frac{1000k_f \times W_B}{W_A \times \Delta T_f} \;;\; k_f \text{ for water} = 1.86 \text{ K kg mol}^{-1}$$

$$M_B = \frac{1000 \times 1.86 \times 18}{200 \times 0.93} = 180$$

Molecular mass of the solute = 180

(10) $\Delta T_b = \dfrac{K_b \times W_B}{M_B} \times \dfrac{1000}{W_A} = \dfrac{0.52 \times 12.5}{60 \times 170} \times 1000 = 0.637$ K

Boiling point of solution = 373 + 0.637 K = 373.64 K

(11) **Step-1 :** Calculation of observed molar mass of acetic acid

$$M_B = \frac{k_f \times W_B}{\Delta T_f \times W_A} = \frac{5.12 \times 0.3}{0.45 \times 0.03} = 113.8 \text{ g/mol}$$

Step 2 : Calculation of van't Hoff factor

Normal molar mass of CH_3COOH = 60g/mol

$$i = \frac{\text{Normal molar mass}}{\text{Observed molar mass}} = \frac{60}{113.8} = 0.53$$

CHAPTER- 2 : SOLUTIONS

EXERCISE-1

(1) **(D).** Powdered sugar has large surface area and thus, dissolves faster in hot water. As solution feels cool to touch, dissolution is endothermic so, dissolution will be favoured at high temperature.

(2) **(C).** At equilibrium,
Rate of dissolution = Rate of crystallisation.

(3) **(C).** Amalgam of mercury with sodium is an example of solid solution.

(4) **(D).** Solution is homogeneous mixture of two or more substances. Since benzene is insoluble in water so it is not the example of solution.

(5) **(B).** A saturated solution cannot dissolve any more solute at that temperature. If precipitation occurs, it is supersaturated.

(6) **(C).** $M = \dfrac{\text{No. of moles of solute}}{\text{Volume of solution in L}}$

$$m = \frac{n_B}{\text{Mass of solvent in kg}}$$

$$x = \frac{n_B}{n_A + n_B}$$

$$\text{Mass fraction} = \frac{W_B}{W_A + W_B}$$

(7) **(A).** Mole fraction is very useful in relating some physical properties of solutions like vapour pressure and calculations involving gaseous mixtures.

(8) **(B).** $\text{ppm} = \dfrac{\text{Mass of solute}}{\text{mass of solution}} \times 10^6$

$$= \frac{1.04}{10^5} \times 10^6 = 10.4 \text{ ppm}$$

(9) **(B).** 10% ethanol solution in water means that 10mL of ethanol is dissolved in water such that total volume of the solution is 100mL.

(10) **(C).** We know that

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litre}}$$

$$2.0 = \frac{0.5}{\text{Volume of solution in litre}}$$

∴ Volume of solution in litre

$$= \frac{0.5}{2.0} = 0.250 \text{ litre} = 250 \text{ ml.}$$

(11) **(C).** $\text{Molarity} = \dfrac{w}{\text{m.wt.} \times \text{volume in litre}}$

$$= \frac{171}{342 \times 1} = 0.5M.$$

(12) **(B).** Molarity of $H_2SO_4 = 0.5$ M

Normality of H_2SO_4 $(N_1) = 0.5 \times 2 = 1$ N

$$N_1V_1 = N_2V_2 ; \ 1 \times 1 = N_2 \times 10$$

or $N_2 = \dfrac{1}{10} = 0.1N.$

(13) **(B).** The unit of molality is mole per kilogram.

(14) **(A).** Amount of $AgNO_3$ added in 60 ml of solution $= 60 \times 0.03 = 1.8g$

(15) **(A).** Molarity is defined as the number of moles of solute dissolved in one litre of solution. Since volume changes with change in temperature, the molarity also changes. Other terms involve mass which does not change with temperature.

(16) **(C).** Concentration (ppm) $= \dfrac{0.2}{500} \times 10^6 = 400$

(17) **(C).** No. of moles of NaOH $= \dfrac{10}{40} = 0.25$ mol

$$M = \frac{0.25 \times 1000}{500} = 0.5 \text{ mol L}^{-1}$$

(18) **(C).** NaCl solution contain 3.50g of NaCl in 100g of water.
Water in solution = 100 – 3.5 = 96.5g = 0.0965 kg

$$\text{Molality} = \frac{3.5}{58.5 \times 0.0965} = 0.62 \text{ m}$$

(19) **(D).** Molarity of Na_2CO_3 solution $= \dfrac{2.65}{106} \times \dfrac{1000}{250} = 0.1$ M

10 mL of this solution is diluted to 500 mL

$$M_1V_1 = M_2V_2$$

$$0.1 \times 10 = M_2 \times 500 \Rightarrow M_2 = 0.002 \text{ M}$$

(20) **(B).** Molality $= \dfrac{\text{Number of moles of solute}}{\text{Weight of solvent (in g)}} \times 1000$

$$m = \frac{648}{18} \times \frac{1000}{648} = 55.5 \text{ m}$$

(21) **(D).** Solubility depends on all these factors.

(22) **(B).** $p = K_Hx$. Higher the value of K_H at a given pressure, lower is the solubility of the gas in the liquid.

(23) **(C).** The slope of this law is the Henry's law constant K_H.

(24) **(B).** At high altitudes, the partial pressure of oxygen is less than that at the ground level. This leads to low concentrations of oxygen in the blood and tissues of people living at high altitudes or climbers. Low blood oxygen causes climbers to become weak and unable to think clearly, symptoms of a condition known as anoxia.

(25) **(C).** Maximum amount of a solid solute that can be dissolved in a specified amount of a given liquid solvent does not depend upon pressure.

(26) **(A).** According to Henry's law, $p = K_Hx$

$$x = \frac{p}{K_H} = \frac{760}{4.27 \times 10^5} = 1.78 \times 10^{-3}$$

(27) **(B).** The solubility of gas in a liquid increases with increase in pressure and is directly proportional to the pressure of the gas.

(28) **(B).** Henry's law states that at constant temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of gas present above the surface of liquid or solution

(29) **(A).** Dalton a contemporary of Henry concluded independently that the solubility of gas in a liquid solution is a function of partial pressure of the gas.

(30) **(B).** Solubility of gas increases with decrease in temperature. It is due to the reason that aquatic species are more comfortable in cold water rather than in warm water.

(31) **(D).** Mercury is non-volatile.

(32) **(A).** For solutions containing non-volatile solutes, the Raoult's law may be stated as at a given temperature, the vapour pressure of a solution containing non-volatile solute is directly proportional to the mole fraction of the solvent.

(33) **(A).** Raoult's law becomes a special case of Henry's law in which K_H become equal to p_1°.

(34) **(C).** For a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction.
Depending on the vapour pressures of the pure components total vapour pressure over the solution decreases or increases with the increase of the mole fraction of any component.

(35) **(A).** When a non-volalite solute (NaCl) is dissolved in a liquid, its vapour pressure decreases.

(36) **(B).** Raoult's law states that for solutions of volatile liquids, the partial vapour pressure of each components of the solution is directly proportional to its mole fraction present in the solution.

(37) **(C).** The lower is boiling point more is vapour pressure. Boiling point order, HCl < HBr < HI < HF.

(38) **(A).** In ideal solution, enthalpy of mixing of the pure components to form the solution is zero and the volume of mixing is also zero, i.e. $\Delta_{mix}H = 0; \Delta_{mix}V = 0$

(39) **(A).** For the ideal solution ΔS_{mix} is not equal to zero.

(40) **(C).** $P_s = \overset{\circ}{P}_A . x_A + \overset{\circ}{P}_B . x_B$
$= 80 \times 0.4 + 120 \times 0.6 = 32 + 72 = 104\text{mm}$
(Vapour pressure of ideal solution)
$\because$ Vapour pressure of real solution is less than that of ideal solution so solution shows –ve deviation.

(41) **(C).** Solution of n-hexane + n-heptane, bromoethane + chloroethane, benzene and toluene etc. fall into ideal solution category.

(42) **(D).** Escaping tendency of molecules for each component decreases and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law

(43) **(C).** The solution which show large positive deviation from Raoult's law form minimum boiling azeotrope at a specific composition.

(44) **(C).** CH_3COCH_3 + $CHCl_3$ is an example of solution showing negative deviation from Raoult's law since A – B attractions (acetone + chloroform) are more than A – A (acetone-acetone) and B – B (chloroform-chloroform) attractions.

(45) **(A).** Since the new interactions (A–B) are stronger than (A–A) and (B–B) interactions, the solution shows negative deviation, i.e. less vapour pressure and hence higher boiling point.

(46) **(B).** The solution containing n-heptane and ethanol shows non-ideal behaviour with positive deviation from Raoult's law. This is because the ethanol molecules are held together by strong H-bonds, however the forces between n-heptane and ethanol are not very strong, as a result they easily vapourise showing higher vapour pressure than expected.

(47) **(C).** Acetone + ethyl alcohol solution shows positive deviation while acetone + chloroform shows negative deviation.
Other examples:Positive deviations- Acetone + ethyl alcohol, acetone + benzene, water + ethyl alcohol
Negative deviations - Nitric acid + water,
benzene + chloroform

(48) **(B).** Mixture of bromoethane and chloroethane is an ideal solution and will follow Raoult's law as intermolecular interactions of A–A and B–B type are nearly same as A–B type interactions.

(49) **(C).** Raoult's law is valid for ideal solutions only. The element of non-ideality enters into the picture when the molecules of the solute and solvent effect each others intermolecular forces. A solution containing components of A and B behaves as an ideal solution when A-B attraction force remains same as A-A and B-B.

(50) **(D).** Azeotropes are formed by the solutions which show deviations from ideal behaviour.

(51) **(D).** It is capillary action.

(52) **(B).** The proportionality constant K_f depends on nature of solvent is known as freezing point depression constant or molal depression constant or cryoscopic constant, unit of K_f is K kg mol^{-1}.

$$M_2 = \frac{K_f \times w_2 \times 1000}{\Delta T_f \times w_1}$$

where w_2 is the mass of solute having molar mass of M_2 present in w_1 gram of solvent.

(53) **(A). Isotonic solution :** Solution having same osmotic pressure at a given temperature as that of given solution.

(54) **(D).** $\dfrac{P^0 - P_s}{P^0} = \dfrac{\frac{w}{m}}{\frac{w}{m} + \frac{W}{M}}$ or $0.00713 = \dfrac{71.5/m}{\frac{71.5}{m} + \frac{1000}{18}}$;
$m = 180$

(55) **(B).** HgI_2 although insoluble in water but shows complex formation with KI and freezing point decreases.

(56) **(A).** Camphor has the maximum value of K_f (= 39.7).

(57) **(B).** The relative lowering of the vapour pressure of dilute solution is equal to the mole fraction of the solute molecule present in the solution.

(58) **(D).** Osmotic pressure method is especially suitable for the determination of molecular masses of macromolecules such as protein & polymer because for these substances the value of other colligative properties such as elevation in boiling point or depression in freezing point are too small to be measured on the other hand osmotic pressure of such substances are measurable.

(59) **(B).** Hypertonic solution has high osmotic pressure. When a plant cell is placed in hypertonic solution water will diffuse out of the cell resulting in shrinking of the cell.

(60) **(D).** PQ corresponds to increase in vapour pressure of solvent with temperature and XY corresponds to increase in vapour pressure of solution with temperature. ΔT is the elevation in boiling point of a solution.

(61) **(B). Hypotonic solution :** A solution whose osmotic pressure is less than that of another.

(62) **(A).** Unit of ebulioscopic constant (K_b) is
$K\ kg\ mol^{-1}$ or $K(molality)^{-1}$
($\because$ Molality = $mol\ kg^{-1}$)

(63) **(C).** $\Delta T_b = K_b \times m$ or $K_b = \frac{\Delta T_b}{m} = \frac{1}{\frac{1}{50} \times \frac{1000}{50}} = \frac{5}{2} = 2.5$

(64) **(B).** $\pi = \frac{n}{V} RT$. Hence, $\pi \propto n$

(65) **(B).** Colligative properties depend on the number of solute particles in solution.

(66) **(C).** No. of moles of urea $= \frac{10}{60} = \frac{1}{6}$

Weight of solute, X = 6 g

No. of moles of X $= \frac{6}{M}$

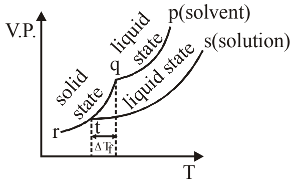
For isotonic solutions, $n_1 = n_2$

or $\frac{1}{6} = \frac{6}{M}$ or $M = 36\ g\ mol^{-1}$

(67) **(B).** Reverse osmosis will occur.

(68) **(D).** Colligative properties are those properties that depend only on the number of particles (ions, atoms, molecules) present in the solution e.g. lowering in vapour pressure, elevation in boiling point, depression in freezing point, osmotic pressure, etc.

(69) **(B).**



(70) **(C).** When a non-volatile solute is added to water there is elevation in boiling point and depression in freezing point.

(71) **(B).** When salt is spread over snow, snow starts melting from the surface because of depression in freezing point and helps in clearing the roads.

(72) **(D).** $i = \frac{\text{Total number of particles after association/dissociation}}{\text{Number of particles taken before association/dissociation}}$

(73) **(C).** $5A \rightarrow A_5$

$$i = 1 - \left(1 - \frac{1}{n}\right) = 1 - \left(1 - \frac{1}{5}\right) = 0.2$$

(74) **(B).** Since number of particles of $AlCl_3$ in solution is more than that of $CaCl_2$, ΔT_b of $AlCl_3$ is more. Hence, boiling point of $AlCl_3$ solution is higher.

(75) **(C).** For urea (NH_2CONH_2) the van't Hoff factor can not be greater than unity because urea is non-ionisable.

(76) **(B).** In case of dissociation: $A_n \rightarrow n\,A$
Initial number of moles 1 0
After dissociation $1 - \alpha$ $n\alpha$
No. of particles = $1 - \alpha + n\alpha$

$$i = \frac{1 - \alpha + n\alpha}{1} \quad \text{or} \quad i = 1 - \alpha + n\alpha$$

$$i - 1 = n\alpha - \alpha = (n - i)\alpha \quad \therefore \quad \alpha = \frac{i - 1}{n - 1}$$

(77) **(A).** For Na_3PO_4, i = 4 ; $BaCl_2$, i = 3 ;
NaCl, i = 2 ; Glucose, i = 1
Lowering of vapour pressure is maximum for sodium phosphate.

(78) **(A).** Due to association or dissociation of solute molecules there is a change in number of particles. Since colligative properties depend on number of particles there is a change in molecular mass.

(79) **(D).** Lesser the number of particles in solution, lesser the depression in freezing point, higher the freezing point.

(80) **(B).** For the same concentration of different solvents any colligative property $\propto i$
For NaCl, i = 2
Sugar solution, i = 1
$BaCl_2$, i = 3; $FeCl_3$, i = 4
Thus, for sugar solution depression in freezing point is minimum i.e., highest freezing point.

EXERCISE-2

(1) **(C).** $N_1V_1 + N_2V_2 = NV$
$4x + 10(1 - x) = 6 \times 1$
$-6x = -4 \Rightarrow x = 0.66$

(2) **(C).** M.eq. of HCl = M.eq. of $CaCO_3$

$$N \times 50 = \frac{1}{50} \times 1000\ ;\ N = \frac{1 \times 1000}{50 \times 50} = 0.4N$$

(3) **(A).** When vapour pressure of solvent decreases, then the boiling point of solvent increases.

(4) **(A).** 1000 ml of CH_3OH requires methanol = 32 g.
150 ml of 2 M CH_3OH requires methanol

$$= \frac{32}{1000} \times 150 \times 2 = 9.6g$$

(5) **(A).** Aromatic compound generally separated by fractional distillation. e.g. Benzene + Toluene.

(6) **(D).** C_2H_5I and C_2H_5OH do not form ideal solution.

(7) **(D).** Azeotropic mixture is constant boiling mixture, it is not possible to separate the components of azeotropic mixture by boiling.

(8) **(B).** Isotonic solution $= \frac{w_1}{m_1V_1} = \frac{w_2}{m_2V_2}$

$$\frac{w_1}{342\times1} = \frac{6}{60\times1}\ ;\ w_1 = \frac{342\times6}{60} = 34.2g.$$

(9) **(C).** $\pi = CRT,\ C = \frac{\pi}{RT} = \frac{0.0821}{0.0821\times300} = 0.33\times10^{-2}$.

(10) **(C).** $\Delta T_f = \frac{100\times K\times w}{m\times W}\ ;\ 0.186 = \frac{100\times18.6\times w}{60\times500}\ ;\ w = 3g$

(11) **(A).** $m = \frac{K_f\times1000\times w}{\Delta T_f\times W_{Solvent}\,(gm)} = \frac{5.12\times1000\times1}{0.40\times50} = 256$ gm/mol

(12) **(C).** $BaCl_2 \Rightarrow Ba^{2+} + 2Cl^- = 3$ ion

$NaCl \Rightarrow Na^+ + Cl^- = 2$ ion

Glucose $\Rightarrow$ No ionisation

$\therefore$ $BaCl_2 > NaCl >$ Glucose

(13) **(A).** $Al_2(SO_4)_3$ gives maximum osmotic pressure because it is gives 5 ion.

(14) **(A).** Highest osmotic pressure is given by solution which produce maximum number of ions i.e. $CaCl_2$.

(15) **(D).** We know that lowering of freezing point is a colligative property which is directly proportional to the number of particles formed by one mole of compound therefore 0.1M $Al_2(SO_4)_3$ solution will have minimum freezing point.

(16) **(B).** $(2.5\times1 + 3\times0.5) = M_3\times5.5$ or $2.5 + 1.5 = M_3\times5.5$

or $M_3 = \frac{4}{5.5} = 0.73M$

(17) **(C).** 99% by weight H_2SO_4 means

99 g of H_2SO_4 is present in 100 g solution

$$V_{solution} = \frac{M}{d} = \frac{100}{1.9}mL$$

$$\text{Molarity} = \frac{\text{Moles of } H_2SO_4}{\text{Volume of solution (mL)}}\times1000$$

$$\text{Moles of } H_2SO_4 = \frac{99}{98}$$

$$\text{Molarity} = \frac{\frac{99}{98}}{100/1.9}\times1000 = \frac{99\times1.9}{98\times100}\times1000 = 19.1\text{ M}$$

(18) **(A).** $N = \frac{w\times1000}{E\times\text{volume in ml.}}\ ;\ E = \frac{98}{3} = 32.6$

$$N = \frac{4.9\times1000}{32.6\times500} = 0.3N$$

(19) **(A).** 100 ml. of 0.30M $= \frac{100\times0.3}{1000} = 0.03$ mole of NaCl

100 ml of 0.40M $= \frac{100\times0.4}{1000} = 0.04$ mole of NaCl

Moles of NaCl to be added = 0.04 – 0.03 = 0.01 mole

m = 0.01 × 58.5 = 0.585 gm

(20) **(D).** The solutions which show a large positive deviation from Raoults law (i.e. A-B interactions are weaker than those between A-A or B-B) form minimum boiling azeotrope at a specific composition.

(21) **(A).** Due to stronger intermolecular interactions in acetone and chloroform lesser number of molecules vaporise resulting in low vapour pressure and high boiling point.

(22) **(A).** $20\times0.4 = 40\times N$ or $N = 0.2$ or $M = \frac{0.2}{2} = 0.1$ M

(23) **(B).** $M_1V_1 = M_2V_2\ ;\ M_2 = \frac{0.25\times25}{500} = 0.0125$

(24) **(D).** 10% glucose solution means

$10g = \frac{10}{180}$ mole in 100 cc. i.e., 0.1 litre

Hence 1 mole will be present in $\frac{0.1\times180}{10} = 1.8$ litre.

(25) **(A).** $M_1V_1 = M_2V_2$ i.e. $5\times1 = M_2\times10 \Rightarrow M_2 = 0.5$

Normality of the solution $= \frac{0.5}{2} = 0.25.$

(26) **(C).** $N = \frac{w\times1000}{\text{Eq.wt.}\times\text{Volume}} = \frac{10\times1000}{60\times100} = 1.66\,N$

(27) **(C).** $H_2O_2 \to H_2O + \frac{1}{2}O_2$

1 M H_2O_2 solution = 2N

= 34 gm/litre = 11.2

Normality $= \frac{2\times10}{11.2} = 1.78$

(28) **(D).** $3CaCl_2 + 2Na_3PO_4 \to Ca_3(PO_4)_2 + 6NaCl$

$\therefore$ 2 Mole of Na_3PO_4 = 3 mole of $CaCl_2$

= 1 mole $Ca_3(PO_4)_2$

$\therefore$ 0.2 mole of Na_3PO_4 = 0.3 mole of $CaCl_2$ = 0.1 mole of $Ca_3(PO_4)_2$.

(29) **(A).** $N_1V_1 = N_2V_2$

10 × 10 = 0.1 × Volume of new solution

Volume of water = 1000 – 10 = 990 ml.

(30) **(D).** $\Delta T_b = \frac{K_b\times w\times1000}{m\times W}$

$$m = \frac{K_b\times w\times1000}{\Delta T_b\times W} = \frac{2.53\times10\times1000}{1\times100} = 253g.$$

(31) **(B).** According to Raoult's Law

$\frac{P^0 - P_s}{P^0} = x_B$ (Mole fraction of solute)

$$x_B = \frac{0.8-0.6}{0.8} = 0.25.$$

(32) **(A).** The vapour pressure increases with increase in intermolecular forces. When the forces are weak, the liquid has high volatility and maximum vapour pressure. Diethyl ether has highest vapour pressure while water has lowest vapour pressure.

(33) **(C).** Due to more volatile nature of A

$p^\circ_A > p^\circ_B$, A will be not evaporated and form large amount of vapour.

So, (Vapour amount)$_A$ > (liquid amount)$_A$

$y_A > x_A$

(34) **(B).** NaCl and $ZnSO_4$ gives 2 ions but NaCl is more ionic than $ZnSO_4$.

(35) **(D).** $\pi = CRT = i\frac{n}{V}RT$

$$n = \frac{\pi \times V}{i \times R \times T} = \frac{0.5 \times 2}{2.47 \times 0.0821 \times 300} = 0.0164 \text{ mol}$$

Amount of $CaCl_2 = n \times M = 0.0164 \times 111 = 1.820$ g

(36) **(D).** The number of moles of ions produced by 1 mole of ionic compound = i

Applying, $\Delta T_f = i \times K_f \times m$

$$0.00732 = i \times 1.86 \times 0.002 \Rightarrow i = \frac{0.00732}{1.86 \times 0.002} = 1.96 \approx 2$$

(37) **(B).** $p = K_H x$; $x = \frac{p}{K_H} = \frac{1}{100 \times 10^3} = 1 \times 10^{-5}$

$$\text{Mole fraction} = \frac{\text{Moles of gas}}{\text{Total moles}}$$

$$\text{Moles of } H_2O = \frac{1000}{18} = 55.55$$

$$\text{Mole fraction} = \frac{x}{x + 55.55} \quad (55.55 >>> x)$$

$$\therefore \quad 10^{-5} = \frac{x}{55.55} \text{ or } x = 55.55 \times 10^{-5}$$

(38) **(B).** $\text{No.of moles of polymer} = \frac{1}{150{,}000}$

$$\pi = cRT = \frac{n}{V}RT$$

$$\pi = \frac{1}{150{,}000} \times \frac{8.314 \times 10^3 \times 310}{0.5} = 34.36 \text{ Pa}$$

(39) **(C).** When acetone and chloroform are mixed together, hydrogen bonds are formed between them which increases intermolecular interactions hence decreases the vapour pressure showing negative deviation.

(40) **(B).** Greater is the effective molarity (i × C), higher the ΔT_f value and lower the freezing point.

(41) **(A).** $\pi = \frac{n_B RT}{V}$; $n_B = \frac{W_B}{M_B}$; $\pi = \frac{W_B}{M_B} \times \frac{RT}{V}$

$$M_B = \frac{W_B}{V} \times \frac{RT}{\pi} = \frac{2 \times 0.0821 \times 300 \times 760}{0.3 \times 20}$$

$= 6239.6 \text{ g mol}^{-1}$

(42) **(A).** $MgCl_2 \rightleftharpoons Mg^{2+} + 2Cl^-$, $i = 3$

$$\Delta T_b = i K_b m = 3 \times 0.52 \times \frac{9.43}{94.3 \times 1} = 0.156$$

(43) **(C).** $P'_A = P^\circ_A X_A = P_T.Y_A$

$P'_B = P^\circ_B X_B = P_T.Y_B$

$$\therefore \frac{P^\circ_A}{P^\circ_B}.\frac{X_A}{X_B} = \frac{Y_A}{Y_B} \quad \because \frac{P^\circ_A}{P^\circ_B} > 1 \quad \therefore \frac{X_A}{X_B} < \frac{Y_A}{Y_B}$$

(44) **(B).** $\text{Molality} = \frac{\Delta T_f}{K_f} = \frac{0.52}{1.86}$

$$\pi = CRT = \frac{0.52}{1.86} \times 0.0821 \times 310 = 7.1 \text{ atm}$$

(45) **(B).** $V_1 = 30$ ml., $M_1 = 0.5$, $V_2 = 500$ ml., $M_2 = ?$

$M_1V_1 = M_2V_2$

$0.5 \times 30 = M_2 \times 500$ or $M_2 = 0.03$ M

(46) **(C).** Mass of glucose = 10

Number of moles of glucose = 10/180

Mass of urea = 5

Number of moles of urea = 5/60

Mass of KCl = 1

Moles of KCl = 1/74.5

Number of ions furnished by one molecule of KCl is 2.

Thus actual number of particles = 2/74.5

Total number of particles

$$\frac{10}{180} + \frac{5}{60} + \frac{2}{74.5} = 0.056 + 0.083 + 0.027 = 0.166$$

Mass of water = 100 – 10 – 5 – 1 = 84

$$\text{Molality} = \frac{0.166}{84} \times 1000 = 1.97$$

$\Delta T_b = 1.97 \times 1.86 = 3.67$

$T_b = T_b^\circ - \Delta T_b = 0 - 3.67 = -3.67°C$

(47) **(A).** $K_4[Fe(CN)_6] \rightarrow 4K^+ + [Fe(CN)_6]^{4-}$

$Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3SO_4^{2-}$

(48) **(B).** 15 ppm means 15 g of $CHCl_3$ are dissolved in 10^6 g of solvent.

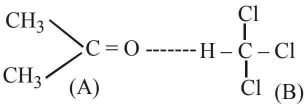
$$\text{Molality} = \frac{w_B/m_B}{\text{Mass of solvent}} \times 1000$$

$w_B = 15$ g, $m_B = 119.5$, $M_B = 10^6$ g

$$\text{Molality} = \frac{15/119.5}{10^6} \times 1000 = 1.25 \times 10^{-4} \text{ m}$$

(49) **(B).** When acetone and chloroform are mixed together, a hydrogen bond is formed between them which increases intermolecular interactions.

Hence, A – B interactions are stronger than A – A and A – B interactions.



(50) **(B).** $\Delta T_f = K_f \times m = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1}$

$$W_2 = \frac{10 \times 92 \times 600}{1.86 \times 1000} = 296.77\ \text{g}$$

(51) **(C).** $m = \frac{\Delta T_f}{K_f} = \frac{\Delta T_b}{K_b}$

$(\Delta T_b = 100.18 - 100 = 0.18°C)$

$$\Delta T_f = \frac{0.18 \times 1.86}{0.512} = 0.65°C$$

$\Delta T_f = T_0 - T_f \Rightarrow T_f = 0 - 0.65 = -0.65°C$

(Freezing point of pure water = 0°C)

EXERCISE-3

(1) **1.** The solubility of gas is related to the mole fraction in aqueous solution. The mole fraction of the gas in the solution is calculated by applying Henry's law. Thus:

$$x\ (\text{Nitrogen}) = \frac{p\ (\text{nitrogen})}{K_H} = \frac{0.987\ \text{bar}}{76{,}480\ \text{bar}} = 1.29 \times 10^{-5}$$

As 1 litre of water contains 55.5 mol of it, therefore if n represents number of moles of N_2 in solution,

$$x\ (\text{Nitrogen}) = \frac{n\ \text{mol}}{n\ \text{mol} + 55.5\ \text{mol}} = \frac{n}{55.5} = 1.29 \times 10^{-5}$$

(n in denominator is neglected as it is << 55.5)

Thus $n = 1.29 \times 10^{-5} \times 55.5\ \text{mol} = 7.16 \times 10^{-4}\ \text{mol}$

$$= \frac{7.16 \times 10^{-4}\ \text{mol} \times 1000\text{mol}}{1\ \text{mol}} = 0.716\ \text{mmol}$$

(2) **46.** $\Delta T = i \times K_b \times \text{molality} = i \times K_b \times \frac{w \times 1000}{m \times W}$ .....(i)

$$\alpha = \frac{1 - i}{1 - 1/n}\ ;\quad 0.84 = \frac{1 - i}{1 - 1/2}\ ;\ i = 0.58$$

$$\Delta T = 0.58 \times 2.3 \times \frac{0.61 \times 1000}{122 \times 50} = 0.1334$$

$T - T_0 = 0.1334$

$T = T_0 + 0.1334 = 46.2 + 0.1334 = 46.3334$

(3) **90.** From the boiling point of the solution, boiling point elevation and freezing point depression constants for the solvent, acetic acid, the molality can be calculated. The change in the boiling point is

$\Delta T_b = 120.17 - 117.90 = 2.27°C$

The molal concentration of the solute is found with Equation, $\Delta T_b = (\text{b.p.}_{\text{solution}} - \text{b.p.}_{\text{solvent}}) = mk_b$

Using the boiling point elevation constant.

$\Delta T_b = mk_b$

$$m = \frac{2.27°C}{3.07°C/\text{molal}} = 0.739\ \text{molal}$$

The solution contains 0.739 mol of solute for each kilogram of solvent. Since the solution was prepared using 15.0 g of the solvent, we use the molal concentration of the solution as a conversion factor to find the amount of solute present in our sample.

moles solute

$$= 15.0\text{g solvent}\left(\frac{1\ \text{kg}}{1000\text{g}}\right)\left(\frac{0.739\ \text{mol solute}}{1\ \text{kg solvent}}\right)$$

$= 1.11 \times 10^{-2}$ mol solute

The molar mass is now calculated from the known mass of the sample (1.00 g) and the moles of solute determined in the boiling point elevation experiment.

$$\text{Molar mass} = \frac{1.00\text{g}}{1.11 \times 10^{-2}\ \text{mol}} = 90.1\ \text{g/mol}$$

(4) **4.** Before applying Henry's law we must find the partial pressure of the oxygen in the gas phase, which is simply the mole fraction of oxygen (0.21) times the total pressure (Dalton's law of partial pressure):

$P_{\text{oxygen}} = 0.21 \times 1.00\ \text{atm} = 0.21\ \text{atm}$

The Henry's law constant for oxygen at 20°C is 1.43×10^{-3} molal/atm. Using this constant and the partial pressure of oxygen in Equation C = kP, we calculate the concentration in solution.

$C = kP = (1.43 \times 10^{-3}\ \text{molal/atm})\ (0.21\ \text{atm})$

$= 3.0 \times 10^{-4}$ molal

(5) **180.** We make use of the equation, $\Delta T = K_b m_{\text{solute}}$

where $\Delta T = 100.34°C - 100.00°C = 0.34°C$

For water, $K_b = 0.51$. The molarity of this solution then can be calculated by rearranging the boiling point elevation equation to give

$$m_{\text{solute}} = \frac{\Delta T}{K_b} = \frac{0.34°C}{0.51\frac{°C\ \text{kg}}{\text{mol}}} = 0.67\ \text{mol/kg}$$

The solution was prepared using 0.150 kg of water. Using the definition of molality, we can find the number of mole of glucose in the solution.

$$m_{\text{solute}} = 0.67\ \text{mol/kg} = \frac{\text{mol solute}}{\text{kg solvent}} = \frac{n_{\text{glucose}}}{0.1500\text{kg}}$$

$n_{\text{glucose}} = (0.670\ \text{mol/kg})\ (0.1500\ \text{kg}) = 0.10\ \text{mol}$

Thus 0.10 mol of glucose weighs 18.00g, and 1.0 mol of glucose weighs 180g (10 × 18.00g). The molecular weight of glucose is 180.

(6) **2.** $\alpha = 0.5$

$$\begin{array}{ccccc} MX_2 & \rightleftharpoons & M^{+2} & + & 2X^- \\ (1-\alpha) & & \alpha & & 2\alpha \end{array}$$

$$i = \frac{1 - \alpha + \alpha + 2\alpha}{1}$$

$i = 1 + 2\alpha$

$i = 1 + 2 \times 0.5 = 2$

(7) **1.** $\Delta T_f = K_f \times i \times m$

$0.0558 = 1.86 \times i \times 0.01\ ;\ i = 3$

Given complex behaves as a strong electrolyte

$\alpha = 100\ \%$

n = 3 (no. of particles given by complex)

$\therefore$ complex is $[Co(NH_3)_5Cl]\ Cl_2$

No. of Cl^- ions in the co-ordination sphere of the complex = 1

(8) **9.** $m = \frac{\chi_B \times 1000}{\chi_B \times M_A} \Rightarrow m = \frac{1000}{9M_A}$ .... (1)

Also using,

$m = \frac{1000M}{1000d - MM_B} \Rightarrow MM_B = 1000$ .... (2)

$I = \frac{1000}{1000 \times 2 - MM_B}$

Using eq. (1) and (2), $\frac{M_B}{M_A} = 9$ (Molality = molarity)

(9) **30.** $\frac{23.76 - 23.392}{23.76} = \frac{w}{342x5.65}$

w = 30g

EXERCISE-4

(1) **(A).** Molarity is affected by change in temperature.

(2) **(B).** $\Delta T_f = k_f \times m \quad \therefore \quad m = \frac{\Delta T_f}{k_f} = \frac{0.186}{1.86} = 0.1m$

$\Delta T_b = k_b \times m = 0.512 \times 0.1 = 0.0512$

(3) **(A).** For solution showing negative deviation, $\Delta V_{mix} < 0$
So, A – B interaction is stronger than A – A and B–B interaction.

(4) **(D).** A pressure cooker reduces cooking time for good because boiling point of water involved in cooking in increased.

(5) **(C).** Two liquid A and B form an ideal solution the enthalpy of mixing is zero.

(6) **(B).** $\alpha = 0.3$. Thus, $\frac{i-1}{2-1} = 0.3$ or $i = 1.3$

$\Delta T_f = 1.3 \times 0.2 \times 1.85 = 0.481$

(7) **(C).** $Ba(OH)_2 + 2HCl \longrightarrow BaCl_2 + 2H_2O$
1 mole 2 mole
For HCl, $M = N = 0.1$; $N_1V_1 = N_2V_2$,
$25 \times N_1 = 0.1 \times 35$

$N_1 = \frac{0.1 \times 35}{25}$ or $M = \frac{0.1 \times 35}{25 \times 2} = 0.07$

(8) **(A).** The concentration of particles is highest in 0.01M Na_2SO_4 and so, elevation of boiling point will be maximum.

(9) **(C).** $H_3PO_3 \rightarrow$ Dibasic acid and it will react with KOH as
$H_3PO_3 + 2KOH \longrightarrow K_2HPO_3 + 2H_2O$

$\therefore \quad \frac{20 \times 0.1}{1} = \frac{V \times 0.1}{2}$; $V = 20 \times 2 = 40ml.$

(10) **(B).** Benzene-methanol are the liquid pairs shows a positive deviation from Raoult's law.

(11) **(D).** Two sucrose solutions of same molarity prepared in different solvent will have different freezing point.

(12) **(D).** Na_2SO_4 dissociate to give three particle.

$\therefore \quad \alpha = \frac{i-1}{3-1}$ or $C = 1 + 2\alpha$

(13) **(B).** $n_b = \frac{78}{78} = 1$, $n_t = \frac{46}{92} = 0.5$

$x_b = \frac{1}{1.5}, x_t = \frac{0.5}{1.5}$; $P_b = P_b^0 . x_b = \frac{75 \times 1}{1.5} = 50$ torr.

(14) **(D).** $M_1V_1 + M_2V_2 = M_3 (V_1 + V_2)$

$M_3 = \frac{720 + 624}{1000} = 1.344$ M

(15) **(D).** Equimolar solution in the same solvent have same boiling and same freezing point.

(16) **(C).** $\frac{\Delta P}{P_0} = x_B = \frac{w_B \times M_A}{M_B \times w_A} = \frac{18 \times 18}{180 \times 178.2} = 0.01$

$\frac{(P_0 - P)}{P^\circ}$ or $\frac{\Delta P}{P^\circ} = 0.01$

or $P = (1 - 0.01) \times P_0 = 0.99 \times 760 = 752.4$ torr

(17) **(B).** Mass of 100ml solution = 1000 × 1.02 = 1020 gm.
Mass of water = 1020 – 2.05 × 60 = 897gm.

$m = \frac{2.05 \times 1000}{897} = 2.285$ mole/kg.

(18) **(A).** $P_t = 290mm$, P_A° (for propyl alochol) = 200

$X_{C_2H_5OH} = 0.6$, P_B° (for ethyl alcohol) = ?

Now, $P_t = 0.6 \times P_B^\circ + 0.4 \times 200 = 290 \Rightarrow 0.6 P_B^\circ = 210$

$P_B^\circ = \frac{210}{0.6} = 350mm$

(19) **(D).** Isotonic means equal osmotic pressure

$\frac{5.25}{100 \times m} = \frac{1.5}{100 \times 60} \Rightarrow m = \frac{5.25 \times 60}{1.5} = 210.0$ gm/mol.

(20) **(C).** Molarity $= \frac{x \times d \times 10}{\text{Mol. wt.}}$

$d = \frac{\text{Molarity} \times \text{Mol. wt.}}{x \times 10} = \frac{3.6 \times 98}{29 \times 10} = 1.216 = 1.22$

(21) **(C).** $\frac{P_A^0 - P_A}{P_A^0} = \frac{n_B}{n_A}$; $P_A^0 = 17.5, n_B = \frac{18}{180} = 0.1$

$P_A^0 = ?,\ n_A = \frac{178.2}{18} = 9.9$; $\frac{17.5 - P_A}{17.5} = \frac{0.1}{9.9}$

$9.9(17.5 - P_A) = 17.5 \times 0.1 = 17.325$ mm Hg

(22) **(C).** $P_{mixture} = 1$ atm = 760mm Hg

$P_{mixture} = P_A^0 X_A + P_B^0 X_B$

Let us consider $x_A + x_B = 1$; $x_B = 1 - x_A$
From the formula on putting value
$760 = 520 \times x_A + 1000(1 - x_A) = 520x_A + 1000 - 1000x_A$
$760 = 480x_A + 1000$; $480x_A = 1000 - 760$

$$x_A = \frac{240}{480} = 0.5 = 50 \text{ mole \%}$$

(23) **(A).** When n–heptane is added to ethanol, the H-bonding interaction between ethanol molecules is loosened, so weaker interaction among molecules leads to higher vapour pressure. Thus, it forms a non-ideal solution with positive deviation from Raoult's law.

(24) **(C).**
$$\left.\begin{aligned}\chi_X &= \frac{1}{4}\\ \chi_Y &= \frac{3}{4}\end{aligned}\right\} \begin{aligned} &P = p_x^0\chi_x + p_y^0\chi_y \\ &550 = \frac{p_x^0}{4} + p_y^0 \times \frac{3}{4} \text{......(1)}\end{aligned}$$

After addition of 1 mole of Y further,

$$560 = \frac{p_x^0}{4} + p_y^0 \times \frac{4}{5} \text{......(2)}$$

By solving equation (1) and (2)

$p_0{}^x = 400$mm Hgf, $p_0{}^y = 600$mm Hg

(25) **(B).** Vant Hoff's factor (i) for $Na_2SO_4 = 3$

$$\therefore \ \Delta T_f = (i)\, k_f m = 3 \times 1.80 \times \frac{0.01}{1} = 0.0558 \text{ K}$$

(26) **(A).** Mole fraction of Heptane

$$= \frac{25/100}{\frac{25}{100} + \frac{35}{114}} = \frac{0.25}{0.557} = 0.45$$

$X_{\text{Heptane}} = 0.45$.

$\therefore$ Mole fraction of octane = 0.55 = X_{octane}

Total pressure = $\sum X_i P_i^0$

$$= (105 \times 0.45) + (45 \times 0.55) \text{ kPa} = 72.0 \text{ KPa}$$

(27) **(A).** $\Delta T_f = i\, K_f m$; $\Delta T_f = 6°C$; $i = 1$

$$6 = 1 \times 1.86 \times \frac{w}{62 \times 4} \ ; w = 804.32\text{g}$$

(28) **(D).** $$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of sol. } (\ell)} = \frac{120 \times 1.15}{60 \times 1120} \times 1000$$

$$= 2.05 \text{ M}$$

(29) **(B).** $\Delta T_f = i \times k_f \times m$

$$2.8 = 1 \times 1.86 \times \frac{x}{62 \times 1} \ ; \ x = \frac{2.8 \times 62}{1.86} = 93\text{gm}$$

(30) **(A).** $$M_f = \frac{M_1V_1 + M_2V_2}{V_1 + V_2} = \frac{0.5 \times \frac{3}{4} + 2 \times \frac{1}{4}}{1} = 0.875 \text{ M}$$

(31) **(C).** For C_2H_5OH, $\pi = 1 \times 0.5 \times RT$

For KBr, $\pi = 2 \times 0.25 \times RT$

For $Mg_3(PO_4)_2$, $\pi = 5 \times 0.1 \times RT$

For Na_3PO_4, $\pi = 4 \times 0.125 \times RT$

So, all are isotonic solutions.

(32) **(A).** Vapour pressure of pure acetone $P°_A = 185$ torr

Vapour pressure of solution, $P_S = 183$ torr

Molar mass of solvent, $M_A = 58$ g/mole

$$\frac{P°_A - P_S}{P_S} = \frac{n_B}{n_A} \Rightarrow \frac{185 - 183}{183} = \frac{W_B}{M_B} \times \frac{M_A}{W_A}$$

$$\Rightarrow \frac{2}{183} = \frac{1.2}{M_B} \times \frac{58}{100} \Rightarrow M_B = \frac{1.2}{2} \times \frac{58}{100} \times 183$$

$$= 63.68 \text{ g/mole}$$

(33) **(B).** $$n_{C_6H_{12}O_6} = \frac{18}{180} = 0.1, \ \ n_{n_{20}} = \frac{178.2}{18} = 9.9$$

$$\Rightarrow \ \chi_{C_6H_{12}O_6} = \frac{0.1}{0.1 + 9.9} = \frac{0.1}{10} = 0.01.$$

$$\frac{\Delta P}{\overset{\circ}{P}_A} = \chi_B \Rightarrow \frac{\Delta P}{760} = 0.01 \Rightarrow \Delta P = 7.6 \text{ torr}$$

$$P_{\text{sol}^n} = \overset{\circ}{P}_{\text{water}} - \Delta P = 760 - 7.6 = 752.4 \text{ torr}$$

(34) **(A).** $\Delta T_f = i \times K_f \times m$

$$\Rightarrow \ 0.45 = i \times 5.12 \times \frac{0.2}{60} \times \frac{1000}{20} \Rightarrow i = 0.527$$

$$2AcOH \rightleftharpoons (AcOH)_2$$

$$1 - \alpha \qquad \alpha/2$$

$$i = 1 - \frac{\alpha}{2} \ ; \ 0.527 = 1 - \frac{\alpha}{2}$$

$\alpha = 0.946$ or 94.6 %

(35) **(B).** Depression in freezing point, $\Delta T_f = i\, K_f m$

Less the value of i,

Higher the value of freezing pt.

For (B) i = 1 (min)

(36) **(B).** Liquid solution, $P_{gas} = K_H \times X_{gas}$

More is K_H less is solubility, lesser solubility is at higher temperature. So more is temperature more is K_H.

(37) **(D).** $P_{total} = X_A.\, P_A{}^0 + X_B.\, P_B{}^0$

$= 0.5 \times 400 + 0.5 \times 600 = 500$ mmHg

Now, mole fraction of A in vapour,

$$Y_A = \frac{P_A}{P_{total}} = \frac{0.5 \times 400}{500} = 0.4$$

and mole fraction of B in vapour,

$Y_B = 1 - 0.4 = 0.6$

(38) **(C).** $P°_N > P°_M$

$y_N > X_N$ & $X_M > y_M$

Multiply we get, $y_N X_M > X_N y_M$

(39) **(B).** $K_f = 4$ K-kg/mol, m = 0.03 mol/kg, i = 3

$\Delta T_f = i\, K_f \times m$

$\Delta T_f = 3 \times 4 \times 0.03 = 0.36$ K

(40) **(C).** Lowering of vapour pressure = $p^0 - p = p^0.x_{\text{solute}}$

$$\therefore \ \ \Delta p = 35 \times \frac{0.6/60}{\frac{0.6}{60} + \frac{360}{18}} = 35 \times \frac{0.01}{0.01 + 20}$$

$$= 35 \times \frac{0.01}{20.01} = .017 \text{ mm Hg}$$

(41) **(A).** $\pi_{XY} = 4\pi_{BaCl_2}$

$2 \times [XY] = 4 \times 3 \times 0.01$

(Assuming same temperature)

$\Rightarrow [XY] = 0.06\,M$

(42) **(C).** The vapour pressure of mixture (= 600 mm Hg) is greater than the individual vapour pressure of its constituents (Vapour pressure of $CS_2 = 512$ mm Hg, acetone = 344 mm Hg). Hence, the solution formed shows positive deviation from Raoult's law.

(A) $\Delta_{Sol}H > 0$,

(B) Raoult's law is not obeyed

(C) $\Delta_{sol.}$ Volume > 0

(D) CS_2 and Acetone are less attracted to each ether than to themselves.

(43) **(C).** The pure solvent solution will try to maintain higher vapour pressure in the sealed container and in return the solvent vapour molecules will condense in the solution of non-volatile solute as it maintains an equilibrium with lower vapour pressure.

(Lowering of vapour pressure is observed when a non volatile solute is mixed in a volatile solvent)

This will eventually lead to increase in the volume of solution and decrease in the volume of solvent.

(44) **(1.75 or 1.76)**

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

$0.2 = 2 \times 2 \times \dfrac{w/58.5}{600/1000}$; $w = 1.755$ gm

EXERCISE-5

(1) **(A).** $P_T = P_P^0 X_P + P_Q^0 X_Q$

$$P_T = 80 \times \frac{3}{5} + 60 \times \frac{2}{5}$$

$P_T = 48 + 24 = 72$ torr .

(2) **(B).** As $\Delta T_f = K_f m$; $\Delta T_b = K_b m$

$$m = \frac{\Delta T_f}{K_f} = \frac{\Delta T_b}{K_b} \;;\; \Delta T_f = \Delta T_b \frac{K_f}{K_b}$$

$\Delta T_b = 100.18 - 100 = 0.18°C$

$$\Delta T_f = 0.18 \times \frac{1.86}{0.512} = 0.654°C$$

As the freezing point of pure water is 0°C,

$\Delta T_f = 0 - \Delta T_f$; $T_f = -0.654$

(3) **(B).** One molal solution means one mole solute present in 1 kg (1000g) solvent, i.e., mole of solute = 1

$$\text{Mole of solvent } (H_2O) = \frac{1000g}{18g} = \frac{1000}{18}$$

$$\text{Mole fraction of solute} = \frac{1}{\left(1+\frac{1000}{18}\right)} = \frac{18}{1018} = 0.018$$

(4) **(D).** The ratio of pentane to hexane = 1 : 4

Mole fraction of pentane = 1/5

Mole fraction of hexane = 4/5

Vapour pressure $= X_P P_P° + X_H P_H°$

$$= \left(\frac{1}{5} \times 440 + \frac{4}{5} \times 120\right) = 184 \text{ mm}$$

$\because$ Vapour pressure of pentane in mixture

= Vapour pressure of mixture × Mole fraction of pentane in vapour phase

88 = 184 × Mole fraction of pentane in vapour phase

Mole fraction of pentane in vapour phase

$$= \frac{88}{184} = 0.478$$

(5) **(A).** Osmotic pressure of urea

$$\pi V = nRT \Rightarrow \pi = \frac{nRT}{V} = \frac{10}{60} \times 0.821 \times T$$

[$1\,dm^3 = 1$ litre]

5% solution means

$100ml \equiv 5gm$; $1000ml \equiv 50g/L$

Osmotic pressure of solution having non-volatile solute $\pi_2 = \dfrac{50}{M} \times 0.821 \times T$

For isotonic solution, $\pi_1 = \pi_2$

$$\frac{10}{60} \times 0.821 \times T = \frac{50}{M} \times 0.821 \times T \;;\; M = 300 g\,mol^{-1}$$

(6) **(C).** $\Delta T = K_f m = 5.12 \times \dfrac{1}{250} \times \dfrac{1000}{51.2} = 0.4$ K

(7) **(A).** A solution of acetone in ethanol shows positive deviation from Raoult's law. It is because ethanol molecules are strongly hydrogen bonded. When acetone is added, these molecules break the hydrogen bonds and ethanol becomes more volatile. Therefore its vapour pressure is increased.

(8) **(C).** During osmosis water flows through semipermeable membrane from lower concentration to higher concentration.

(9) **(C).** Molarity of H_2SO_4 solution

$$= \frac{98 \times 1000}{98 \times 100} \times 1.84 = 18.4$$

Suppose V ml. of this H_2SO_4 is used to prepare 1 lit. of 0.1 M H_2SO_4

$\therefore$ $V \times 18.02 = 1000 \times 0.1$

or $V = \dfrac{1000 \times 0.1}{18.02} = 5.55$ ml.

(10) **(B).** As $\Delta T_f = i\,K_f m$

For HX $\rightleftharpoons H^+ + X^-$

$t = 0$ 1 0 0

t_{eq} $(1 - 0.20)$ 0.20 0.20

Total no. of moles

$= 1 - 0.20 + 0.20 + 0.20 = 1 + 0.20 = 1.2$

$\Delta T_f = 1.2 \times 1.86 \times 0.5 = 1.1160 \approx 1.12K$

(11) **(D).** $\Delta T_f = i \times k_f \times m$

$$i = \frac{\Delta T_f}{k_f \times m} = \frac{0.00732}{1.86 \times 0.002} = 2$$

(12) **(D).** Addition of water to an aqueous solution of KI causes the concentration of the solution to decrease thereby increasing the vapour pressure. In the other three options the electrolytes undergo ionisation, which leads to lowering of vapour pressure.

(13) **(C).** Depression in freezing point,
$\Delta T_f = k_f \times m$, where, m = molality

$$= \frac{W_B \times 1000}{M_B . W_A} = \frac{68.5 \times 1000}{342 \times 1000} = \frac{68.5}{342}$$

$$\Delta T_f = 1.86 \times \frac{68.5}{342} = 0.372^\circ C$$

$\Delta T_f = T^\circ - T_s = 0 - 0.372^\circ C = 0.372^\circ C$

(14) **(C).** Using, $\Delta T_f = i \times K_f \times m$

$$i = \frac{\Delta T_f \times W_A}{K_f \times n_B \times 1000}$$

$$= \frac{3.82 \times 45}{1.86 \times \left(\frac{5}{142}\right) \times 1000} = 2.63$$

(15) **(D).** For dissociation i > 1.
For association i < 1

(16) **(C).** Mole fraction of solute $= \frac{1}{56.55} = 0.0177$

(17) **(D).** $\Delta T_f = i K_f m$

$HA \rightarrow H^+ + A^-$
$1-\alpha \quad \alpha \quad \alpha$
$1-0.3 \quad 0.3 \quad 0.3$
$i = 1 - 0.3 + 0.3 + 0.3$; $i = 1.3$
$\Delta T_f = 1.3 \times 1.86 \times 0.1 = 0.2418$
$T_f = 0 - 0.2418 = -0.2418\,^\circ C$

(18) **(C).** $\pi = CRT = \frac{wt \times 1000}{GMM \times V} RT$

$$2.57 \times 10^{-3} = \frac{1.26 \times 1000}{GMM \times 200} \times 0.083 \times 300$$

GMM = 61038g

(19) **(D).** $P = P_A X_A + P_B X_B = P_A X_A + P_B (1 - X_A)$
$= P_A X_A + P_B - P_B X_A = P_B + X_A (P_A - P_B)$

(20) **(D).** $n_{CHCl_3} = \frac{25.5}{119.5} = 0.213$; $n_{CH_2Cl_2} = \frac{40}{85} = 0.47$

$$P_T = P_A^\circ X_A + P_B^\circ X_B = 200 \times \frac{0.213}{0.683} + 41.5 \times \frac{0.47}{0.683}$$

$= 62.37 + 28.55 = 90.92$

(21) **(B).**

$$M = \frac{W \times 1000}{M_w \times V_{solution}(mL)} \; ; \; 2 = \frac{W \times 1000}{63 \times 250} \Rightarrow W = 31.5g$$

70% HNO_3 means 70g HNO_3 is present in 100g solution.

∴ 31.5g HNO_3 will be present in

$$= \frac{100}{70} \times 31.5 = 45 \text{ g of solution}$$

(22) **(C).** Colligative properties ∝ Net molality
(A) For KCl Net molality = 0.1 × 2 = 0.2
(B) For Glucose Net molality = 0.1 × 1 = 0.1
(C) For $Al_2(SO_4)_3$ Net molality = 0.1 × 5 = 0.5
(D) For K_2SO_4 Net molality = 0.1 × 3 = 0.3

(23) **(D).** When solute undergoes dissociation than vant Hoff factor i > 1 ; $\Delta T_b = i K_b m$

(24) **(C).** $Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3SO_4^{2-}$; i = 5
$Al(NO_3)_3 \rightarrow Al^{3+} + 3NO_3^-$; i = 4
$K_4[Fe(CN)_6] \rightarrow 4K^+ + [Fe(CN)_6]^{4-}$
i = 5
$K_2SO_4 \rightarrow 2K^+ + SO_4^{2-}$; i = 3
$K_3[Fe(CN)_6] \rightarrow 3K^+ + [Fe(CN)_6]^{3-}$
i = 4

(25) **(A).** In case of ideal solution, $\Delta S_{mix} > 0$

(26) **(B).** 1.00 m solution means 1 mole solute is present in 1000g water. $n_{H_2O} = \frac{1000}{18} = 55.5$ mol H_2O

$$X_{solute} = \frac{n_{solute}}{n_{solute} + n_{H_2O}} = \frac{1}{1 + 55.5} = 0.0177$$

(27) **(A).** The component having higher vapour pressure will have higher percentage in vapour phase.

(28) **(A).** $\frac{P_A^0 - P_S}{P_S} = \frac{n_B}{n_A}$

$$\Rightarrow \frac{760 - 732}{732} = \frac{W_B \times M_A}{M_B \times W_A} \Rightarrow \frac{28}{732} = \frac{6.5 \times 18}{M_B \times 100}$$

$\Rightarrow M_B = 30.6$

$$\therefore \; \Delta T_b = 0.52 \times \frac{6.5 \times 1000}{30.6 \times 100} = 1.10$$

⇒ Boiling point = 100 + 1.1 = 101.1°C ≈ 101°C

(29) **(D).** For ideal solution inter molecular forces are identical so, $\Delta H_{mix} = 0$, $\Delta U_{mix} = 0$, $\Delta G_{mix} < 0$

(30) **(C).** K_f does not depend on concentration of solution. It only depends on nature of solvent so it will be unchanged.

(31) **(A).** Solutions showing negative deviation from Raoult's law form maximum boiling azeotrope Water and Nitric acid → forms maximum boiling azeotrope.

(32) **(C).** For ideal solution,
$\Delta_{mix}H = 0$; $\Delta_{mix}S > 0$; $\Delta_{mix}G < 0$; $\Delta_{mix}V = 0$