

# **SOLUTION & COLLIGATIVE PROPERTIES**

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## **Syllabus**

Raoult's law; Molecular weight determination from lowering of vapour pressure, elevation of boiling point and depression of freezing point.

Name : \_\_\_\_\_ Contact No. \_\_\_\_\_

# SOLUTION AND COLLIGATIVE PROPERTIES

## Concentration Terms :

### % Concentration

$$\bullet \text{ \% w/w} = \frac{\text{weight of solute (g)}}{\text{weight of solution (g)}} \times 100$$

$$\text{\% w/v} = \frac{\text{gram of solutes}}{\text{volume of solution in mL}} \times 100$$

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

$$M = \frac{n}{V(\text{in L})} = \left(\frac{W}{M}\right) \times \frac{1000}{V(\text{in mL})}$$

**Molality** = No. of moles of solute per kg(1000 g) of solvent.

$$\text{molality} = \left(\frac{w}{M}\right) \times \frac{1000}{W(\text{g})}$$

### Normality

$$\bullet \text{ No. of equivalents per litre of solution} = \frac{\text{no. of equivalents of solute}}{\text{volume of solution (in L)}}$$

## Mole Fraction :

For binary mixture

$$X_{\text{solute}} = \frac{\text{moles of solute}}{\text{total moles in solutions}} = \frac{n}{n+N}$$

$$X_{\text{solvent}} = \frac{\text{moles of solvent}}{\text{Total moles in solutions}} = \frac{N}{n+N}$$

$$X_{\text{solute}} + X_{\text{solvent}} = 1$$

## ppm (Parts Per Million).

$$\text{ppm (w/w)} = \frac{\text{wt. of solute (ing)}}{\text{wt. of solution (ing)}} \times 10^6 = 1 \text{ million}$$

## Colligative Properties :

### • Colligative properties :

The properties of the solution which are dependent only on the total no. of particles or total concentration of particles in the solution & are not dependent on the nature of particle i.e. shape, size, neutral / charge etc. of the particles.

There are 4 colligative properties of solution.

- Osmotic pressure
- Relative lowering in vapour pressure  $\left(\frac{\Delta P}{P}\right)$
- Elevation in boiling point ( $\Delta T_b$ )
- Depression in freezing point ( $\Delta T_f$ )

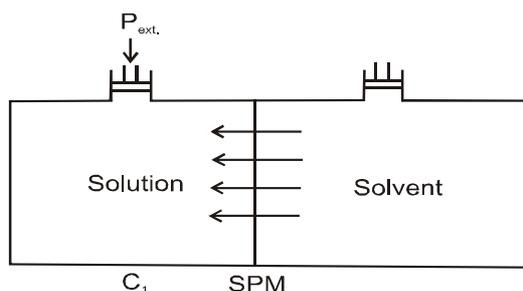
## Osmosis :

The spontaneous flow of solvent particles from solvent side to solution side or from solution of low concentration side to solution of high concentration side through a semipermeable membrane (SPM) is known as osmosis.

**SPM** : A membrane which allows only solvent particles to move across it.

- Natural : Semi permeable membrane  
Animal/plant cell membrane formed just below the outer skins.
- Artificial membranes also : A copper ferrocyanide.  
 $\text{Cu}_2[\text{Fe}(\text{CN})_6]$  & Silicate of Ni, Fe, Co can act as SPM.

## Osmotic Pressure :



**Definition** : The external pressure which must be applied on solution side to stop the process of osmosis is called osmotic pressure of the solution.

$C_1 > C_2$  particle movement.

$$P_{ext.} = (\pi_1 - \pi_2)$$

$P_{ext.}$  must be applied on the higher concentration side.

- $\pi \propto$  concentration (molarity)  
 $\propto T$   
 $\pi = CST$   
S = ideal solution constant  
 $= 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$  (exp value)  
 $= R$  (ideal gas) constant

$$\pi = \text{atm.} \left\{ \begin{array}{l} C - \text{mol/lit.} \\ R - 0.082 \text{ lit.atm. mol}^{-1} \text{ K}^{-1} \\ T - \text{kelvin} \end{array} \right.$$

$$\pi = CRT = \frac{n}{V} RT \text{ (just like ideal gas equation)}$$

## Type of solutions :

(a) **Isotonic solution** : Two solutions having same osmotic pressure are considered as isotonic solution.

$$\pi_1 = \pi_2 \text{ (at same temperature)}$$

(b) **Hypertonic** : If  $\pi_1 > \pi_2$ , 1<sup>st</sup> solution is hypertonic solution w.r.t. 2<sup>nd</sup> solution

(c) **Hypotonic** : 2<sup>nd</sup> solution is hypotonic w.r.t. 1<sup>st</sup> solution.

## Abnormal Colligative Properties :

### Vant – Hoff correction

- For electrolytic solutes the No. of particles would be different than the No. of particles actually added, due to dissociation or association of solute.
- The actual extent of dissociation/association can be expressed as a correction factor known as Vant Hoff factor ( $i$ ).

**Vant – Hoff factor** :  $i = \frac{\text{moles of particles in solution after dissociation/association}}{\text{moles of solute dissolved}}$

- If solute gets associated or dissociated in solution then experimental / observed / actual value of colligative property will be different from theoretically predicted value so it is also known as **abnormal colligative property**.

- This abnormality can be calculated in terms of Vant-Hoff factor.

$$i = \frac{\text{exp/observed/actual/abnormal value of colligative property}}{\text{Theoretical value of colligative property}}$$

$$= \frac{\text{exp./observed no. of particles or concentration}}{\text{Theoretical no. of particles or concentration}}$$

$$= \frac{\text{Theoretical mass of substance}}{\text{experimental molar mass of the substance}}$$

$i > 1$  dissociation

$i < 1$  association

$$i = \frac{\pi_{\text{exp.}}}{\pi_{\text{theor.}}}$$

### Case - I : Electrolyte dissociates

Relation between  $i$  &  $\alpha$  (degree of dissociation) :

Let the electrolyte be  $A_xB_y$



$$n = x + y$$

= no. of particles in which 1 molecules of electrolyte dissociates

$$i = \frac{C[1+(n-1)\alpha]}{C}$$

$$i = 1 + (n-1)\alpha$$

### Case - II : Electrolyte associates

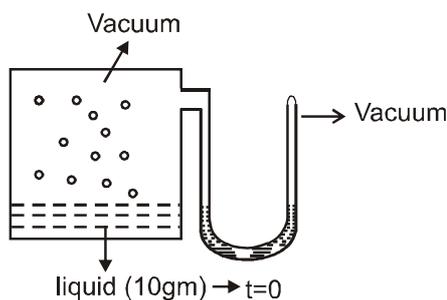
Relation between degree of association  $\beta$  &  $i$ .

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

### Relative lowering in vapour pressure ( RLVP ) :

#### ● Vapour Pressure :

The conversion of a liquid to a vapour takes place in a visible way when the liquid boils, it takes place under all conditions.

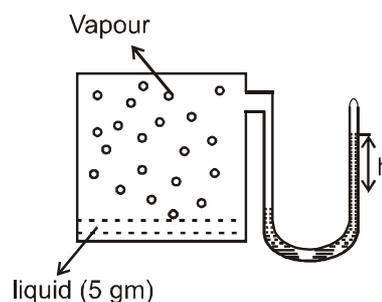


At eq. : the rate of evaporation = rate of condense

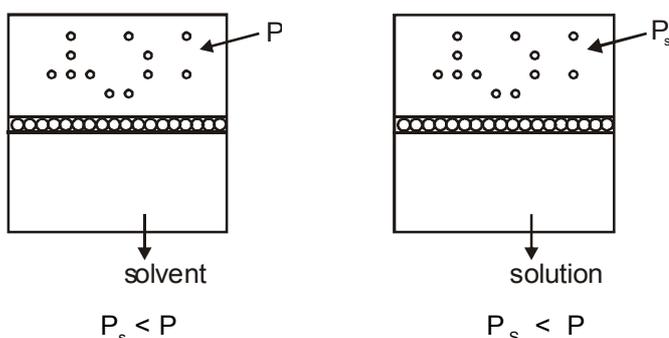


$$K_p = P_{H_2O(g)} \text{ eq.}$$

∴ finally



- Since vapour pressure is an equilibrium constant so its value is dependent only on temperature for a particular liquid
- It does not depend on the amount of liquid taken or surface area of the liquid or on volume or shape of the container. It is a characteristic constant for a given liquid.
- **Vapour Pressure of a solution**  
Vapour Pressure of a solution of a non-volatile solute (solid solute) is always found to be less than the vapour pressure of pure solvent.
- **Reason :**  
Some of the solute molecules will occupy some surface area of the solution so the tendency of the solvent particles to go into the vapour phase is slightly decreased hence



**Figure**

Lowering in Vapour pressure =  $P - P_s = \Delta P$

Relative lowering in Vapour pressure =  $\frac{\Delta P}{P}$

- **Raoult's law :** – ( For non – volatile solutes )

Experimentally relative lowering in Vapour pressure = mole fraction of the non-volatile solute in solutions.

$$\text{RLVP} = \frac{P - P_s}{P} = X_{\text{Solute}} = \frac{n}{n + N}$$

$$\frac{P - P_s}{P_s} = \frac{n}{N}$$

$$\frac{P - P_s}{P_s} = (\text{molality}) \times \frac{M}{1000} \quad (M = \text{molar mass of solvent})$$

### Elevation in Boiling point ( $\Delta T_b$ )

- **Boiling point of a Liquid :**

The temperature at which vapour pressure of a liquid becomes equal to the external pressure present at the surface of the liquid is called boiling point of liquid at that pressure.

**Using Raoult's law :**

$$\Delta T_b = K_b \times \text{molality}$$

- $K_b$  is dependent on property of solvent and known as molal elevation constant of solvent.
- It is also known as ebullioscopic constant.
- $K_b$  = elevation in boiling point of 1 molal solution.

- **Units** :  $\frac{\Delta T_b}{\text{molality}} = \frac{K}{\text{mol/kg}} = K \text{ kg mol}^{-1}$

Using thermodynamics

- $K_b = \frac{RT_b^2}{1000 \times L_{\text{vap}}}$

∴  $L_{\text{vap}}$  – is latent heat of vapourisation in cal/g or J/g

$$R = 2 \text{ cal mol}^{-1} \text{ K}^{-1} \text{ or } 8.314 \text{ J mol}^{-1} \text{ K}^{-1}.$$

$T_b$  = boiling point of liquid (in kelvin)

$$K_b = K \text{ kg mol}^{-1}$$

- Also  $K_b = \frac{RT_b^2 M}{1000 \times \Delta H_{\text{vap}}}$

$\Delta H_{\text{vap}}$  – molar enthalpy of vapourisation in cal/mole or J/mole

Here  $M \Rightarrow$  mole wt. of solvent

$$L_{\text{vap}} = \left( \frac{\Delta H_{\text{vap}}}{M} \right)$$

- If solute gets associated/dissociated.

$$\Delta T_b = i \times K_b \times \text{molality}$$

### Depression in freezing point ( $\Delta T_f$ )

**Freezing point** : Temperature at which vapour pressure of solid becomes equal to vapour pressure of liquid is called freezing point of liquid or melting point of solid.

$$\therefore \Delta T_f = K_f \cdot \text{Molality}$$

- $K_f$  = molal depression constant = cryoscopic constant

$$K_f = \frac{RT_f^2}{1000 \times L_{\text{fusion}}} = \frac{RT_f^2 M}{1000 \times \Delta H_{\text{fusion}}}$$

for water  $T_f = 273 \text{ K}$  &  $L_{\text{Fusion}} = 80 \text{ cal / gm}$

$$K_f = \frac{2 \times 273 \times 273}{1000 \times 80} = 1.86 \text{ K kg mol}^{-1}$$

**SOLUTIONS CONTAINING**  $\left. \begin{array}{l} \text{VOLATILE SOLVENT} \\ \text{VOLATILE SOLUTE} \end{array} \right\}$  Liq. solution  
 Liq. solution

According to Raoult's law (experimentally)

$$P_A \propto X_A$$

$$P_A = X_A P_A^{\circ}$$

$P_A^{\circ}$  = vapour pressure of pure liquid A = constant (at a particular temperature)

Similarly,

$$P_B \propto X_B$$

$$\therefore P_B = X_B P_B^{\circ} \text{ (vapour pressure of pure liquid B)}$$

∴ According to Dalton's law

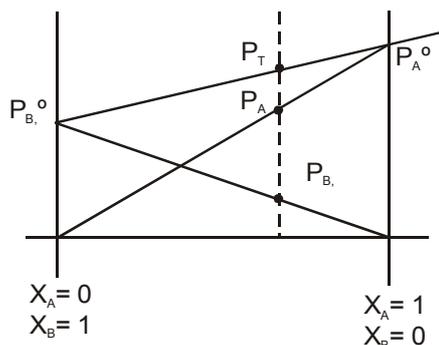
$$P_T = P_A + P_B = X_A P_A^{\circ} + X_B P_B^{\circ}$$

$x_A'$  = mole fraction of A in vapour above the liquid / solution.

$x_B'$  = mole fraction of B

$$\frac{1}{P_T} = \frac{x_A'}{P_A^{\circ}} + \frac{x_B'}{P_B^{\circ}}$$

## Graphical Representation :



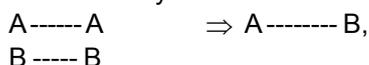
A is more volatile than B  $P_A^0 > P_B^0$

### ● Ideal solutions (mixtures) :

The mixtures which follow Raoult's law at all temperature & at all compositions will be known as ideal mixtures / ideal solution.

#### Characteristic of an ideal solution

- Ideal solution will be obtained only when the forces of attraction between the liquid molecules are exactly of same nature & almost of same magnitude



- $\Delta H_{\text{mix}} = 0$
- $\Delta V_{\text{mix}} = 0$
- $\Delta S_{\text{mix}} = + \text{ve}$  as for process to proceed
- $\Delta G_{\text{mix}} = - \text{ve}$

eg. (1) Benzene + Toluene.  
(2) Hexane + heptane.  
(3)  $\text{C}_2\text{H}_5\text{Br} + \text{C}_2\text{H}_5\text{I}$ .

### ● Non - Ideal solutions :

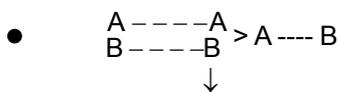
The mixtures which do not follow Raoult's law will be known as non ideal mixtures/solution.

#### Non ideal solution can be of two types :

- Non ideal solutions showing positive deviation
- Non ideal solutions showing negative deviation

#### + ve deviation

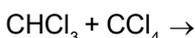
- $P_{T,\text{exp}} > (X_A P_A^0 + X_B P_B^0)$



Weaker force of attraction

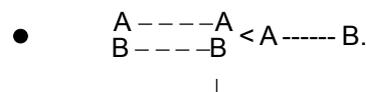
- $\Delta H_{\text{mix}} = + \text{ve}$  energy absorbed
- $\Delta V_{\text{mix}} = + \text{ve}$  (  $1\text{L} + 1\text{L} > 2\text{L}$  )
- $\Delta S_{\text{mix}} = + \text{ve}$
- $\Delta G_{\text{mix}} = - \text{ve}$

eg.  $\text{H}_2\text{O} + \text{CH}_3\text{OH}$ .  
 $\text{H}_2\text{O} + \text{C}_2\text{H}_5\text{OH}$   
 $\text{C}_2\text{H}_5\text{OH} + \text{hexane}$   
 $\text{C}_2\text{H}_5\text{OH} + \text{cyclohexane}$ .



#### -ve deviation

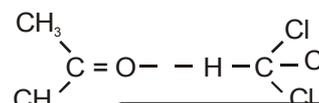
- $P_{T,\text{exp}} < X_A P_A^0 + X_B P_B^0$



strong force of attraction.

- $\Delta H_{\text{mix}} = - \text{ve}$
- $\Delta V_{\text{mix}} = - \text{ve}$  (  $1\text{L} + 1\text{L} < 2\text{L}$  )
- $\Delta S_{\text{mix}} = + \text{ve}$
- $\Delta G_{\text{mix}} = - \text{ve}$

eg.  $\text{H}_2\text{O} + \text{HCOOH}$   
 $\text{H}_2\text{O} + \text{CH}_3\text{COOH}$   
 $\text{H}_2\text{O} + \text{HNO}_3$   
 $\text{CHCl}_3 + \text{CH}_3\text{OCH}_3$



## Immiscible Liquids :

- It is used to purify an organic liquid from impurity.
- When two liquids are mixed in such a way that they do not mix at all then

$$P_{\text{total}} = P_A + P_B$$

$$P_A = P_A^0 X_A$$

$$X_A = 1$$

$$P_A = P_A^0$$

$$P_B = P_B^0 X_B$$

$$X_B = 1$$

$$P_B = P_B^0$$

$$P_{\text{total}} = P_A^0 + P_B^0$$

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

- **Henry Law :**

Henry law deal with effect of pressure on the solubility of gas.

### Statement :

The solubility of a gas in a liquid at a given temperature is directly proportional to the pressure at which it is dissolved.

Let  $X$  = Mole fraction of gas at a given temperature as a measure of its solubility.

$p$  = Partial pressure gas in equilibrium with the solution.

Then according to Henry's law.

$$X \propto p$$

or  $p \propto X$

or  $p = K_H X$

where  $K_H$  = Henry law constant.

# EXERCISE # 1

## PART - I : OBJECTIVE QUESTIONS

\* Marked Questions are having more than one correct option.

### Section (A) : Concentration terms and Their Interconversions

- A-1.** The volume of water that must be added to a mixture of 250 ml of 0.6 M HCl and 750 ml of 0.2 M HCl to obtain 0.25 M solution of HCl is :  
(A) 750 ml (B) 100 ml (C) 200 ml (D) 300 ml
- A-2.** What approximate volume of 0.40 M Ba(OH)<sub>2</sub> must be added to 50.0 mL of 0.30 M NaOH to get a solution in which the molarity of the OH<sup>-</sup> ions is 0.50 M?  
(A) 33 mL (B) 66 mL (C) 133 mL (D) 100 mL
- A-3.** 500 ml of 0.1 M KCl, 200 ml of 0.01 M NaNO<sub>3</sub> and 500 ml of 0.1 M AgNO<sub>3</sub> was mixed. The molarity of K<sup>+</sup>, Ag<sup>+</sup>, Cl<sup>-</sup>, Na<sup>+</sup>, NO<sub>3</sub><sup>-</sup> in the solution would be  
(A) [K<sup>+</sup>] = 0.0416 [Ag<sup>+</sup>] = 0.04 [Na<sup>+</sup>] = 0.002 [Cl<sup>-</sup>] = 0.04 [NO<sub>3</sub><sup>-</sup>] = 0.042  
(B) [K<sup>+</sup>] = 0.0416 [Na<sup>+</sup>] = 0.00166 [NO<sub>3</sub><sup>-</sup>] = 0.0433  
(C) [K<sup>+</sup>] = 0.04 [Ag<sup>+</sup>] = 0.05 [Na<sup>+</sup>] = 0.0025 [Cl<sup>-</sup>] = 0.05 [NO<sub>3</sub><sup>-</sup>] = 0.0525  
(D) [K<sup>+</sup>] = 0.05 [Na<sup>+</sup>] = 0.0025 [NO<sub>3</sub><sup>-</sup>] = 0.0525
- A-4.** Mole fraction of A in H<sub>2</sub>O is 0.2. The molality of A in H<sub>2</sub>O is :  
(A) 13.9 (B) 15.5 (C) 14.5 (D) 16.8
- A-5.** What is the molarity of H<sub>2</sub>SO<sub>4</sub> solution that has a density of 1.84 g/cc and contains 98% by mass of H<sub>2</sub>SO<sub>4</sub>? (Given atomic mass of S = 32)  
(A) 4.18 M (B) 8.14 M (C) 18.4 M (D) 18 M
- A-6.** The molality of a sulphuric acid solution is 0.2. Calculate the total weight of the solution having 1000 gm of solvent.  
(A) 1000 g (B) 1098.6 g (C) 980.4 g (D) 1019.6g
- A-7.** Mole fraction of C<sub>3</sub>H<sub>5</sub>(OH)<sub>3</sub> in a solution of 36 g of water and 46 g of glycerine is :  
(A) 0.46 (B) 0.36 (C) 0.20 (D) 0.40

### Section (B) : Osmosis and osmotic pressure

- B-1.** A solution containing 4 gm of a non-volatile organic solute per 100 ml was found to have an osmotic pressure equal to 500 cm of mercury at 27°C. The molecular weight of solute is -  
(A) 14.97 (B) 29.44 (C) 149.7 (D) 137.2
- B-2.** A solution containing 8.6 gm urea in one litre was found to be isotonic with a 5% (wt/vol) solution of an organic volatile solute. The molecular weight of solute is -  
(A) 348.9 (B) 34.89 (C) 861.2 (D) 86.12
- B-3.** The osmotic pressure of a solution containing 100 ml of 3.4% solution (w/v) of urea (m. wt. 60) and 50 ml of 1.6% solution (w/v) of cane-sugar (m. wt 342) at 27°C is -  
(A) 10.56 atm (B) 8.98 atm (C) 17.06 atm (D) 9.70 atm

- B-4.** Two solutions each in 100 mL having 4 g glucose and 10 g sucrose respectively. How much urea should be added to one of them in order to make them isotonic ?  
 (A) 0.4218 g urea in glucose solution (B) 0.77 g urea in glucose solution  
 (C) 0.72 g urea in sucrose solution (D) 0.421 g urea in sucrose solution
- B-5.** 5 g of a polymer of molecular weight  $50 \text{ kg mol}^{-1}$  is dissolved in  $1 \text{ dm}^3$  solution. If the density of this solution is  $0.96 \text{ kg dm}^{-3}$  at 300 K, the height of solution that will represent its osmotic pressure is -  
 (A) 28.13 mm (B) 20.85 mm (C) 26.52 mm (D) 24.94 mm
- B-6.** 100 mL aqueous solution of glucose with osmotic pressure 1.2 atm at  $25^\circ\text{C}$  is mixed with 300 mL aqueous solution of urea at 2.4 atm at  $25^\circ\text{C}$ . Osmotic pressure of the mixture is -  
 (A) 1.37 atm (B) 2.59 atm (C) 1.85 atm (D) 2.13 atm
- B-7.** 10 g of solute A and 20 g of solute B are present in 500 mL of solution. The solution has the same osmotic pressure as 6.67 g of A and 30 g of B present in same volume of solution at same temperature. The ratio of molar masses of solute A and B will be -  
 (A) 0.25 (B) 0.66 (C) 0.33 (D) 0.75
- B-8.** At  $10^\circ\text{C}$ , the osmotic pressure of urea solution is 500 mm. The solution is diluted and the temperature is raised to  $25^\circ\text{C}$ , when the osmotic pressure is found to be 105.3 mm. Find out the extent of dilution  
 (A) 5 (B) 2.5 (C) 1.25 (D) 6.5
- B-9.** The relation ship between osmotic pressure at 273 K, when 10 gm glucose ( $P_1$ ), 10 gm urea ( $P_2$ ) and 10 gm sucrose ( $P_3$ ) are dissolved in 250 ml of water is  
 (A)  $P_1 > P_2 > P_3$  (B)  $P_3 > P_1 > P_2$  (C)  $P_2 > P_1 > P_3$  (D)  $P_2 > P_3 > P_1$
- B-10.** What osmotic pressure would the 1.25 molal sucrose solution exhibit at  $25^\circ\text{C}$  ? The density of this solution is  $1.34 \text{ g/mL}$ .  
 (A) 28.70 atm (B) 30.22 atm (C) 21.72 atm (D) 24.55 atm
- B-11.** At certain temperature, the osmotic pressure of an aqueous solution of urea was found to be 405 mm. How many times the solution should be diluted in order to exhibit the osmotic pressure of 81 mm at the same temperature ?  
 (A) 2 times (B) 4 times (C) 8 times (D) 5 times
- B-12.** If 'A' contains 2% NaCl and is separated by a semipermeable membrane from 'B' which contains 10% NaCl, which event will occur ?  
 (A) NaCl will flow from 'A' to 'B' (B) NaCl will flow from 'B' to 'A'  
 (C) Water will flow from 'A' to 'B' (D) Water will flow from 'B' to 'A'
- B-13.** Osmotic pressure of blood is 7.40 atm at  $27^\circ\text{C}$ . Number of mol of glucose to be used per L for an intravenous injection that is to have the same osmotic pressure as blood is :  
 (A) 0.3 (B) 0.2 (C) 0.1 (D) 0.4
- B-14.** A solution of glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) is isotonic with 4 g of urea ( $\text{NH}_2\text{-CO-NH}_2$ ) per liter of solution. The concentration of glucose is :  
 (A)  $4 \text{ g/l}$  (B)  $8 \text{ g/l}$  (C)  $12 \text{ g/l}$  (D)  $14 \text{ g/l}$
- B-15.** A solution of a substance containing 1.05 g per 100 mL. was found to be isotonic with 3% glucose solution. The molecular mass of the substance is :  
 (A) 31.5 (B) 6.3 (C) 630 (D) 63
- B-16.** Osmotic pressure of 30% solution of glucose is 1.20 atm and that of 3.42% solution of cane sugar is 2.5 atm. The osmotic pressure of the mixture containing equal volumes of the two solutions will be  
 (A) 2.5 atm (B) 3.7 atm (C) 1.85 atm (D) 1.3 atm.

## Section (C) : Vont Hoff factor and its application

- C-1.** An electrolyte A gives 3 ions and B is a non-electrolyte. If 0.1 M solution of B produces an osmotic pressure P, then 0.05 M solution of A will produce an osmotic pressure, assuming that the electrolyte is completely ionised.  
(A) 1.5 P (B) P (C) 0.5 P (D) 0.75 P
- C-2.** Which is the correct relation between osmotic pressure of 0.1 M NaCl solution and 0.1 M Na<sub>2</sub>SO<sub>4</sub> solution?  
(A) the osmotic pressure of Na<sub>2</sub>SO<sub>4</sub> is less than NaCl solution  
(B) the osmotic pressure of Na<sub>2</sub>SO<sub>4</sub> is more than NaCl solution  
(C) both have same osmotic pressures  
(D) none of the above
- C-3.** Which one of the following pairs of solutions will be expected to be isotonic under the same temperature?  
(A) 0.1 M urea and 0.1 M NaCl (B) 0.1 M urea and 0.2 M MgCl<sub>2</sub>  
(C) 0.1 M NaCl and 0.1 M Na<sub>2</sub>SO<sub>4</sub> (D) 0.1 M Ca(NO<sub>3</sub>)<sub>2</sub> and 0.1 M Na<sub>2</sub>SO<sub>4</sub>
- C-4.** The van't Hoff factor of a 0.005 M aqueous solution of KCl is 1.95. The degree of ionisation of KCl is -  
(A) 0.95 (B) 0.97 (C) 0.94 (D) 0.96
- C-5.** Two solution of KNO<sub>3</sub> and CH<sub>3</sub>COOH are prepared separately molarity of both in 0.1 M and osmotic pressure are P<sub>1</sub> & P<sub>2</sub>. The correct relationship between the osmotic pressure is -  
(A) P<sub>2</sub> > P<sub>1</sub> (B) P<sub>1</sub> > P<sub>2</sub> (C) P<sub>1</sub> = P<sub>2</sub> (D)  $\frac{P_1}{P_1 + P_2} + \frac{P_2}{P_1 + P_2}$
- C-6.** A 5.8% wt/vol. NaCl solution will exert an osmotic pressure closest to which one of the following -  
(A) 5.8% (wt/vol) sucrose solution (B) 5.8% (wt/vol) glucose solution  
(C) 2 molal sucrose solution (D) 1 molal glucose solution
- C-7.** Sea water is found to contain NaCl & MgCl<sub>2</sub>. If NaCl is 80% ionised and MgCl<sub>2</sub> is 50% ionised then van't Hoff factor is -  
(A) 1.3 (B) 5.0 (C) 3.3 (D) 3.8
- C-8.\*** In which case van't Hoff factor are equal ?  
(A) KCl, 50% ionised (B) K<sub>2</sub>SO<sub>4</sub>, 40% ionised  
(C) FeCl<sub>3</sub>, 30% ionised (D) SnCl<sub>4</sub>, 20% ionised
- C-9.** The osmotic pressure of equimolar solutions of BaCl<sub>2</sub>, NaCl and glucose will be in the order  
(A) glucose > NaCl > BaCl<sub>2</sub> (B) BaCl<sub>2</sub> > NaCl > glucose  
(C) NaCl > BaCl<sub>2</sub> > glucose (D) NaCl > glucose > BaCl<sub>2</sub>
- C-10.\*** For the given electrolyte A<sub>x</sub>B<sub>y</sub>, the degree of dissociation 'α' can be given as  
(A)  $\alpha = \frac{i-1}{x+y-1}$  (B)  $i = (1-\alpha) + x\alpha + y\alpha$  (C)  $\alpha = \frac{1-i}{1-x-y}$  (D) None

## Section (D) : Relative Lowering of vapour pressure (RAOULT'S LAW)

- D-1.** The vapour pressure of ether at 20°C is 442 mm. When 7.2 g of a solute is dissolved in 60 g ether, vapour pressure is lowered by 32 units. If molecular weight of ether is 74 then molecular weight of solute is -  
(A) 113.77 (B) 150.35 (C) 116.23 (D) 190.26
- D-2.** The vapour pressure of pure benzene at 25°C is 639.7 mm of Hg and the vapour pressure of a solution of a solute in C<sub>6</sub>H<sub>6</sub> at the same temperature is 631.9 mm of Hg. Molality of solution is -  
(A) 0.079 mol/kg of solvent (B) 0.256 mol/kg of solvent  
(C) 0.158 mol/kg of solvent (D) 0.316 mol/kg of solvent

- D-3.** Find out the weight of solute (M. wt. 60) that is required to dissolve in 180 g water to reduce the vapour pressure to  $\frac{4}{5}$ th of pure water -  
 (A) 130 g (B) 150 g (C) 300 g (D) 75 g
- D-4.** The molality of a solution containing a non-volatile solute if the vapour pressure is 2% below the vapour pressure of pure water, will be -  
 (A) 2.213 (B) 2.518 (C) 1.133 (D) 1.891
- D-5.** The weight of a non-volatile solute (m. wt. 40). Which should be dissolved in 114 g octane to reduce its vapour pressure to 80%, is -  
 (A) 20 gm (B) 10 gm (C) 7.5 gm (D) 5 gm
- D-6.** Twenty gram of a solute are added to 100 g of water at 25°C. The vapour pressure of pure water is 23.76 mm Hg, vapour pressure of solution is 22.41 mm Hg. The mass of this solute that is required in 100 g water to reduce the vapour pressure to one-half of the pure water is -  
 (A) 333 g (B) 666 g (C) 166 g (D) 256 g
- D-7.** Vapour pressure of pure water is 40 mm. If a non-volatile solute is added to it vapour pressure falls by 4 mm. Hence, molality of solution is -  
 (A) 6.173 molal (B) 3.0864 molal (C) 1.543 molal (D) 0.772 molal
- D-8.** The vapour pressure of pure liquid solvent A is 0.80 atm. When a non-volatile substance B is added to the solvent, its vapour pressure drops to 0.60 atm ; mole fraction of the component B in the solution is  
 (A) 0.50 (B) 0.25 (C) 0.75 (D) 0.40
- D-9.** Vapour pressure of  $\text{CCl}_4$  at 25°C is 143 mm Hg. If 0.5 gm of non-volatile solute (mol. mass 65) is dissolved in 100 ml  $\text{CCl}_4$ , then the vapour pressure of the solution at 25°C is -  
 [ Given : Density of  $\text{CCl}_4 = 1.58 \text{ g/cm}^3$  ]  
 (A) 141.93 mm (B) 94.39 mm (C) 199.34 mm (D) 143.99 mm
- D-10.** The vapour pressure of a liquid decreases by 10 torr when a non-volatile solute is dissolved. The mole fraction of the solute in solution is 0.1. What would be the mole fraction of the liquid if the decrease in vapour pressure is 20 torr, the same solute being dissolved -  
 (A) 0.2 (B) 0.9 (C) 0.8 (D) 0.6
- D-11.** How many grams of sucrose must be added to 360 g of water to lower the vapour pressure by 1.19 mmHg at a temperature at which pressure of pure water is 25 mm Hg ?  
 (A) 342 g (B) 360 g (C) 375 g (D) 380 g
- D-12.** The vapour pressure of water depends upon :  
 (A) Surface area of container (B) Volume of container  
 (C) Temperature (D) All
- D-13.** Among the following substances, the lowest vapour pressure is exerted by -  
 (A) Water (B) Mercury (C) Kerosene (D) Rectified spirit
- D-14.** A sample of air is saturated with benzene (vapor pressure = 100 mm Hg at 298 K) at 298K, 750mm Hg pressure. If it is isothermally compressed to one third of its initial volume, the final pressure of the system is  
 (A) 2250 torr (B) 2150 torr (C) 2050 torr (D) 1950 torr
- D-15.** If  $P_0$  and  $P$  are the vapour pressures of a solvent and its solution respectively and  $N_1$  and  $N_2$  are the mole fractions of the solvent and non-volatile solute respectively, then correct relation is :  
 (A)  $P = P_0 N_2$  (B)  $P = P_0 N_1$  (C)  $P_0 = P N_1$  (D)  $P = P_0 (N_1/N_2)$

- D-16.** The vapour pressure of pure liquid A is 10 torr and at the same temperature when 1 g of B solid is dissolved in 20 g of A, its vapour pressure is reduced to 9.0 torr. If the molecular mass of A is 200 amu, then the molecular mass of B is :  
 (A) 100 amu (B) 90 amu (C) 75 amu (D) 120 amu
- D-17.** The vapour pressure of water at room temperature is lowered by 5% by dissolving a solute in it, then the approximate molality of solution is :  
 (A) 2 (B) 1 (C) 4 (D) 3
- D-18.** The vapour pressure of a dilute aqueous solution of glucose is 750 mm of mercury at 373 K. The mole fraction of solute is -  
 (A)  $\frac{1}{10}$  (B)  $\frac{1}{7.6}$  (C)  $\frac{1}{35}$  (D)  $\frac{1}{76}$

### Section (E) : Elevation in boiling point

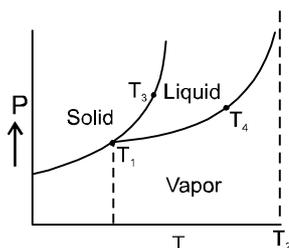
- E-1.** Pressure cooker reduces cooking time because  
 (A) the heat is more evenly distributed inside the cooker  
 (B) a large flame is used  
 (C) boiling point of water is elevated  
 (D) whole matter is converted into steam
- E-2.** At higher altitudes, water boils at temperature  $< 100^\circ\text{C}$  because  
 (A) temperature of higher altitudes is low  
 (B) atmospheric pressure is low  
 (C) the proportion of heavy water increases  
 (D) atmospheric pressure becomes more.
- E-3.** Y gm of non-volatile organic substance of molecular mass M is dissolved in 250 gm benzene. Molal elevation constant of benzene is  $K_b$ . Elevation in its boiling point is given by :  
 (A)  $\frac{M}{K_b Y}$  (B)  $\frac{4K_b Y}{M}$  (C)  $\frac{K_b Y}{4M}$  (D)  $\frac{K_b Y}{M}$
- E-4.\*** Which has the equal boiling point ?  
 (A) 0.1 M  $\text{Na}_2\text{SO}_4$  (B) 0.1 M  $\text{C}_6\text{H}_{12}\text{O}_6$  (glucose)  
 (C) 0.1 M  $\text{MgCl}_2$  (D) 0.1 M  $\text{Al}(\text{NO}_3)_3$
- E-5.** 1 mol each of following solutes are taken in 5 mol water,  
 A. NaCl B.  $\text{K}_2\text{SO}_4$  C.  $\text{Na}_3\text{PO}_4$  D. glucose  
 Assuming 100% ionisation of the electrolyte, relative decrease in vapour pressure will be in order :  
 (A)  $A < B < C < D$  (B)  $D < C < B < A$  (C)  $D < A < B < C$  (D) same
- E-6.** Consider equimolal aqueous solutions of  $\text{NaHSO}_4$  and  $\text{NaCl}$  with  $\Delta T_b$  and  $\Delta T'_b$  as their respective boiling point elevations. The value of  $\lim_{m \rightarrow 0} \frac{\Delta T_b}{\Delta T'_b}$  will be :  
 (A) 1 (B) 1.5 (C) 3.5 (D) 2 / 3
- E-7.** Aluminium phosphate is 100% ionised in 0.01 molal aqueous solution. Hence,  $\Delta T_b / K_b$  is :  
 (A) 0.01 (B) 0.015 (C) 0.0175 (D) 0.02
- E-8.** 1.0 molal aqueous solution of an electrolyte  $\text{X}_3\text{Y}_2$  is 25% ionized. The boiling point of the solution is ( $K_b$  for  $\text{H}_2\text{O} = 0.52 \text{ K kg/mol}$ )  
 (A) 375.5 K (B) 374.04 K (C) 377.12 K (D) 373.25 K

- E-9.** A solution containing 28 g of phosphorus in 315 g CS<sub>2</sub> (b.p. 46.3°C) boils at 47.98°C. If K<sub>b</sub> for CS<sub>2</sub> is 2.34 K kg mol<sup>-1</sup>. The formula of phosphorus is (at. mass of P = 31).  
 (A) P<sub>6</sub> (B) P<sub>4</sub> (C) P<sub>3</sub> (D) P<sub>2</sub>.
- E-10.** A solution containing 0.52 g of C<sub>10</sub>H<sub>8</sub> in CCl<sub>4</sub> produced an elevation in boiling point by 0.402°C. On the other hand a solution of 0.62 g of an unknown solute dissolved in same amount of CCl<sub>4</sub> produced an elevation by 0.65°C. Molecular weight of solute is :  
 (A) 85.53 (B) 181.51 (C) 94.38 (D) 160.62
- E-11.** 0.65 g naphthalene (C<sub>10</sub>H<sub>8</sub>) was dissolved in 100 g methyl acetate. Elevation of b. pt of methyl acetate solution was 0.103°C. If b. pt. of pure methyl acetate is 57°C, its molar heat of vaporisation will be -  
 (A) 8.96 kcal mol<sup>-1</sup> (B) 7.946 kcal mol<sup>-1</sup> (C) 6.24 kcal mol<sup>-1</sup> (D) 15.65 kcal mol<sup>-1</sup>
- E-12.** When 174.5 mg of octa-atomic sulphur is added to 78 g of bromine, the boiling point of bromine is -  
 [Given K<sub>b</sub> for Br<sub>2</sub> is 5.2 K mol<sup>-1</sup> kg and b. pt. of Br<sub>2</sub> is 332.15 K ]  
 (A) 415.23 K (B) 330 K (C) 220.92 K (D) 332.19 K
- E-13.** The molal boiling point constant of water is 0.53°C. When 2 mole of glucose are dissolved in 4000 gm of water, the solution will boil at :  
 (A) 100.53°C (B) 101.06°C (C) 100.265°C (D) 99.47°C

### Section (F) : Depression in freezing point

- F-1.** The boiling point of an aqueous solution of a non-volatile solute is 100.15°C. What is the freezing point of an aqueous solution obtained by diluting the above solution with an equal volume of water ?  
 [ K<sub>b</sub> and K<sub>f</sub> for water are 0.512 and 1.86 K molality<sup>-1</sup> ]  
 (A) -0.544°C (B) -0.512°C (C) -0.272°C (D) -1.86°C
- F-2.** Elevation in b. p of a solution of non-electrolyte in CCl<sub>4</sub> is 0.60. What is depression in f. p. for the same solution? K<sub>f</sub> (CCl<sub>4</sub>) = 30.00 kg mol<sup>-1</sup> K ; K<sub>b</sub> (CCl<sub>4</sub>) = 5.02 kg mol<sup>-1</sup> K.  
 (A) 0° (B) 5.39° (C) 3.59° (D) 2.49°
- F-3.** The freezing point of a solution prepared from 1.25 gm of non-electrolyte and 20 gm of water is 271.9 K. If molar depression constant is 1.86 K molality<sup>-1</sup>. Then molar mass of the solute will be -  
 (A) 105.68 (B) 106.7 (C) 115.3 (D) 93.9
- F-4.** Density of 1 M solution of a non-electrolyte C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> is 1.18 g/mL. If K<sub>f</sub> (H<sub>2</sub>O) is 1.86 K mol<sup>-1</sup> kg, solution freezes at :  
 (A) 1.58°C (B) -1.86°C (C) -3.16°C (D) 1.86°C
- F-5.** When a solution containing w g of urea in 1 kg of water is cooled to -.372°C, 200 g of ice is separated. If K<sub>f</sub> for water is 1.86 K kg mol<sup>-1</sup>, w is -  
 (A) 4.8 g (B) 12.0 g (C) 9.6 g (D) 6.0 g
- F-6.** Glucose is added to 1 litre water to such an extent that ΔT<sub>f</sub>/K<sub>f</sub> becomes equal to 1/1000, the weight of glucose added is  
 (A) 180 gm (B) 18 gm (C) 1.8 gm (D) 0.18 gm
- F-7.** 4.00 g of substance A, dissolved in 100 g H<sub>2</sub>O depressed the f. pt. of water by 0.1°C. While 4 g of another substance B, depressed the f. pt. by 0.2 °C. What is the relation between molecular weights of the two substance -  
 (A) M<sub>A</sub> = 4M<sub>B</sub> (B) M<sub>A</sub> = M<sub>B</sub> (C) M<sub>A</sub> = 0.5M<sub>B</sub> (D) M<sub>A</sub> = 2M<sub>B</sub>

- F-8.** The temperature at which ice will begin to separate from a mixture of 20 mass percent of glycol ( $C_2H_6O_2$ ) in water, is - [ $K_f(\text{water}) = 1.86 \text{ K kg mol}^{-1}$ ]  
 (A) 280.5 K (B) 265.5 K (C) 276.5 K (D) 269.5 K
- F-9.** Which of the following has been arranged in order of decreasing freezing point?  
 (A)  $0.05 \text{ M KNO}_3 > 0.04 \text{ M CaCl}_2 > 0.140 \text{ M sugar} > 0.075 \text{ M CuSO}_4$   
 (B)  $0.04 \text{ M BaCl}_2 > 0.140 \text{ M sucrose} > 0.075 \text{ M CuSO}_4 > 0.05 \text{ M KNO}_3$   
 (C)  $0.075 \text{ M CuSO}_4 > 0.140 \text{ M sucrose} > 0.04 \text{ M BaCl}_2 > 0.05 \text{ M KNO}_3$   
 (D)  $0.075 \text{ M CuSO}_4 > 0.05 \text{ M NaNO}_3 > 0.140 \text{ M sucrose} > 0.04 \text{ M BaCl}_2$
- F-10.** Aqueous solution of barium phosphate which is 100% ionised has  $\Delta T_f / K_f$  as 0.05. Hence, given solution is:  
 (A) 0.01 molal (B) 0.02 molal (C) 0.04 molal (D) 0.05 molal
- F-11.** Observe the P-T phase diagram for a given substance A. Then melting point of A(s), boiling point of A(l), critical point of A and triple point of A (at their respective pressures) are respectively :



- (A)  $T_1, T_2, T_3, T_4$  (B)  $T_4, T_3, T_1, T_2$  (C)  $T_3, T_4, T_2, T_1$  (D)  $T_2, T_1, T_3, T_4$

### Section (G) : Raoult's law

- G-1.** Mixture of volatile components A and B has total vapour pressure (in Torr)  $p = 254 - 119 x_A$  where  $x_A$  is mole fraction of A in mixture. Hence  $p_A^0$  and  $p_B^0$  are (in Torr)  
 (A) 254, 119 (B) 119, 254 (C) 135, 254 (D) 119, 373
- G-2.** What is the mole ratio of benzene ( $P_B^0 = 150 \text{ torr}$ ) and toluene ( $P_T^0 = 50 \text{ torr}$ ) in vapour phase if the given solution has a vapour pressure of 120 torr?  
 (A) 7 : 1 (B) 7 : 3 (C) 8 : 1 (D) 7 : 8
- G-3.** At 323 K, the vapour pressure in millimeters of mercury of a methanol-ethanol solution is represented by the equation  $p = 120 X_A + 140$ , where  $X_A$  is the mole fraction of methanol. Then the value of  $\lim_{x_A \rightarrow 1} \frac{p_A}{X_A}$  is  
 (A) 250 mm (B) 140 mm (C) 260 mm (D) 20 mm
- G-4.** Two liquids A and B form ideal solution at 300 K. The vapour pressure of a solution containing one mole of A and four mole of B is 560 mm of Hg. At the same temperature if one mole of B is taken out from the solution, the vapour pressure of solution decreases by 10 mm of Hg. Vapour pressures of A and B in pure state will be:  
 (A) 330, 550 (B) 200, 300 (C) 400, 600 (D) 800, 1200
- G-5.** The vapour pressure of two volatile liquid mixture is  $P_T = (5.3 - 2X_B)$  in cm of Hg ; where  $X_B$  is mole fraction of B in mixture. What are vapour pressure of pure liquids A and B ?  
 (A) 3.3 and 2.1 cm of Hg (B) 2.3 and 3.3 cm of Hg  
 (C) 5.3 and 2.3 cm of Hg (D) 5.3 and 3.3 cm of Hg

- G-6.** At 40°C the vapour pressure in torr of methanol and ethanol solution is  $P = 119x + 135$  where  $x$  is the mole fraction of methanol, hence,  
 (A) vapour pressure of pure methanol is 119 torr  
 (B) vapour pressure of pure ethanol is 135 torr  
 (C) vapour pressure of equimolar mixture of each is 127 torr  
 (D) mixture is completely immiscible
- G-7.** Solution of two volatile liquids A and B obey Raoult's law. At a certain temperature, it is found that when the total vapour pressure above solution is 400 mm of Hg, the mole fraction of A in vapour phase is 0.45 and in liquid phase 0.65 then the vapour pressures of two pure liquids at the same temperature will be -  
 (A) 138.4 mm, 628.57 mm (B) 276.9 mm, 628.57 mm  
 (C) 276.9 mm, 314.28 mm (D) 138.4 mm, 314.28 mm
- G-8.** The vapour pressure of benzene and toluene at 20°C are 75 mm of Hg and 22 mm of Hg respectively. 23.4 g of benzene and 64.4g of toluene are mixed. If two forms ideal solution, the mole fraction of benzene in vapour phase when vapours are in equilibrium with liquid mixture, is -  
 (A) 0.59, 0.41 (B) 0.25, 0.75 (C) 0.5, 0.5 (D) 0.35, 0.65
- G-9.** The vapour pressure of two liquids are 15000 and 30000 in a unit. When equimolar solution of liquids is made. Then the mole fraction of A and B in vapour phase will be :  
 (A)  $\frac{2}{3}, \frac{1}{3}$  (B)  $\frac{1}{3}, \frac{2}{3}$  (C)  $\frac{1}{2}, \frac{1}{2}$  (D)  $\frac{1}{4}, \frac{3}{4}$
- G-10.** At 90°C, the vapour pressure of toluene is 400 mm and that of xylene is 150 mm. The composition of liquid mixture that will boil at 90°C when the pressure of mixture is 0.5 atm, is -  
 (A) 0.8, 0.2 (B) 0.75, 0.25 (C) 0.92, 0.08 (D) 0.66, 0.34
- G-11.** Mole fraction of a liquid A in an ideal mixture with another liquid b is  $X_A$ . If  $X'_A$  is the mole fraction of component A in the vapour in equilibrium, the total pressure of the liquid mixture is -  
 ( $P^\circ_A$  = vapour pressure of pure A ;  $P^\circ_B$  = vapour pressure of pure B )  
 (A)  $P^\circ_A \frac{X'_A}{X_A}$  (B)  $\frac{P^\circ_A X_A}{X'_A}$  (C)  $\frac{P^\circ_B X'_A}{X_A}$  (D)  $\frac{P^\circ_B X_A}{X'_A}$

## Section (H) : Ideal and Non-ideal solution and fractional and steam distillation

- H-1.\*** Which of the following is correct for an ideal solution ?  
 (A) Raoult's law is obeyed for entire concentration range and temperatures  
 (B)  $\Delta H_{\text{mix}} = 0$  (C)  $\Delta V_{\text{mix}} = 0$  (D)  $\Delta S_{\text{mix}} = 0$
- H-2.** Which of the following is less than zero for ideal solutions ?  
 (A)  $\Delta H_{\text{mix}}$  (B)  $\Delta V_{\text{mix}}$  (C)  $\Delta G_{\text{mix}}$  (D)  $\Delta S_{\text{mix}}$
- H-3.** Consider a binary mixture of volatile liquids. If at  $X_A = 0.4$  the vapour pressure of solution is 580 torr then the mixture could be ( $p_A^\circ = 300$  torr,  $p_B^\circ = 800$  torr) :  
 (A)  $\text{CHCl}_3 - \text{CH}_3\text{COCH}_3$  (B)  $\text{C}_6\text{H}_5\text{Cl} - \text{C}_6\text{H}_5\text{Br}$   
 (C)  $\text{C}_6\text{H}_6 - \text{C}_6\text{H}_5\text{CH}_3$  (D)  $n\text{C}_6\text{H}_{14} - n\text{C}_7\text{H}_{16}$
- H-4.\*** Which of the following will form non-ideal solution ?  
 (A)  $\text{C}_2\text{H}_5\text{OH}$  and water (B)  $\text{HNO}_3$  and water  
 (C)  $\text{CHCl}_3$  and  $\text{CH}_3\text{COCH}_3$  (D)  $\text{C}_6\text{H}_6$  and  $\text{C}_6\text{H}_5\text{CH}_3$
- H-5.** Which of the following shows negative deviation from Raoult's law ?  
 (A)  $\text{CHCl}_3$  and acetone (B)  $\text{CHCl}_3$  and  $\text{C}_2\text{H}_5\text{OH}$  (C)  $\text{C}_6\text{H}_5\text{CH}_3$  and  $\text{C}_6\text{H}_6$  (D)  $\text{C}_6\text{H}_6$  and  $\text{CCl}_4$
- H-6.** A maxima or minima obtained in the temperature composition curve of a mixture of two liquids indicates  
 (A) an azeotropic mixture  
 (B) an eutectic formation  
 (C) that the liquids are immiscible with one another  
 (D) that the liquids are partially miscible at the maximum or minimum

## PART - II : MISCELLANEOUS QUESTIONS

### COMPREHENSION

#### Comprehension # 1

Read the following comprehension and answer the questions.

The main application of osmotic pressure measurement is in the determination of the molar mass of a substance which is either slightly soluble or has a very high molar mass such as proteins, polymers of various types and colloids. This is due to the fact that even a very small concentration of the solution produces fairly large magnitude of osmotic pressure. In the laboratory the concentrations usually employed are of the order of  $10^{-3}$  to  $10^{-4}$  M. At concentration of  $10^{-3}$  mol  $\text{dm}^{-3}$ , the magnitude of osmotic pressure at 300 K is :

$$P = 10^{-3} \times 0.082 \times 300 = 0.0246 \text{ atm}$$
$$\text{or } 0.0246 \times 1.01325 \times 10^5 = 2492.595 \text{ Pa}$$

At this concentration, the values of other colligative properties such as boiling point elevation and depression in freezing point are too small to be determined experimentally.

Further polymers have following two types of molar masses :

(A) Number average molar mass ( $\bar{M}_n$ ), which is given by  $\frac{\sum_i N_i M_i}{\sum_i N_i}$

where  $N_i$  is the number of molecules having molar mass  $M_i$ .

(B) Mass average molar mass ( $\bar{M}_m$ ), which is given by  $\frac{\sum_i N_i M_i^2}{\sum_i N_i M_i}$

Obviously the former is independent of the individual characteristics of the molecules and gives equal weightage to large and small molecules in the polymer sample. On the other hand later gives more weightage to the heavier molecules. Infact with the help of a colligative property only one type of molar mass of the polymer can be determined.

- One gram each of polymer A (molar mass = 2000) and B (molar mass = 6000) is dissolved in water to form one litre solution at  $27^\circ\text{C}$ . The osmotic pressure of this solution will be  
(A) 0.0164 atm      (B) 1862 Pa      (C) both are correct      (D) none of these
- What will be the observed molecular weight of the above polymer sample generating osmotic pressure equal to the answer in the previous question at  $27^\circ\text{C}$  :  
(A) 4000      (B) 3000      (C) 2500      (D) 1200
- Answer of the previous question will correspond to  
(A) Number average molar mass of the polymer sample  
(B) Mass average molar mass of the polymer sample  
(C) For the given sample ( $\bar{M}_n$ ) will be equal to ( $\bar{M}_m$ )  
(D) It is impossible to determine ( $\bar{M}_n$ ) by osmotic pressure measurements
- Which of the following solutions of NaOH in water will be able to generate osmotic pressure equal to the answer of question number 24 at  $27^\circ\text{C}$  assuming NaOH to be completely ionised  
(A) M/1000      (B) M/1500      (C) M/2000      (D) M/3000
- What will be the value of  $\Delta T_f$  for the solution in question 4. Given that molal depression constant for water is  $1.86 \text{ K kg mol}^{-1}$  and density of solution equal to  $1 \text{ gm/cc}$   
(A) 0.00248      (B) 0.00372      (C) 0.00124      (D) 0.00062

## Comprehension # 2

When a liquid is completely miscible with another liquid, a homogeneous solution consisting of a single phase is formed. If such a solution is placed in a closed evacuated vessel, the total pressure exerted by the vapour, after the system attained equilibrium will be equal to the sum of partial pressures of the constituents. A solution is said to be ideal if its constituents follow Raoult's law under all conditions of concentrations. i.e., the partial pressures of each and every constituent is given by  $p_i = x_i p_i^0$  where  $p_i$  is the partial pressures of the constituent  $i$ , whose mole fraction in the solution is  $x_i$  and  $p_i^0$  is the corresponding vapour pressure of the pure constituent.

The changes in the thermodynamic functions when an ideal solution is formed by mixing pure components is given by the following expression.

$$\Delta_{\text{mix}} G = n_{\text{total}} RT \sum_i x_i \ln x_i \quad \dots(\text{i})$$

where  $n_{\text{total}}$  is the total amount of all the constituents present in the solution.

$$\Delta_{\text{mix}} S = - n_{\text{total}} R \sum_i x_i \ln x_i \quad \dots(\text{ii})$$

$$\Delta_{\text{mix}} H = n_{\text{total}} RT \sum_i x_i \ln x_i - n_{\text{total}} R \sum_i x_i \ln x_i = 0 \quad \dots(\text{iii})$$

$$\Delta_{\text{mix}} U = 0. \quad \dots(\text{iv})$$

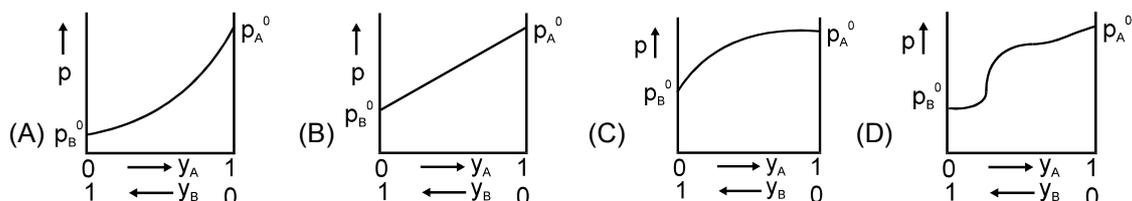
Since both the components of an ideal binary liquid system follow Raoult's law of the entire range of the composition, the partial pressure exerted by the vapours of these constituents over the solution will be given by

$$p_A = x_A p_A^0 \quad \dots(\text{v})$$

$$p_B = x_B p_B^0 \quad \dots(\text{vi})$$

where  $x_A$  and  $x_B$  are the mole fractions of the two constituents in the liquid phase and  $p_A^0$  and  $p_B^0$  are the respective vapour pressures of the pure constituents. The total pressure ( $p$ ) over the solution will be the sum of the partial pressures. The composition of the vapour phase ( $y_A$ ) can be determined with the help of Dalton's law of partial pressures.

6. For an ideal solution in which  $p_A^0 > p_B^0$ , the plot of total pressure ( $p$ ) verses the mole fraction of A at constant temperature in the vapour phase is :



7. A plot of reciprocal of total pressure  $\left(\frac{1}{p}\right)$  (y-axis) verses  $y_A$  (x-axis) gives

(A) an linear plot with slope =  $\left(\frac{1}{p_B^0} - \frac{1}{p_A^0}\right)$       (B) a linear plot with slope =  $\left(\frac{1}{p_A^0} - \frac{1}{p_B^0}\right)$

(C) a linear plot with slope =  $\frac{1}{p_B^0}$       (D) a linear plot with slope =  $p_A^0 p_B^0$

8. Two liquids A and B form an ideal solution at temperature T. When the total vapour pressure above the solution is 600 torr, the mole fraction of A in the vapour phase is 0.35 and in the liquid phase 0.70. The vapour pressures of pure B and A are  
 (A) 800 torr ; 1300 torr    (B) 1300 torr ; 300 torr    (C) 300 torr ; 1300 torr    (D) 300 torr ; 800 torr

## MATCH THE COLUMN

### 9. Column I Properties

- (a) Molal depression constant ( $K_f$ )
- (b) degree of dissociation
- (c) degree of association
- (d) Van't Hoff factor
- (e)  $M_{\text{solute}}$  (observed)

### Column II Formula

- (i)  $\frac{1000 \times K_f \times W}{W \times \Delta T_f}$
- (ii)  $\frac{i-1}{\frac{1}{n}-1}$
- (iii)  $\frac{M_{\text{solute}}(\text{normal})}{M_{\text{solute}}(\text{observed})}$
- (iv)  $\frac{i-1}{n-1}$
- (v)  $\frac{R T_f^2}{1000 \times L_f}$

### 10. Column I

#### Condition for various solutions

- (a)  $P_A + P_B < P_A^\circ x_A + P_B^\circ x_B$
- (b) A–B attractive forces should be weaker than B–B attractive forces.
- (c)  $\Delta V_{\text{mix}} > 0$  & Endothermic dissolution
- (d)  $\Delta H_{\text{mix}} < 0$  & volume decreased during dissolution
- (e) Raoult's law is obeyed at every range of temperature

### Column II

#### Type of solutions

- (i) Positive deviation from ideal behaviour
- (ii) Negative deviation from ideal behaviour
- (iii) Ideal solution

### 11. Column -I

- (a) Relative lowering in vapour pressure
- (b) Depression in freezing point
- (c)  $\Delta H_{\text{mix}} < \text{Zero}$
- (d) Osmotic pressure

### Column -II

- (P) negative deviation from ideal behaviour
- (Q) Walker and Ostwald Method
- (R) Beckmann thermometer
- (S) Berkeley and Hartley's method

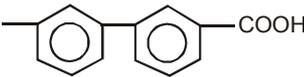
- 12. Column I**
- Examples of solution**
- (a) Acetone + Aniline  
 (b) Water + Methanol  
 (c) Benzene + Toluene  
 (d) n-Hexane + N-heptane  
 (e) Water + HCl
- Column II**
- Types of solution**
- (i) Positive deviation from ideal behaviour  
 (ii) Negative deviation from ideal behaviour  
 (iii) Ideal solution
- 13. Column I**
- (A) Acetone +  $\text{CHCl}_3$   
 (B) Ethanol + Water  
 (C)  $\text{C}_2\text{H}_5\text{Br} + \text{C}_2\text{H}_5\text{I}$   
 (D) Acetone + Benzene
- Column II**
- (p)  $\Delta S_{\text{mix}} > 0$   
 (q)  $\Delta V_{\text{mix}} > 0$   
 (r)  $\Delta H_{\text{mix}} < 0$   
 (s) Maximum boiling azeotropes  
 (t) Minimum boiling azeotropes

## ASSERTION / REASONING

### DIRECTIONS :

Each question has 5 choices (A), (B), (C), (D) and (E) out of which ONLY ONE is correct.

- (A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.  
 (B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.  
 (C) Statement-1 is True, Statement-2 is False.  
 (D) Statement-1 is False, Statement-2 is True.  
 (E) Statement-1 and Statement-2 both are False.

- 14. Statement-1** : The freezing of water is an endothermic process.  
**Statement-2** : Heat must be removed from the water to make it freeze.
- 15. Statement-1** : Addition of ethylene glycol (non-volatile) to water lowers the freezing point of water hence used as antifreeze.  
**Statement-2** : Addition of any substance to water lowers its freezing point of water.
- 16. Statement -1** : The difference in the boiling points of equimolar solution of HCl and HF decreases as their molarity is decreased.  
**Statement -2** : The extent of dissociation decreases steadily with increasing dilution.
- 17. Statement -1** : The molar mass obtained for benzoic acid in benzene is found to be nearly 244.  
**Statement -2** : Benzoic acid has the formula  $\text{HOOC}$    $\text{COOH}$
- 18. Statement -1** : When 'a' mL of a 0.1 molal urea solution is mixed with another 'b' mL of 0.1 molal glucose solution, the boiling point of the solution is no different from the boiling points of the samples prior to mixing but if 'a' mL of 0.1 molal urea is mixed with 'b' mL of 0.1 molal HF the boiling point of the mixture is different from the boiling points of the separate samples.  
**Statement -2** : HF is an electrolyte (weak) whereas glucose is a non electrolyte.

19. **Statement -1** : The freezing point of water is depressed by the addition of glucose.  
**Statement -2** : Entropy of solution is less than entropy of pure solvent.
20. **Statement -1** : In binary ideal solution more volatile component boils at less temperature and less volatile component boils at high temperature than their normal boiling point of pure component.  
**Statement -2** : For any composition, mixture boils at temperature in between the their normal boiling point temperature of pure component.
21. **Statement -1** : The boiling point of 0.1 M urea solution is less than that of 0.1 M KCl solution.  
**Statement -2** : Elevation of boiling point is directly proportional to the number of moles of non-volatile solute particles present in the solution.
22. **Statement -1** : The observed molar mass of acetic acid in benzene is more than the normal molar mass of acetic acid.  
**Statement -2** : Molecules of acetic acid dimerise in benzene due to hydrogen bonding.

### TRUE / FALSE

23. Relative lowering of vapour pressure is a colligative property.
24. Lowering of vapour pressure of a solution is equal to the mole fraction of the non-volatile solute present in it.
25. The components of an azeotropic solution can be separated by simple distillation.
26. Vapour pressure of a liquid depends on the size of the vessel.
27. Addition of non-volatile solute to water always lowers its vapour pressure.
28. Reverse osmosis is generally used to make saline water fit for domestic use.
29. A 6% (w/v) solution of NaCl should be isotonic with 6% (w/v) solution of sucrose.
30. A real solution obeys Raoult's law.
31. Boiling point is a characteristic temperature at which vapour pressure of the liquid becomes higher than the atmospheric pressure.
32. Molal depression constant is independent of the nature of solute as well as that of solvent.
33. The real solutions can exhibit ideal behaviour at high concentrations.
34. The osmotic pressure decreases on addition of solvent to the solution.
35. For urea the value of Van't Hoff's factor 'i' is equal to 1.
36. The unit of  $k_b$  is  $\text{kg K}^{-1} \text{mol}^{-1}$ .
37. 0.1 M solution of urea would be hypotonic with 0.1 M solution of NaCl.
38. Acetic acid undergoes association in benzene. The molar mass of acetic acid, determined by elevation of boiling point is always higher than its normal molar mass.
39. A plant cell swells when placed in a hypertonic solution.
40. Osmotic pressure measurements can be used for determination of molar mass of polymers.
41. The value of Van't Hoff factor is more than one in dissociation and less than one in association of solute.

## EXERCISE # 2

### PART - I : MIXED OBJECTIVE

#### Single Choice Type

1. What volume of 0.10 M  $\text{H}_2\text{SO}_4$  must be added to 50 mL of a 0.10 M NaOH solution to make a solution in which the molarity of the  $\text{H}_2\text{SO}_4$  is 0.050 M ?  
(A) 400 mL (B) 50 mL (C) 100 mL (D) 150 mL
2. The van't Hoff factor  $i$  for an infinitely dilute solution of  $\text{NaHSO}_4$  is :  
(A)  $1/2$  (B)  $1/3$  (C) 3 (D) 2
3. pH of a 0.1 M monobasic acid is found to be 2. Hence its osmotic pressure at a given temp. T K is-  
(A) 0.1 RT (B) 0.11 RT (C) 1.1 RT (D) 0.01 RT
4. Lowering of vapour pressure of 1.00 m solution of a non-volatile solute in a hypothetical solvent of molar mass 40 g at its normal boiling point, is :  
(A) 29.23 torr (B) 30.4 torr (C) 35.00 torr (D) 40.00 torr
5. The mole fraction of the solvent in the solution of a non-volatile solute is 0.980. The relative lowering of vapour pressure is -  
(A) 0.01 (B) 0.980 (C) 0.02 (D) 0.49
6. The vapour pressure of pure benzene  $\text{C}_6\text{H}_6$  at  $50^\circ\text{C}$  is 260 Torr. How many moles of nonvolatile solute per mole of benzene are required to prepare a solution of benzene having a vapour pressure of 167.0 Torr at  $50^\circ\text{C}$  ?  
(A) 0.305 mol (B) 0.605 mol (C) 0.336 mol (D) 0.663 mol
7. Lowering of vapour pressure due to a solute in 1 molal aqueous solution at  $100^\circ\text{C}$  is :  
(A) 13.44 Torr (B) 14.12 Torr (C) 312 Torr (D) 352 Torr
8. A vessel has nitrogen gas and water vapours in equilibrium with liquid water at a total pressure of 1 atm. The partial pressure of water vapours is 0.3 atm. The volume of this vessel is reduced to one third of the original volume, at the same temperature, then total pressure of the system is : (Neglect volume occupied by liquid water)  
(A) 3.0 atm (B) 1 atm (C) 3.33 atm (D) 2.4 atm
9. A solute 'S' undergoes a reversible trimerization when dissolved in a certain solvent. The boiling point elevation of its 0.1 molal solution was found to be identical to the boiling point elevation in case of a 0.08 molal solution of a solute which neither undergoes association nor dissociation. To what percent had the solute 'S' undergone trimerization ?  
(A) 30% (B) 40% (C) 50% (D) 60%
10. Barium ions,  $\text{CN}^-$  and  $\text{Co}^{2+}$  form an ionic complex. If that complex is supposed to be 75% ionised in water with vant Hoff factor ' $i$ ' equal to four, then the coordination number of  $\text{Co}^{2+}$  in the complex can be :  
(A) Six (B) Five (C) Four (D) Six and Four both
11. Consider following cases -  
I : 2M  $\text{CH}_3\text{COOH}$  solution in benzene at  $27^\circ\text{C}$  where there is dimer formation to the extent of 100%  
II : 0.5 M KCl aq. solution at  $27^\circ\text{C}$ , which ionises 100%  
Which is/are true statements(s) -  
(A) both are isotonic (B) I is hypertonic (C) II is hypotonic (D) none is correct

12.  $\text{PtCl}_4 \cdot 6\text{H}_2\text{O}$  can exist as a hydrated complex 1 molal aq. solution has depression in freezing point of  $3.72^\circ$ . Assume 100% ionisation and  $K_f(\text{H}_2\text{O}) = 1.86^\circ \text{ mol}^{-1} \text{ kg}$ , then complex is :  
 (A)  $[\text{Pt}(\text{H}_2\text{O})_6]\text{Cl}_4$  (B)  $[\text{Pt}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl}_2 \cdot 2\text{H}_2\text{O}$   
 (C)  $[\text{Pt}(\text{H}_2\text{O})_3\text{Cl}_3]\text{Cl} \cdot 3\text{H}_2\text{O}$  (D)  $[\text{Pt}(\text{H}_2\text{O})_2\text{Cl}_4] \cdot 4\text{H}_2\text{O}$
13. When only a little quantity of  $\text{HgCl}_2(\text{s})$  is added to excess  $\text{KI}(\text{aq})$  to obtain a clear solution, which of the following is true for this solution? (no volume change on mixing)  
 (A) Its boiling and freezing points remain same (B) Its boiling point is lowered  
 (C) Its vapour pressure become lower (D) Its boiling point is raised
14. How many moles of sucrose should be dissolved in 500 gms of water so as to get a solution which has a difference of  $104^\circ\text{C}$  between boiling point and freezing point. ( $K_f = 1.86 \text{ K Kg mol}^{-1}$ ,  $K_b = 0.52 \text{ K Kg mol}^{-1}$ )  
 (A) 1.68 (B) 3.36 (C) 8.40 (D) 0.840
15. 1g of arsenic dissolved in 86 g of benzene brings down the freezing point to  $5.31^\circ\text{C}$  from  $5.50^\circ\text{C}$ . If  $K_f$  of benzene is  $4.9 \frac{^\circ\text{C}}{\text{m}}$ , the atomicity of the molecule is : (As – 75)  
 (A) 8 (B) 2 (C) 3 (D) 4
16. An ideal mixture of liquids A and B with 2 moles of A and 2 moles of B has a total vapour pressure of 1 atm at a certain temperature. Another mixture with 1 mole of A and 3 moles of B has a vapour pressure greater than 1 atm. But if 4 moles of C are added to the second mixture, the vapour pressure comes down to 1 atm. Vapour pressure of C,  $P_C^0 = 0.8 \text{ atm}$ . Calculate the vapour pressures of pure A and pure B.  
 (A)  $P_A^0 = 1.4 \text{ atm}$ ,  $P_B^0 = 0.7 \text{ atm}$  (B)  $P_A^0 = 1.2 \text{ atm}$ ,  $P_B^0 = 0.6 \text{ atm}$   
 (C)  $P_A^0 = 1.4 \text{ atm}$ ,  $P_B^0 = 0.6 \text{ atm}$  (D)  $P_A^0 = 0.6 \text{ atm}$ ,  $P_B^0 = 1.4 \text{ atm}$
17. The vapor pressures of benzene, toluene and a xylene are 75 Torr, 22 Torr and 10 Torr at  $20^\circ\text{C}$ . Which of the following is **not** a possible value of the vapor pressure of an equimolar binary/ternary solution of these at  $20^\circ\text{C}$ ? Assume all form ideal solution with each other.  
 (A)  $48\frac{1}{2}$  (B) 16 (C)  $35\frac{2}{3}$  (D)  $53\frac{1}{2}$
18. The vapour pressure of the solution of two liquids A ( $p^0 = 80 \text{ mm}$ ) and B ( $p^0 = 120 \text{ mm}$ ) is found to be 100 mm 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 concentration and negative deviations for higher concentrations.
19. How many mmoles of sucrose should be dissolved in 500 gms of water so as to get a solution which has a difference of  $103.57^\circ\text{C}$  between boiling point and freezing point.  
 ( $K_f = 1.86 \text{ K Kg mol}^{-1}$ ,  $K_b = 0.52 \text{ K Kg mol}^{-1}$ )  
 (A) 500 mmoles (B) 900 mmoles (C) 750 mmoles (D) 650 mmoles
20. The vapour pressure of pure liquid solvent A is 0.80 atm. When a non-volatile substance B is added to the solvent, its vapour pressure drops to 0.60 atm. Mole fraction of the component B in the solution is :  
 (A) 0.50 (B) 0.25 (C) 0.75 (D) 0.40
21. The vapour pressure of a solution of a non-volatile solute B in a solvent A is 95% of the vapour pressure of the solvent at the same temperature. If the molecular weight of the solvent is 0.3 times the molecular weight of the solute, what is the ratio of weight of solvent to solute.  
 (A) 0.15 (B) 5.7 (C) 0.2 (D) none of these

22. Relative decrease in vapour pressure of an aqueous solution containing 2 moles  $[\text{Cu}(\text{NH}_3)_3\text{Cl}]\text{Cl}$  in 3 moles  $\text{H}_2\text{O}$  is 0.50. On reaction with  $\text{AgNO}_3$ , this solution will form (assuming no change in degree of ionisation of substance on adding  $\text{AgNO}_3$ )  
 (A) 1 mol  $\text{AgCl}$  (B) 0.25 mol  $\text{AgCl}$  (C) 0.5 mol  $\text{AgCl}$  (D) 0.40 mol  $\text{AgCl}$
23. Moles of  $\text{K}_2\text{SO}_4$  to be dissolved in 12 mol water to lower its vapour pressure by 10 mmHg at a temperature at which vapour pressure of pure water is 50 mm is :  
 (A) 3 mol (B) 2 mol (C) 1 mol (D) 0.5 mol
24. At a constant temperature,  $\Delta S$  will be maximum for which of the following processes :  
 (A) Vaporisation of a pure solvent  
 (B) Vaporisation of solvent from a solution containing nonvolatile and nonelectrolytic solute in it  
 (C) Vaporisation of solvent from a solution containing nonvolatile but electrolytic solute in it  
 (D) Entropy change will be same in all the above cases
25. A solution of a non-volatile solute in water has a boiling point of 375.3 K. The vapour pressure of water above this solution at 338 K is :  
 [Given  $p_0$  (water) = 0.2467 atm at 338 K and  $K_b$  for water =  $0.52 \text{ K kg mol}^{-1}$ ]  
 (A) 0.18 atm (B) 0.23 atm (C) 0.34 atm (D) 0.42 atm
26. Elevation in boiling point of an aqueous urea solution is  $0.52^\circ$ . ( $K_b = 0.52 \text{ K kg mol}^{-1}$ ). Hence mole fraction of urea in this solution is :  
 (A) 0.982 (B) 0.0567 (C) 0.943 (D) 0.018
27. Relative decrease in V. P. of an aqueous glucose dilute solution is found to be 0.018. Hence, elevation in boiling point is : (it is given 1 molal aq. urea solution boils at  $100.54^\circ\text{C}$  at 1 atm. pressure)  
 (A)  $0.018^\circ$  (B)  $0.18^\circ$  (C)  $0.54^\circ$  (D)  $0.03^\circ$
28. An aqueous solution containing 5% by weight of urea and 10% by weight of glucose. Freezing point of solution is [ $K_f$  for  $\text{H}_2\text{O}$  is  $1.86 \text{ K mol}^{-1} \text{ kg}$ ]  
 (A)  $3.04^\circ\text{C}$  (B)  $-3.04^\circ\text{C}$  (C)  $-5.96^\circ\text{C}$  (D)  $5.96^\circ\text{C}$
29. The amount of ice that will separate out from a solution containing 25 g of ethylene glycol in 100 g of water and is cooled to  $-10^\circ\text{C}$ , will be : [Given :  $K_f$  for  $\text{H}_2\text{O} = 1.86 \text{ K mol}^{-1} \text{ kg}$ ]  
 (A) 50.0 g (B) 25.0 g (C) 12.5 gm (D) 30.0 gm
30. It has been found that minimum temperature recorded in a hill station is  $-10^\circ\text{C}$ . The amount of glycerine to be added to  $40 \text{ dm}^3$  water used in car radiator, so that it does not freeze, is - [ $\Delta H_{\text{fusion}} = 6.01 \text{ kJ mol}^{-1}$ ]  
 (A) 39.78 kg (B) 22.45 kg (C) 19.89 kg (D) 42.66 kg
31. In winter, the normal temperature in Kullu valley was found to be  $-11^\circ\text{C}$ . Is a 28% (by mass) aqueous solution of ethylene glycol suitable for a car radiator ?  $K_f$  for water =  $1.86 \text{ K kg mol}^{-1}$ .  
 (A) Yes (B) No (C) can't predict (D) None of these
32. A 0.2 molal aqueous solution of a weak acid (HX) is 20 per cent ionised. The freezing point of this solution is (Given  $k_f = 1.86^\circ\text{C kg mol}^{-1}$  for water) :  
 (A)  $-0.45^\circ\text{C}$  (B)  $-0.90^\circ\text{C}$  (C)  $-0.31^\circ\text{C}$  (D)  $-0.53^\circ\text{C}$ .
33. A complex of iron and cyanide ions is 100% ionised at 1m (molal). If its elevation in b.p. is 2.08. Then the complex is ( $K_b = 0.52^\circ \text{ mol}^{-1} \text{ kg}$ ) :  
 (A)  $\text{K}_3[\text{Fe}(\text{CN})_6]$  (B)  $\text{Fe}(\text{CN})_2$  (C)  $\text{K}_4[\text{Fe}(\text{CN})_6]$  (D)  $\text{Fe}(\text{CN})_4$
34. The fraction of phenol dimerised in benzene if 20 g of phenol in 1 kg benzene exhibits a freezing point depression of 0.69 K. ( $K_f$  benzene =  $5.12 \frac{\text{K} \cdot \text{kg}}{\text{mol}}$ ), (MW phenol = 94)  
 (A) 0.74 (B) 0.37 (C) 0.46 (D) 0.64

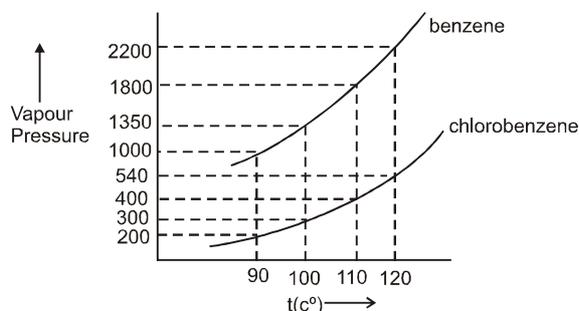
35. For a solution of 0.849 g of mercurous chloride in 50 g of  $\text{HgCl}_2(\ell)$  the freezing point depression is  $1.24^\circ\text{C}$ .  $K_f$  for  $\text{HgCl}_2$  is 34.3. What is the state of mercurous chloride in  $\text{HgCl}_2$ ? ( $\text{Hg} = 200$ ,  $\text{Cl} = 35.5$ )  
 (A) as  $\text{Hg}_2\text{Cl}_2$  molecules (B) as  $\text{HgCl}$  molecules  
 (C) as  $\text{Hg}^+$  and  $\text{Cl}^-$  ions (D) as  $\text{Hg}_2^{2+}$  and  $\text{Cl}^-$  ions

36. A solution of x moles of sucrose in 100 grams of water freezes at  $-0.2^\circ\text{C}$ . As ice separates the freezing point goes down to  $0.25^\circ\text{C}$ . How many grams of ice would have separated?  
 (A) 18 grams (B) 20 grams (C) 25 grams (D) 23 grams

37. Consider two liquids A & B having pure vapour pressures  $P_A^\circ$  &  $P_B^\circ$  forming an ideal solution. The plot of  $\frac{1}{X_A}$  v/s  $\frac{1}{Y_A}$  (where  $X_A$  and  $Y_A$  are the mole fraction of liquid A in liquid and vapour phase respectively) is linear with slope and Y intercepts respectively :

(A)  $\frac{P_A^\circ}{P_B^\circ}$  and  $\frac{(P_A^\circ - P_B^\circ)}{P_B^\circ}$  (B)  $\frac{P_A^\circ}{P_B^\circ}$  and  $\frac{(P_B^\circ - P_A^\circ)}{P_B^\circ}$  (C)  $\frac{P_B^\circ}{P_A^\circ}$  and  $\frac{(P_A^\circ - P_B^\circ)}{P_B^\circ}$  (D)  $\frac{P_B^\circ}{P_A^\circ}$  and  $\frac{(P_B^\circ - P_A^\circ)}{P_B^\circ}$

38. Assuming the formation of an ideal solution, determine the boiling point of a mixture containing 1560 g benzene (molar mass = 78) and 1125 g chlorobenzene (molar mass = 112.5) using the following against an external pressure of 1000 Torr.



- (A)  $90^\circ\text{C}$   
 (B)  $100^\circ\text{C}$   
 (C)  $110^\circ$   
 (D)  $120^\circ\text{C}$

39. Liquids A and B form an ideal solution and the former has stronger intermolecular forces. If  $X_A$  and  $X'_A$  are the mole fractions of A in the solution and vapour in equilibrium, then :

(A)  $\frac{X'_A}{X_A} = 1$  (B)  $\frac{X'_A}{X_A} > 1$  (C)  $\frac{X'_A}{X_A} < 1$  (D)  $X'_A + X_A = 1$

40. At a certain temperature pure liquid A and liquid B have vapour pressures 10 torr and 37 torr respectively. For a certain ideal solution of A and B, the vapour in equilibrium with the liquid has the components A and B in the partial pressure ratio  $P_A : P_B = 1 : 7$ . What is the mole fraction of A in the solution ?

- (A) 0.346 (B) 0.654 (C) 0.5 (D) none of these

41. Two liquids A and B forms an ideal solution at temperature T. When the total vapour pressure above the solution is 400 torr, the mole fraction of A in the vapour phase is 0.40 and in the liquid phase 0.75. The vapour pressure of pure A and B respectively are :

- (A) 165.54 torr , 772.00 torr (B) 240.24 torr , 840.00 torr  
 (C) 213.33 torr , 960.00 torr (D) 312.15 torr , 865.00 torr

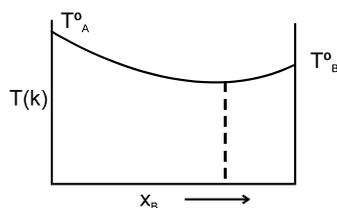
42. An aqueous solution containing 28% by mass of a liquid A (mol. mass = 140) has a vapour pressure of 160 mm at  $37^\circ\text{C}$ . The vapour pressure of water at  $37^\circ\text{C}$  is 150 mm, then the pressure of pure liquid A, is -

- (A) 180.22 mm (B) 300.32 mm (C) 360.15 mm (D) 276.55 mm

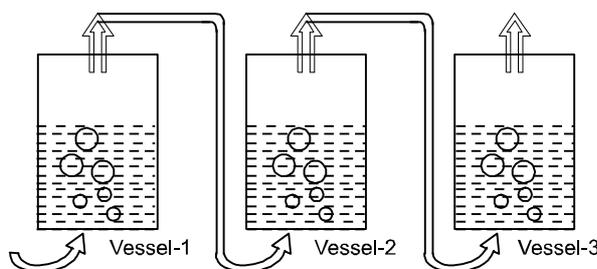
43. If vapour pressures of pure liquids 'A' & 'B' are 300 and 800 torr respectively at 25°C. When these two liquids are mixed at this temperature to form a solution in which mole percentage of 'B' is 92, then the total vapour pressure is observed to be 0.95 atm. Which of the following is true for this solution.  
 (A)  $\Delta V_{\text{mix}} > 0$                       (B)  $\Delta H_{\text{mix}} < 0$                       (C)  $\Delta V_{\text{mix}} = 0$                       (D)  $\Delta H_{\text{mix}} = 0$
44. A liquid is kept in a closed vessel. If a glass plate (negligible mass) with a small hole is kept on top of the liquid surface, then the vapour pressure of the liquid in the vessel is :  
 (A) More than what would be if the glass plate were removed  
 (B) Same as what would be if the glass plate were removed  
 (C) Less than what would be if the glass plate were removed  
 (D) Cannot be predicted

### Multiple Choice Type

45. The diagram given below represents boiling point composition diagram of solution of component A and B, which is/are incorrect among the following ?



- (A) The solution shows negative deviation (B) A-B-interactions are stronger than A-A and B-B  
 (C) The solution is ideal solution (D) The solution shows positive deviation.
46. For chloroform and acetone or for a solution of chloroform and acetone if  $p_s$  (observed (actual)) is compared with  $p_s$  (Theoretical (Raoult)) then which of the following is /are true ?  
 (A)  $p_s(\text{actual}) < p_s(\text{raoult})$                       (B)  $\lim_{X_{\text{chloroform}} \rightarrow 0} (p_{\text{acetone}}^{\circ} - p_s(\text{actual})) = 0$   
 (C)  $\lim_{X_{\text{acetone}} \rightarrow 0} (p_{\text{chloroform}}^{\circ} - p_s(\text{actual})) = 0$                       (D)  $p_{\text{acetone}}^{\circ} > p_{\text{chloroform}}^{\circ}$  near room temperature
47. In which of the following pairs of solutions will the values of the vant Hoff factor be the same?  
 (A) 0.05 M  $K_4[Fe(CN)_6]$  and 0.10 M  $FeSO_4$   
 (B) 0.10 M  $K_4[Fe(CN)_6]$  and 0.05 M  $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$   
 (C) 0.20 M  $NaCl$  and 0.10 M  $BaCl_2$   
 (D) 0.05 M  $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$  and 0.02 M  $KCl \cdot MgCl_2 \cdot 6H_2O$
48. Dry air is slowly passed through three solutions of different concentrations,  $c_1$ ,  $c_2$  and  $c_3$ ; each containing (non volatile) NaCl as solute and water as solvent, as shown in the Fig. If the vessel 2 gains weight and the vessel 3 loses weight, then :



- (A)  $c_1 > c_2$                       (B)  $c_1 < c_2$                       (C)  $c_1 < c_3$                       (D)  $c_2 > c_3$

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## PART - II : SUBJECTIVE QUESTIONS

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1. Calculate the molality and molarity of a solution made by mixing equal volumes of 30% by weight of  $\text{H}_2\text{SO}_4$  (density = 1.20 g/mL) and 70% by weight of  $\text{H}_2\text{SO}_4$  (density = 1.60 g/mL).
2. At  $2^\circ\text{C}$  the osmotic pressure of a urea solution is found to be 500 mm of Hg. The solution is diluted and the temperature is raised to  $27^\circ\text{C}$ , when the osmotic pressure is found to be 109.09 mm of Hg. Determine the extent of dilution.
3. The vapour pressure of water at  $80^\circ\text{C}$  is 355 torr. A 100 ml vessel contained water-saturated oxygen at  $80^\circ\text{C}$ , 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 vapour, what was the total pressure in the final equilibrated state? Neglect the volume of any water which might condense.
4. Twenty grams of a solute are added to 100 g of water at  $25^\circ\text{C}$ . The vapour pressure of pure water is 23.76 mmHg; the vapour pressure of the solution is 22.41 Torr.
  - (a) Calculate the molar mass of the solute.
  - (b) What mass of this solute is required in 100 g of water to reduce the vapor pressure to one-half the value for pure water?
5. 2 g of a non-volatile hydrocarbon solute dissolved in 100 g of a hypothetical organic solvent (molar mass=50) was found to lower the vapour pressure from 75.00 to 74.50 mm of Hg at  $20^\circ\text{C}$ . Given that the hydrocarbon contains 96% of C, what is the molecular formula of the hydrocarbon?
6. The degree of dissociation of  $\text{Ca}(\text{NO}_3)_2$  in a dilute aqueous solution containing 7 g salt per 100 g of water at  $100^\circ\text{C}$  is 70%. If the vapour pressure of water at  $100^\circ\text{C}$  is 760 mm of Hg, calculate the vapour pressure of the solution.
7. Dry air was passed through bulbs containing a solution of 40 grams of nonelectrolytic solute in 360 grams of water, then through bulbs containing pure water at the same temperature and finally through a tube in which pumice moistened with strong  $\text{H}_2\text{SO}_4$  was kept. The water bulbs lost 0.0870 grams and the sulphuric acid tube gained 2.175 grams. Calculate the molecular weight of solute.
8. A solution containing 1.5 g of ethyl benzoate in 65 g of benzene has density of 0.8 g/cc and vapor pressure of 747 mm Hg at  $80^\circ\text{C}$ . Vapor pressure of pure benzene is 756 mm Hg. What is the osmotic pressure of the solution in Torr? Note that the solute may have some extent of association in the solvent.
9.
  - (a) A solution containing 0.5 g of naphthalene in 50 g  $\text{CCl}_4$  yield a boiling point elevation of 0.4 K, while a solution of 0.6 g of an unknown solute in the same mass of the solvent gives a boiling point elevation of 0.65 K. Find the molar mass of the unknown solute.
  - (b) The boiling point of a solution of 0.1 g of a substance in 16 g of ether was found to be  $0.100^\circ\text{C}$  higher than that of pure ether. What is the molecular mass of the substance.  $K_b(\text{ether}) = 2.16 \text{ K kg mol}^{-1}$
10. The boiling point of a solution of 5 g of sulphur in 100 g of carbon disulphide is  $0.474^\circ\text{C}$  above that of pure solvent. Determine the molecular formula of sulphur in this solvent. The boiling point of pure carbon disulphide is  $47^\circ\text{C}$  and its heat of vaporisation is 84 calories per gram.
11. Calculate the freezing point of a solution of a non-volatile solute in a unknown solvent of molar mass 30 g/mole having mole fraction of solvent equal to 0.8. Given that latent heat of fusion of solid solvent =  $2.7 \text{ kcal mol}^{-1}$ , freezing point of solvent =  $27^\circ\text{C}$  and  $R = 2 \text{ cal mol}^{-1} \text{ K}^{-1}$ .

12. 1 g of a monobasic acid dissolved in 200 g of water lowers the freezing point by  $0.186^{\circ}\text{C}$ . On the other hand when 1 g of the same acid is dissolved in water so as to make the solution 200 mL, this solution requires 125 mL of 0.1 N NaOH for complete neutralization. Calculate % dissociation of acid ? ( $K_f = 1.86 \frac{\text{K}-\text{kg}}{\text{mol}}$ )
13. 0.001 molal solution of a ionic complex with molecular formula  $\text{Pt}(\text{NH}_3)_4 \text{Cl}_4$  lowers the freezing point of water by  $0.0054^{\circ}\text{C}$ . Assume the above compound to be 100% ionised and  $k_f$  for water =  $1.86 \text{ k kg mol}^{-1}$ .
- (i) Write IUPAC name of the above compound.  
Now 0.001 moles of above complex is taken separately and enough  $\text{AgNO}_3(\text{aq})$  is added to it for complete precipitation of free  $\text{Cl}^-$  as  $\text{AgCl}$ . The precipitate is filtered and dried. It requires at least five times the volume of  $\text{NH}_3(\text{aq.})$  needed stoichiometrically for its dissolution.
- (ii) Calculate the volume of 1.0 M  $\text{NH}_3(\text{aq.})$  required for this purpose.
- (iii) Write IUPAC name of the second complex formed.  
Assume molality to be equal to molarity when ever needed.
14. The amount of benzene that will separate out (in grams) if a solution containing 7.32 g of triphenylmethane in 1000 g of benzene is cooled to a temperature which is  $0.2^{\circ}\text{C}$  below the freezing point of benzene? ( $K_f = 5.12 \text{ K-Kg/mol}$ )
15. Two liquids A and B form an ideal solution. At 300 K, the vapour pressure of a solution containing 1 mole of A and 3 moles of B is 550 mm of Hg. At the same temperature, if one mole of B is added to this solution, the vapour pressure of the solution increases by 10 mm of Hg. Determine the vapour pressure of A and B in their pure states.
16. Two liquids, A and B, form an ideal solution. At the specified temperature, the vapour pressure of pure A is 200 mmHg while that of pure B is 75 mmHg. If the vapour over the mixture consists of 50 mol percent A, what is the mole percent A in the liquid ?
17. At  $80^{\circ}\text{C}$ , the vapour pressure of pure benzene is 753 mm Hg and of pure toluene 290 mm Hg. Calculate the composition of a liquid in mole per cent which at  $80^{\circ}\text{C}$  is in equilibrium with the vapour containing 30 mole per cent of benzene.
18. At a constant temperature liquid 'A' has vapour pressure of 170 mm Hg and liquid 'B' has vapour pressure of 280 mm Hg. A solution of the two at the same temperature in which mole fraction of A is 0.7 has a total vapour pressure of 376 mm. Identify whether the solution process is Endothermic or Exothermic ?
19. Boiling point of a mixture of water and nitrobenzene is  $99^{\circ}\text{C}$ , the vapour pressure of water is 733 mm of Hg and the atmospheric pressure is 760 mm of Hg. The molecular weight of nitrobenzene is 123. Find the ratio of weights of the components of the distillate.
20. A mixture of an organic liquid A and water distilled under one atmospheric pressure at  $99.2^{\circ}\text{C}$ . How many grams of steam will be condensed to obtain 1.0 g of liquid A in the distillate ? (Vapour pressure of water at  $99.2^{\circ}\text{C}$  is 739 mm Hg. Molecular weight of A = 123)
21. The partial pressure of ethane over a solution containing  $6.56 \times 10^{-3}$  g of ethane is 1 bar. If the solution contains  $5.00 \times 10^{-2}$  g of ethane, then what shall be the partial pressure of the gas ?
22. A membrane permeable only to water separates a 0.01 M solution of sucrose from another 0.001 M sucrose solution. On which solution must pressure be applied to bring the system into equilibrium ? Find this pressure if the  $T = 298 \text{ K}$ .

23. A solution contains 68.4 gms of cane sugar ( $C_{12}H_{22}O_{11}$ ) in 1000 gms of water. Calculate the following for this solution (a) Vapour pressure; (b) Osmotic pressure at  $20^\circ\text{C}$ ; (c) Freezing point; (d) Boiling point. [density of the solution =  $1.024\text{ gm cm}^{-3}$ ; vapour pressure of water =  $17.54\text{ mm}$ ; latent heat of fusion =  $80\text{ cal gm}^{-1}$  latent heat of vaporization =  $540\text{ cal gm}^{-1}$ ]
24. A solution containing 24g of a non - electrolyte per kg of water starts to freeze at  $-0.75^\circ\text{C}$ . The molar mass of the solute is  $60\text{ g mol}^{-1}$ . Calculate the molal depression constant for water. If the solution is cooled to  $-1^\circ\text{C}$ , how much of ice would separate ?
25. If  $N_2$  gas is bubbled through water at  $293\text{ K}$ , how many millimoles of  $N_2$  gas would dissolve in 1 litre of water. Assume that  $N_2$  exerts a partial pressure of  $0.987\text{ bar}$ . Given that Henry's law constant for  $N_2$  at  $293\text{ K}$  is  $76.48\text{ kbar}$ .
26. An aqueous solution containing 288 gm of a non-volatile compound having the stoichiometric composition  $C_xH_{2x}O_x$  in 90 gm water boils at  $101.24^\circ\text{C}$  at 1.00 atmospheric pressure. What is the molecular formula?  
 $K_b(\text{H}_2\text{O}) = 0.512\text{ K mol}^{-1}\text{ kg}$   
 $T_b(\text{H}_2\text{O}) = 100^\circ\text{C}$
27. The degree of dissociation of  $\text{Ca}(\text{NO}_3)_2$  in a dilute aqueous solution containing 7 gm of the salt per 100 gm of water at  $100^\circ\text{C}$  is 70%. If the vapour pressure of water at  $100^\circ\text{C}$  is 760 mm. Calculate the vapour pressure of the solution.
28. The addition of 3 gm of substance to 100 gm  $\text{CCl}_4$  ( $M = 154\text{ gm mol}^{-1}$ ) raises the boiling point of  $\text{CCl}_4$  by  $0.60^\circ\text{C}$  of  $K_b$  ( $\text{CCl}_4$ ) is  $5.03\text{ kg mol}^{-1}\text{ K}$ . Calculate  
 (a) the freezing point depression  
 (b) the relative lowering of vapour pressure  
 (c) the osmotic pressure at  $298\text{ K}$   
 (d) the molar mass of the substance  
 Given  $K_f(\text{CCl}_4) = 31.8\text{ kg mol}^{-1}\text{ K}$  and  $\rho$  (density) of solution =  $1.64\text{ gm/cm}^3$
29. A complex is represented as  $\text{CoCl}_3 \cdot x\text{NH}_3$ . It's 0.1 molal solution in aq. solution shows  $\Delta T_f = 0.558^\circ\text{C}$ .  $K_f$  for  $\text{H}_2\text{O}$  is  $1.86\text{ K mol}^{-1}\text{ kg}$ . Assuming 100% ionisation of complex and coordination no. of Co is six, calculate formula of complex.
30. Calculate the boiling point of a solution containing 0.61g of benzoic acid in 50g of carbon disulphide assuming 84% dimerization of the acid. The boiling point and  $K_b$  of  $\text{CS}_2$  are  $46.2^\circ\text{C}$  and  $2.3\text{ K kg mol}^{-1}$ , respectively.
31. At  $25^\circ\text{C}$ , 1 mol of A having a vapor pressure of 100 torr and 1 mol of B having a vapor pressure of 300 torr were mixed. The vapor at equilibrium is removed, condensed and the condensate is heated back to  $25^\circ\text{C}$ . The vapors now formed are again removed, recondensed and analyzed. What is the mole fraction of A in this condensate?
32. A very dilute saturated solution of a sparingly soluble salt  $A_3B_4$  has a vapour pressure of 20 mm of Hg at temperature T, while pure water exerts a pressure of 20.0126 mm Hg at the same temperature. Calculate the solubility product constant of  $A_3B_4$  at the same temperature.
33. The specific conductivity of a 0.5 M aq. solution of monobasic acid HA at  $27^\circ\text{C}$  is  $0.006\text{ Scm}^{-1}$ . It's molar conductivity at infinite dilution is  $200\text{ S cm}^2\text{ mol}^{-1}$ . Calculate osmotic pressure (in atm) of 0.5 M HA (aq) solution at  $27^\circ\text{C}$ .

$$\text{Given } R = 0.08 \frac{\text{atm L}}{\text{mol K}}$$

34. A 250 mL water solution containing 48.0 g of sucrose,  $C_{12}H_{22}O_{11}$ , at 300 K is separated from pure water by means of a semipermeable membrane. What pressure must be applied above the solution in order to just prevent osmosis?
35. 0.85 % aqueous solution of  $NaNO_3$  is apparently 90% dissociated at  $27^\circ C$ . Calculate its osmotic pressure. ( $R = 0.082 \text{ l atm K}^{-1} \text{ mol}^{-1}$ )
36. An aqueous solution containing 288 gm of a non-volatile compound having the stoichiometric composition  $C_xH_{2x}O_x$  in 90 gm water boils at  $101.24^\circ C$  at 1.00 atmospheric pressure. What is the molecular formula?  
 $K_b(H_2O) = 0.512 \text{ K mol}^{-1} \text{ kg}$   
 $T_b(H_2O) = 100^\circ C$
37. The degree of dissociation of  $Ca(NO_3)_2$  in a dilute aqueous solution containing 7 gm of the salt per 100 gm of water at  $100^\circ C$  is 70%. If the vapour pressure of water at  $100^\circ C$  is 760 mm. Calculate the vapour pressure of the solution.
38. The latent heat of fusion of ice is 80 calories per gram at  $0^\circ C$ . What is the freezing point of a solution of KCl in water containing 7.45 grams of solute in 500 grams of water, assuming that the salt is dissociated to the extent of 95%?
39. The molar volume of liquid benzene (density =  $0.877 \text{ g ml}^{-1}$ ) increases by a factor of 2750 as it vaporizes at  $20^\circ C$  and that of liquid toluene (density =  $0.867 \text{ g ml}^{-1}$ ) increases by a factor of 7720 at  $20^\circ C$ . Solution of benzene & toluene has a vapour pressure of 46.0 torr. Find the mole fraction of benzene in the vapour above the solution.
40. At  $25^\circ C$ , 1 mol of A having a vapor pressure of 100 torr and 1 mol of B having a vapor pressure of 300 torr were mixed. The vapor at equilibrium is removed, condensed and the condensate is heated back to  $25^\circ C$ . The vapors now formed are again removed, recondensed and analyzed. What is the mole fraction of A in this condensate?
41. When the mixture of two immiscible liquids (water and nitrobenzene) boils at 372 K and the vapour pressure at this temperature are 97.7 kPa ( $H_2O$ ) and 3.6 kPa ( $C_6H_5NO_2$ ). Calculate the weight % of nitrobenzene in the vapour.
42. An ideal solution was prepared by dissolving some amount of cane sugar (non-volatile) in 0.9 moles of water. The solution was then cooled just below its freezing temperature ( $271 \text{ K}$ ), where some ice get separated out. The remaining aqueous solution registered a vapour pressure of 700 torr at 373 K. Calculate the mass of ice separated out, if the molar heat of fusion of water is 6 kJ.

## EXERCISE # 3

### PART - I : IIT-JEE PROBLEMS (PREVIOUS YEARS)

\* **Marked Questions are having more than one correct option.**

- To 500 cm<sup>3</sup> of water, 3.0 × 10<sup>-3</sup> kg of acetic acid is added. If 23% of acetic acid is dissociated, what will be the depression in freezing point?  $k_f$  and density of water are 1.86 K kg<sup>-1</sup> and 0.997 g cm<sup>-3</sup> respectively: [JEE 2000]  
 (A) 0.186 K                      (B) 0.228 K                      (C) 0.372 K                      (D) 0.556 K
- An aqueous solution of 6.3 g oxalic acid dihydrate is made up to 250 mL. The volume of 0.1 N NaOH required to completely neutralise 10 mL of this solution is : [JEE 2001]  
 (A) 40 mL                      (B) 20 mL                      (C) 10 mL                      (D) 4 mL.
- The vapour pressure of two miscible liquids A and B are 300 and 500 mm of Hg respectively. In a flask 10 moles of A are mixed with 12 moles of B. However as soon as B is added, A starts polymerizing into a completely insoluble solid. The polymerization follows first-order kinetics. After 100 minutes, 0.525 mole of A are dissolved which arrests the polymerization completely. The final vapour pressure of the solution is 400 mm of Hg. Estimate the rate constant of the polymerization reaction. Assume negligible volume change on mixing and polymerization and ideal behaviour for the final solution. (Given :  $\ln \left( \frac{100}{99} \right) = 10^{-2}$ ) [JEE 2001, 10/100]
- During depression of freezing point in a solution, the following are in equilibrium : [JEE 2003]  
 (A) Liquid solvent-solid solvent                      (B) Liquid solvent-solid solute  
 (C) Liquid solute-solid solute                      (D) Liquid solute-solid solvent
- Match the boiling point with  $K_b$  for x, y and z, if molecular weight of x, y and z are same. [JEE 2003]

	b.pt.	$K_b$
x	100	0.68
y	27	0.53
z	253	0.98
- A 0.004 M solution of Na<sub>2</sub>SO<sub>4</sub> is isotonic with a 0.010 M solution of glucose at same temperature. The apparent degree of dissociation of Na<sub>2</sub>SO<sub>4</sub> is [JEE 2004]  
 (A) 25%                      (B) 50%                      (C) 75%                      (D) 85%
- 1.22 g of benzoic acid is dissolved in (i) 100 g acetone ( $K_b$  for acetone = 1.7) and (ii) 100 g benzene ( $K_b$  for benzene = 2.6). The elevation in boiling points  $T_b$  is 0.17°C and 0.13°C respectively.  
 (a) What are the molecular weights of benzoic acid in both the solutions?  
 (b) What do you deduce out of it in terms of structure of benzoic acid? [JEE 2004]
- The elevation in boiling point of a solution of 13.44 g of CuCl<sub>2</sub> in 1kg of water using the following information will be (Molecular weight of CuCl<sub>2</sub> = 134.4 and  $K_b = 0.52$  K molal<sup>-1</sup>) : [JEE 2005]  
 (A) 0.16                      (B) 0.05                      (C) 0.1                      (D) 0.2
- 72.5 g of phenol is dissolved in 1 kg of a solvent ( $k_f = 14$ ) which leads to dimerization of phenol and freezing point is lowered by 7 kelvin. What percent of total phenol is present in dimeric form? [JEE 2006]
- When 20 g of naphtholic acid (C<sub>11</sub>H<sub>8</sub>O<sub>2</sub>) is dissolved in 50 g of benzene ( $K_f = 1.72$  K kg mol<sup>-1</sup>), a freezing point depression of 2 K is observed. The van't Hoff factor ( $i$ ) is [JEE 2007]  
 (A) 0.5                      (B) 1                      (C) 2                      (D) 3

**Paragraph for Question No. Q.11 to Q.13**

Properties such as boiling point, freezing point and vapour pressure of a pure solvent change when solute molecules are added to get homogeneous solution. These are called colligative properties. Applications of colligative properties are very useful in day-to-day life. One of its examples is the use of ethylene glycol and water mixture as anti-freezing liquid in the radiator of automobiles.

A solution **M** is prepared by mixing ethanol and water. The mole fraction of ethanol in the mixture is 0.9.

Given: Freezing point depression constant of water ( $K_f^{\text{water}}$ ) = 1.86 K kg mol<sup>-1</sup>

Freezing point depression constant of ethanol ( $K_f^{\text{ethanol}}$ ) = 2.0 K kg mol<sup>-1</sup>

Boiling point elevation constant of water ( $K_b^{\text{water}}$ ) = 0.52 K kg mol<sup>-1</sup>

Boiling point elevation constant of ethanol ( $K_b^{\text{ethanol}}$ ) = 1.2 K kg mol<sup>-1</sup>

Standard freezing point of water = 273 K

Standard freezing point of ethanol = 155.7 K

Standard boiling point of water = 373 K

Standard boiling point of ethanol = 351.5 K

Vapour pressure of pure water = 32.8 mm Hg

Vapour pressure of pure ethanol = 40 mm Hg

Molecular weight of water = 18 g mol<sup>-1</sup>

Molecular weight of ethanol = 46 g mol<sup>-1</sup>

In answering the following questions, consider the solutions to be ideal dilute solutions and solutes to be non-volatile and non-dissociative. [JEE 2008, 3/163]

11. The freezing point of the solution **M** is [JEE 2008]  
 (A) 268.7 K (B) 268.5 K (C) 234.2 K (D) 150.9 K
12. The vapour pressure of the solution **M** is [JEE 2008, 3/163]  
 (A) 39.3 mm Hg (B) 36.0 mm Hg (C) 29.5 mm Hg (D) 28.8 mm Hg
13. Water is added to the solution **M** such that the mole fraction of water in the solution becomes 0.9. The boiling point of this solution is [JEE 2008]  
 (A) 380.4 K (B) 376.2 K (C) 375.5 K (D) 354.7 K
14. The Henry's law constant for the solubility of N<sub>2</sub> gas in water at 298 K is 1.0 × 10<sup>5</sup> atm. The mole fraction of N<sub>2</sub> in air is 0.8. The number of moles of N<sub>2</sub> from air dissolved in 10 moles of water at 298 K and 5 atm pressure is [JEE 2009]  
 (A) 4.0 × 10<sup>-4</sup> (B) 4.0 × 10<sup>-5</sup> (C) 5.0 × 10<sup>-4</sup> (D) 4.0 × 10<sup>-5</sup>
15. The freezing point (in °C) of a solution containing 0.1 g of K<sub>3</sub>[Fe(CN)<sub>6</sub>] (Mol. Wt. 329) in 100 g of water ( $K_f = 1.86 \text{ K kg mol}^{-1}$ ) is : [JEE 2011]  
 (A) -2.3 × 10<sup>-2</sup> (B) -5.7 × 10<sup>-2</sup> (C) -5.7 × 10<sup>-3</sup> (D) -1.2 × 10<sup>-2</sup>
16. For a dilute solution containing 2.5 g of a non-volatile non-electrolyte solute in 100 g of water, the elevation in boiling point at 1 atm pressure is 2°C. Assuming concentration of solute is much lower than the concentration of solvent, the vapour pressure (mm of Hg) of the solution is (taken  $K_b = 0.76 \text{ K kg mol}^{-1}$ ) [JEE 2012]  
 (A) 724 (B) 740 (C) 736 (D) 718
- 17.\* Benzene and naphthalene form an ideal solution at room temperature. For this process, the true statement(s) is(are) [IIT-JEE- 2013]  
 (A)  $\Delta G$  is positive (B)  $\Delta S_{\text{system}}$  is positive  
 (C)  $\Delta S_{\text{surroundings}} = 0$  (D)  $\Delta H = 0$

## PART - II : AIEEE PROBLEMS (PREVIOUS YEARS)

1. Which of the following concentration factor is affected by change in temperature ? [AIEEE-2002]  
(1) Molarity (2) Molality (3) Mol fraction (4) Weight fraction
2. Freezing point of an aqueous solution is  $(-0.186)^{\circ}\text{C}$ . Elevation of boiling point of the same solution is  $K_b = 0.512^{\circ}\text{C}$ ,  $K_f = 1.86^{\circ}\text{C}$ , find the increase in boiling point. : [AIEEE 2002]  
(1)  $0.186^{\circ}\text{C}$  (2)  $0.0512^{\circ}\text{C}$  (3)  $0.092^{\circ}\text{C}$  (4)  $0.2372^{\circ}\text{C}$
3. In a mixture A and B components show negative deviation as : [AIEEE 2002]  
(1)  $\Delta V_{\text{mix}} > 0$   
(2)  $\Delta V_{\text{mix}} < 0$   
(3) A—B interaction is weaker than A—A and B—B interaction  
(4) None of the above reasons is correct.
4. 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 : [AIEEE 2003]  
(1)  $-0.480^{\circ}\text{C}$  (2)  $-0.360^{\circ}\text{C}$  (3)  $-0.260^{\circ}\text{C}$  (4)  $+0.480^{\circ}\text{C}$
5. 25 ml of a solution of barium hydroxide on titration with a 0.1 molar solution of hydrochloric acid gave a litre value of 35 ml. The molarity of barium hydroxide solution was : [AIEEE 2003]  
(1) 0.07 (2) 0.14 (3) 0.28 (4) 0.35
6. A pressure cooker reduces cooking time for food because – [AIEEE-2003]  
(1) The higher pressure inside the cooker crushes the food material  
(2) Cooking involves chemical changes helped by a rise in temperature  
(3) Heat is more evenly distributed in the cooking space  
(4) Boiling point of water involved in cooking is increased
8. If liquids A and B form an ideal solution, the [AIEEE 2003]  
(1) enthalpy of mixing is zero  
(2) entropy of mixing is zero  
(3) free energy of mixing is zero  
(4) free energy as well as the entropy of mixing are each zero.
9. Which one of the following aqueous solutions will exhibit highest boiling point ? [AIEEE 2004]  
(1) 0.01 M  $\text{Na}_2\text{SO}_4$  (2) 0.01 M  $\text{KNO}_3$  (3) 0.015 M urea (4) 0.015 M glucose
10.  $6.02 \times 10^{20}$  molecules of urea are present in 100 ml of its solution. The concentration of urea solution is : [AIEEE 2004]  
(1) 0.001 M (2) 0.01 M (3) 0.02 M (4) 0.1 M.
11. To neutralise completely 20 mL of 0.1 M aqueous solution of phosphorus acid ( $\text{H}_3\text{PO}_3$ ), the volume of 0.1 M aqueous KOH solution required is : [AIEEE 2004]  
(1) 10 mL (2) 20 mL (3) 40 mL (4) 60 mL
12. Which of the following liquid pairs shows a positive deviation from Raoult's law ? [AIEEE 2004]  
(1) water – hydrochloric acid (2) benzene - methanol  
(3) water – nitric acid (4) acetone – chloroform
13. Which one of the following statements is false ? [AIEEE 2004]  
(1) Raoult's law states that the vapour pressure of a component over a solution is proportional to its mole fraction.  
(2) The osmotic pressure ( $\pi$ ) of a solution is given by the equation  $\pi = MRT$ , where M is the molarity of the solution.  
(3) The correct order of osmotic pressure for 0.01 M aqueous solution of each compound is  $\text{BaCl}_2 > \text{KCl} > \text{CH}_3\text{COOH} > \text{sucrose}$ .  
(4) Two sucrose solutions of same molality prepared in different solvents will have the same freezing point depression.

14. If  $\alpha$  is the degree of dissociation of  $\text{Na}_2\text{SO}_4$ , the van't Hoff's factor (i) used for calculating the molecular mass is : **[AIEEE 2005]**  
 (1)  $1 + \alpha$  (2)  $1 - \alpha$  (3)  $1 + 2\alpha$  (4)  $1 - 2\alpha$ .
15. Benzene and toluene form nearly ideal solutions. At  $20^\circ\text{C}$ , the vapour pressure of benzene is 75 torr and that of toluene is 22 torr. The partial vapour pressure of benzene at  $20^\circ\text{C}$  for a solution containing 78 g of benzene and 46 g of toluene in torr is : **[AIEEE 2005]**  
 (1) 50 (2) 25 (3) 37.5 (4) 53.5
16. Two solutions of a substance (non electrolyte) are mixed in the following manner. 480 ml of 1.5 M first solution + 520 mL of 1.2 M second solution. What is the molarity of the final mixture ? **[AIEEE 2005]**  
 (1) 1.20 M (2) 1.50 M (3) 1.344 M (4) 2.70 M
17. Equimolar solutions in the same solvent have : **[AIEEE 2005]**  
 (1) same boiling point but different freezing point  
 (2) same freezing point but different boiling point  
 (3) same boiling and same freezing points  
 (4) different boiling and freezing points
18. 18 g of glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) is added to 178.2 g of water. The vapour pressure of water for this aqueous solution at  $100^\circ\text{C}$  is - **[AIEEE 2006]**  
 (1) 7.60 Torr (2) 76.00 Torr (3) 752.40 Torr (4) 759.00 Torr
19. 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]**  
 (1)  $3.28 \text{ mol kg}^{-1}$  (2)  $2.28 \text{ mol kg}^{-1}$  (3)  $0.44 \text{ mol kg}^{-1}$  (4)  $1.14 \text{ mol kg}^{-1}$
20. 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]**  
 (1) 350 (2) 300 (3) 700 (4) 360
21. A 5.25% solution of a substance is isotonic with a 1.5% solution of urea (molar mass =  $60 \text{ g mol}^{-1}$ ) in the same solvent. If the densities of both the solutions are assumed to be equal to  $1.0 \text{ g cm}^{-3}$ , molar mass of the substance will be - **[AIEEE 2007]**  
 (1)  $90.0 \text{ g mol}^{-1}$  (2)  $115.0 \text{ g mol}^{-1}$  (3)  $105.0 \text{ g mol}^{-1}$  (4)  $210.0 \text{ g mol}^{-1}$
22. The density (in  $\text{g mL}^{-1}$ ) of a 3.60 M sulphuric acid solution that is 29%  $\text{H}_2\text{SO}_4$  (Molar mass =  $98 \text{ g mol}^{-1}$ ) by mass will be - **[AIEEE 2007]**  
 (1) 1.64 (2) 1.88 (3) 1.22 (4) 1.45
23. The vapour pressure of water at  $20^\circ\text{C}$  is 17.5 mm Hg. If 18g of glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) is added to 178.2 g of water at  $20^\circ\text{C}$ , the vapour pressure of the resulting solution will be - **[AIEEE 2008]**  
 (1) 15.750 mm Hg (2) 16.500 mm Hg (3) 17.325 mm Hg (4) 17.675 mm Hg
24. At  $80^\circ\text{C}$ , 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  $80^\circ\text{C}$  and 1 atm pressure, the amount of 'A' in the mixture is (1 atm = 760 mm Hg) **[AIEEE 2008]**  
 (1) 34 mol percent (2) 48 mol percent (3) 50 mol percent (4) 52 mol percent
25. 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 ? **[AIEEE 2009]**  
 (1) The solution is non-ideal, showing +ve deviation from Raoult's Law  
 (2) The solution is non-ideal, showing -ve deviation from Raoult's Law  
 (3) n-heptane shows +ve deviation while ethanol shows -ve deviation from Raoult's Law  
 (4) The solution formed is an ideal solution

26. 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]**  
 (1) 300 and 400      (2) 400 and 600      (3) 500 and 600      (4) 200 and 300
27. If sodium sulphate is considered to be completely dissociated into cations and anions in aqueous solution, the change in freezing point of water ( $\Delta T_f$ ), when 0.01 mole of sodium sulphate is dissolved in 1 kg of water, is ( $K_f = 1.86 \text{ K kg mol}^{-1}$ ) **[AIEEE 2010]**  
 (1) 0.0372 K      (2) 0.0558 K      (3) 0.0744 K      (4) 0.0186 K
28. On mixing, heptane and octane form an ideal solution. At 373 K, the vapour pressure of the two liquid components (heptane and octane) are 105 kPa and 45 kPa respectively. Vapour pressure of the solution obtained by mixing 25.0 g of heptane and 35 g of octane will be (molar mass of heptane – 100 g mol<sup>-1</sup> and of octane = 114 g mol<sup>-1</sup>) **[AIEEE 2010]**  
 (1) 72.0 kPa      (2) 36.1 kPa      (3) 96.2 kPa      (4) 144.5 kPa
29.  $K_f$  for water is 1.86 K kg mol<sup>-1</sup>. If your automobile radiator holds 1.0 kg of water, how many grams of ethylene glycol (C<sub>2</sub>H<sub>6</sub>O<sub>2</sub>) must you add to get the freezing point of the solution lowered to – 2.8°C? **[AIEEE 2012]**  
 (1) 72 g      (2) 93 g      (3) 39 g      (4) 27 g

## EXERCISE # 4

### NCERT QUESTIONS

- The partial pressure of ethane over a solution containing  $6.56 \times 10^{-3}$  g of ethane is 1 bar. If the solution contains  $5.00 \times 10^{-2}$  g of ethane, then what shall be the partial pressure of the gas ?
- An aqueous solution of 2% non-volatile solute exerts a pressure of 1.004 bar at the normal boiling point of the solvent. What is the molar mass of the solute ?
- Heptane and octane form an ideal solution. At 373 K, the vapour pressures of the two liquid components are 105.2 kPa and 46.8 kPa respectively. What will be the vapour pressure of a mixture of 26.0 g of heptane and 35g of octane ?
- Calculate the mass of a non-volatile solute (molar mass 40 g mol<sup>-1</sup>) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.
- A solution containing 30g of non-volatile solute exactly in 90 g of water has a vapour pressure of 2.8 kPa at 298 K. Further, 18 g of water is then added to the solution and the new vapour pressure becomes 2.9 kPa at 298 K. Calculate :  
 (i) molar mass of the solute      (ii) vapour pressure of water at 298 K.
- A 5% solution (by mass) of cane sugar in water has freezing point of 271 K. Calculate the freezing point of 5% glucose in water if freezing point of pure water is 273.15 K.
- Two elements A and B form compounds having formula AB<sub>2</sub> and AB<sub>4</sub>. When dissolved in 20 g of benzene (C<sub>6</sub>H<sub>6</sub>), 1 g of AB<sub>2</sub> lowers the freezing point by 2.3 K whereas 1.0 g of AB<sub>4</sub> lowers it by 1.3 K. The molar depression constant for benzene is 5.1 K kg mol<sup>-1</sup>. Calculate atomic masses of A and B.
- At 300 K, 36 g of glucose present in a litre of its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of the solution is 1.52 bars at the same temperature, what would be its concentration ?

9. Henry's law constant for the molality of methane in benzene at 298 K is  $4.27 \times 10^5$  mm Hg. Calculate the solubility of methane in benzene at 298 K under 760 mm Hg.
10. 100 g of liquid A (molar mass  $140 \text{ g mol}^{-1}$ ) was dissolved in 1000 g of liquid B (molar mass  $180 \text{ g mol}^{-1}$ ). 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.
11. Benzene and toluene form ideal solution over the entire range of composition. The vapour pressure of pure benzene and toluene at 300 K are 50.71 mm Hg and 32.06 mm Hg respectively. Calculate the mole fraction to benzene in vapour phase if 80 g of benzene is mixed with 100 g of toluene.
12. The air is a mixture of a number of gases. The major components are oxygen and nitrogen with approximate proportion of 20% is to 79% by volume at 298 K. The water is in equilibrium with air at a pressure of 10 atm. At 298 K if the Henry's law constants for oxygen and nitrogen at 298 K are  $3.30 \times 10^7$  mm and  $6.51 \times 10^7$  mm respectively, calculate the composition of these gases in water.
13. Determine the osmotic pressure of a solution prepared by dissolving 25 mg of  $\text{K}_2\text{SO}_4$  in 2 litre of water at 25 C, assuming that it is completely dissociated.
14. Methanol and ethanol form nearly an ideal solution at 300 K. A solution is made by mixing 32 g methanol and 23 g ethanol. Calculate the partial pressures of its constituents and total vapour pressure of the solution at 300 K.  
( $P_{\text{CH}_3\text{OH}}^\circ = 90 \text{ mm Hg}$  ;  $P_{\text{C}_2\text{H}_5\text{OH}}^\circ = 51 \text{ mm Hg}$ )
15. Vapour pressures of pure benzene and toluene at 293 K is 75 mm Hg and 22 mm Hg respectively. 23.4 g of benzene and 64.4 g of toluene are mixed. If the two form an ideal solution, calculate the mole fraction of benzene in the vapour phase assuming that the vapours are in equilibrium with the liquid mixture at this temperature.
16. The boiling point of water becomes  $100.52^\circ\text{C}$  if 1.5 g of a non-volatile solute is dissolved in 100 mL of it. Calculate the molecular mass of the solute. ( $K_b$  for water =  $0.6 \text{ K m}^{-1}$ )
17. On dissolving 0.25 g of a non-volatile substance in 30 mL benzene (density =  $0.8 \text{ mL}^{-1}$ ), its freezing point decreases by  $0.40^\circ\text{C}$ . Calculate the molecular mass of the substance ( $K_f = 5.12 \text{ K kg mol}^{-1}$ )
18. Osmotic pressure of a solution containing 7 g of a protein per 100 mL of a solution is 25 mm Hg at  $37^\circ\text{C}$ . Calculate molar mass of the protein.
19. The osmotic pressure of a dilute aqueous solution of compound (X) containing 0.12 g per litre is twice the osmotic pressure of a dilute aqueous solution of another compound (Y) containing 0.18 g per litre. What is the ratio of molecular mass of (X) to that of (Y) ? Both (X) and (Y) remain in molecular form in solution.
20. 1 litre aqueous solution of sucrose (molar mass = 342) weighing 1015 g is found to record an osmotic pressure of 4.82 atm at 293 K. What is the molality of the sucrose solution ?  
( $R = 0.0821 \text{ litre atm K}^{-1} \text{ mol}^{-1}$ )
21. Assuming complete ionisation, calculate the expected freezing point of solution prepared by dissolving 6 g of Glauber's salt,  $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$  in 0.1 kg of  $\text{H}_2\text{O}$ . ( $K_f$  for  $\text{H}_2\text{O} = 1.86 \text{ K kg mol}^{-1}$ )
22. Calculate the van't Hoff factor of  $\text{CdSO}_4$  (mol. mass = 208.4) if the dissociation of 5.21 g of  $\text{CdSO}_4$  in half litre water gives a depression in freezing point of  $0.168^\circ\text{C}$ . ( $K_f$  for water =  $1.86 \text{ K kg mol}^{-1}$ )
23. How much urea (molar mass =  $60 \text{ g mol}^{-1}$ ) should be dissolved in 50 g of water so that its vapour pressure at room temperature is reduced by 25% ? Calculate molality of the solution obtained.

# ANSWERS

## EXERCISE # 1

### PART # I

A-1.	(C)	A-2.	(A)	A-3.	(B)	A-4.	(A)	A-5.	(C)	A-6.	(D)	A-7.	(C)
B-1.	(C)	B-2.	(A)	B-3.	(D)	B-4.	(A)	B-5.	(C)	B-6.	(D)	B-7.	(C)
B-8.	(A)	B-9.	(C)	B-10.	(A)	B-11.	(B)	B-12.	(C)	B-13.	(A)	B-14.	(C)
B-15.	(D)	B-16.	(C)	C-1.	(A)	C-2.	(B)	C-3.	(D)	C-4.	(A)	C-5.	(D)
C-6.	(C)	C-7.	(C)	C-8.*	(BD)	C-9.	(B)	C-10.*	(ABC)	D-1.	(A)	D-2.	(C)
D-3.	(B)	D-4.	(C)	D-5.	(B)	D-6.	(A)	D-7.	(A)	D-8.	(B)	D-9.	(A)
D-10.	(C)	D-11.	(A)	D-12.	(C)	D-13.	(B)	D-14.	(C)	D-15.	(B)	D-16.	(B)
D-17.	(D)	D-18.	(D)	E-1.	(C)	E-2.	(B)	E-3.	(B)	E-4.*	(AC)	E-5.	(C)
E-6.	(B)	E-7.	(D)	E-8.	(B)	E-9.	(B)	E-10.	(C)	E-11.	(B)	E-12.	(D)
E-13.	(C)	F-1.	(A)	F-2.	(C)	F-3.	(A)	F-4.	(B)	F-5.	(C)	F-6.	(D)
F-7.	(D)	F-8.	(B)	F-9.	(A)	F-10.	(A)	F-11.	(C)	G-1.	(C)	G-2.	(A)
G-3.	(C)	G-4.	(C)	G-5.	(D)	G-6.	(B)	G-7.	(B)	G-8.	(A)	G-9.	(B)
G-10.	(C)	G-11.	(B)	H-1.*	(ABC)	H-2.	(C)	H-3.	(A)	H-4.*	(ABC)	H-5.	(A)
H-6.	(A)												

### PART # II

1.	(A)	2.	(B)	3.	(A)	4.	(D)	5.	(C)	6.	(A)	7.	(B)
8.	(B)					9.	(a)-(v), (b)-(iv), (c)-(ii), (d)-(iii), (e)-(i)						
10.	(a), (d) - (ii), (b), (c)-(i), (e)-(iii)					11.	(a) Q ; (b) R ; (c) P ; (d) S						
12.	(a), (e) - (ii), (b)-(i), (c), (d)-(iii)					13.	(A) - (p, s, r); (B) - (p, q, t); (C) - (p); (D) - (p, q, t)						
14.	(D)	15.	(C)	16.	(C)	17.	(C)	18.	(A)	19.	(C)	20.	(D)
21.	(A)	22.	(A)	23.	T	24.	F	25.	F	26.	F	27.	T
28.	T	29.	F	30.	F	31.	F	32.	F	33.	F	34.	T
35.	T	36.	F	37.	T	38.	T	39.	F	40.	T	41.	T

## EXERCISE # 2

### PART # I

1.	(C)	2.	(C)	3.	(B)	4.	(A)	5.	(C)	6.	(B)	7.	(A)
8.	(D)	9.	(A)	10.	(B)	11.	(A)	12.	(C)	13.	(B)	14.	(D)
15.	(D)	16.	(D)	17.	(D)	18.	(C)	19.	(C)	20.	(B)	21.	(B)
22.	(C)	23.	(C)	24.	(A)	25.	(B)	26.	(D)	27.	(C)	28.	(B)
29.	(B)	30.	(C)	31.	(A)	32.	(A)	33.	(A)	34.	(A)	35.	(A)
36.	(B)	37.	(B)	38.	(B)	39.	(C)	40.	(A)	41.	(C)	42.	(C)
43.	(B)	44.	(B)	45.	(ABC)	46.	(ABCD)	47.	(BD)	48.	(BD)		

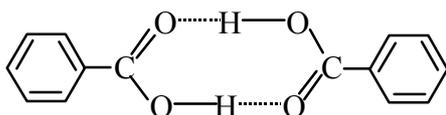
## PART # II

- Molality = 11.44 m, Molarity = 7.55 M
- Volume must have been made 5 times
- $P_{O_2} = 810$  mm Hg,  $P_{H_2O} = 355$  mm Hg,  $P_{total} = 1165$  mm Hg
- (a) 60 g/mol (b) 333.6 g
- $C_{12}H_6$
- 749.9 mm of Hg
- $M = 48$
- 2660.3 Torr
- (a)  $M = 94.52$  (b)  $m = 135$
- $S_8$
- 10.33°C
- 60
- (i) Tetraamminedichloroplatinum (IV) chloride  
(ii) Volume of  $NH_3(aq)$  needed = 20 mL  
(iii) Diamminesilver (I) chloride
- 232
- $p_A^0 = 400$  mm of Hg,  $p_B^0 = 600$  mm of Hg
- 27.3 mole %
- 14.16 mole percent benzene
- Endothermic
- 3.973
- 5.15 g
- 7.62 bar
- 0.24 atm
- (a) 17.48 mm (b) 4.611 atm (c)  $-0.372^\circ C$  (d)  $100.103^\circ C$
- 1.875, 250 gm
- 0.716 m mol
- $C_{44}H_{88}O_{44}$
- 746.24 mm/Hg
- (a)  $3.79^\circ C$  (b) 0.018 (c) 4.65 atm (d) 251.5
- $[Co(NH_3)_5Cl]Cl_2$
- $46.33^\circ C$
- $x_a'' = 0.1$
- $5.4 \times 10^{-13}$
- 12.72
- 13.8 atm
- 4.64 atm
- $C_{44}H_{88}O_{44}$
- 746.24 mm/Hg
- $T_f = -0.73^\circ C$
- 0.73
- 20.11 %
- 12.54

## EXERCISE # 3

### PART # I

- (A)
- (C)
- $1.0 \times 10^{-4}$
- (A)
- $K_b(x) = 0.68$ ,  $K_b(y) = 0.53$ ,  $K_b(z) = 0.98$
- (C)
- (a) 122,  
(b) It means that benzoic acid remains as it is in acetone while it dimerises in benzene as



- (A)
- 35% phenol is present in dimeric form
- (A)
- (D)
- (B)
- (B)
- (A)
- (A)
- (A)
- (BCD)

### PART # II

- (1)
- (2)
- (2)
- (1)
- (2)
- (4)
- (1)
- (1)
- (2)
- (3)
- (2)
- (4)
- (3)
- (1)
- (3)
- (3)
- (3)
- (2)
- (1)
- (4)
- (3)
- (3)
- (3)
- (1)
- (3)
- (2)
- (1)
- (2)

## EXERCISE # 4

- $P_{CH_3OH} = 60$  mm Hg ;  $P_{C_2H_5OH} = 17$  mm Hg ; Total vapour pressure = 77 mm Hg
- 0.59
- 100.28°C
- 133.33
- 54094
- $M_1 : M_2 :: 1 : 3$
- 0.2112 m
- 271.95 K
- 1.806
- Mass of urea = 55.56 g ; molality of solution = 18.52