LIQUID SOLUTION

Vapour Pressure



The pressure exerted by the vapour (molecules in the vapour phase) over the surface of the liquid at the equilibrium at given temperature is called the vapour pressure of the liquid.

Factors affecting vapour pressure

(i) **Temperature :**

Vapour pressure ∞ Temperature

The temperature at which the vapour pressure of the liquid becomes equal to the atmospheric pressure is called its *boiling point*.



(ii) Nature of liquid:

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

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

i) Vapour Pressure of a Solution Containing Non Volatile Solute - Raoult's Law

Raoult's Law : Acccording to this law, the partial pressure of any volatile constituent of a soltuion at a constant temperature is equal to the vapour pressure of pure constituent multiplied by the mole fraction of that constituent in the solution.

$$\mathbf{P}_{\mathbf{A}} \propto \mathbf{X}_{\mathbf{A}} \implies \mathbf{P}_{\mathbf{A}} = \mathbf{P}_{\mathbf{A}}^{0} \mathbf{X}_{\mathbf{A}}$$



Relative Lowering of vapour pressure: For a solution of a non-volatile solute in a liquid, the vapour pressure contribution by the non-volatile solute is negligible. Therefore, the partial vapour pressure of a solution containing a non-volatile solute is equal to the product of vapour pressure of the pure liquid (solvent P_A°) and its mole fraction in the solution.

Let X_A be the mole fraction of solvent A, then (Here $p_B^0 =$ negligible as solute is non-volatile)

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

If X_B be the mole fraction of the solute B, then

$$X_A + X_B = 1 \implies X_A = 1 - X_B$$

hence $P_A = P_A^{\circ}(1 - X_B) = P_A^{\circ} - P_A^{\circ}X_B \implies P_A^{o}X_B = P_A^{o} - P_A$

 $(P_A^o - P_A$ is known as lowering of vapour pressure)

$$\frac{\mathbf{P}_{\mathbf{A}}^{\mathbf{0}} - \mathbf{P}_{\mathbf{A}}}{\mathbf{P}_{\mathbf{A}}^{\mathbf{0}}} = \mathbf{X}_{\mathbf{B}} \quad \left(\frac{\mathbf{P}_{\mathbf{A}}^{\circ} - \mathbf{P}_{\mathbf{A}}}{\mathbf{P}_{\mathbf{A}}^{\circ}} \text{ is called relative lowering of vapour pressure, (RLVP)} \right)$$

Therefore, Raoult's law states that the relative lowering of vapour pressure $\left(\frac{P_A^{\circ} - P_A}{P_A^{\circ}}\right)$, for a non-volatile

solute is equal to the mole fraction of the solute when the solvent alone is volatile.

Example: The vapour pressure of pure water at 37°C is 47.1 torr. What is the vapour pressure of an aqueous solution at 37°C containing 20 g of glucose dissolved in 500 gm of water. Also calculate vapour pressure lowering.

$$\begin{aligned} \textit{Solution:} \quad n_{H_{2}0} &= \frac{500}{18} = 27.78 \text{ mol}, \qquad n_{(glucose)} = \frac{20}{180} = 0.11 \text{ mol} \\ X_{H_{2}0} &= \frac{n_{H_{2}0}}{n_{H_{2}0} + n_{(glucose)}} = \frac{27.78}{27.78 + 0.11} = \frac{27.78}{27.89} = 0.996 \\ \text{According to Raoult's law,} \\ \text{Vapour pressure of solution} \quad P_{H_{2}0} = P_{H_{2}0}^{\circ} X_{H_{2}0} = 47.1 \times 0.996 = 46.9 \text{ torr} \\ \text{Lowring of vapour pressure} \quad P_{H_{2}0}^{\circ} - P_{H_{2}0} = 47.1 - 46.9 = 0.2 \text{ torr} \end{aligned}$$

$$\begin{aligned} \textit{Example:} \qquad \textit{The vapour pressure of ethyl alcohol at 25°C is 59.2 torr. The vapour pressure of a solution of urea in ethyl alcohol is 51.3 torr. What is the molality of the solution? \\ \textit{Given: } P_{A}^{\circ} = 59.2 \text{ torr, } pA = 51.3 \text{ torr} \\ \textit{By RLVP} \Rightarrow X_{solute} = \frac{7.9}{59.2} = .1334 \\ (\text{molality}) \text{ m} = \frac{X_{B}}{X_{A}} \times \frac{1000}{M_{solvent}} = \frac{X_{B}}{(1-X_{B})} \times \frac{1000}{M_{solvent}} \qquad (X_{A} + X_{B} = 1) \\ m = \frac{0.1334}{0.8666} \times \frac{1000}{46} = 3.346 \text{ molal} \end{aligned}$$

		Practic	ce Problems	Ι	
Q.1	The vapour pressur ether, vapour press weight of solute is	re of ether at 20°C is ure is lowered by 32 u	442 mm. When 7. nits. If molecular v	2 g of a solute is di veight of ether is 74	ssolved in 60 g then molecular
	(A) 113.77	(B) 150.35	(C) 116.23	(D) 190.26	i
Q.2	The vapour pressur solution of a solute	The of pure benzene at C_6H_6 at the same to	25°C is 639.7 mm emperature is 631.	of Hg and the vapo 9 mm of Hg. Molali	ur pressure of a ty of solution is
	(A) 0.079 mol/kg o (C) 0.158 mol/kg o	f solvent f solvent	(B) 0.256 mo (D) 0.316 mo	l/kg of solvent l/kg of solvent	
Q.3	A 6% (by weight) of mm Hg. 20 g of is pressure of 1445 m (i) Molecular v (A) 28, 32	of non-volatile solute opentane is now adde m of Hg at the same to veight of solute is - (B) 92.81	in isopentane at 30 ed to the solution. emperature. Then (C) 11	00 K has a vapour p The resulting solutio 3.30 (D)	ressure of 1426 on has a vapour
	(ii) Vapour pres (A) 1541.68	ssure of isopentane at 8 mm (B) 770.89	300 K is -	(C) 1212.46 mm	(D) 981.32
Q.4	Find out the weight vapour pressure to	of solute (M. wt. 60) 4/5th of pure water	that is required to a	lissolve in 180 g wa	ter to reduce the
	(A) 130 g	(B) 150 g	(C) 300 g	(D) 75 g	
Q.5	The molality of a s the vapour pressure (A) 2.213	olution containing a n of pure water, will b (B) 2.518	on-volatile solute e - (C) 1.133	if the vapour pressu (D) 1.891	are is 2% below
Q.6	The weight of a no reduce its vapour p	n-volatile solute (m. v ressure to 80%, is -	wt. 40). Which sho	build be dissolved in $(D) 5$ and	114 g octane to
07	(A) 20 gill	(B) 10 gill	(C) 7.3 gm	(D) 5 gm	re of pure water
Q.1	i 23.76 mm Hg, vap required in 100 g w (A) 333 g	our pressure of solut vater to reduce the vap (B) 666 g	ion is 22.41 mm our pressure to or (C) 166 g	Hg. The mass of th he-half of the pure w (D) 256 g	is solute that is vater is -
Q.8	Vapour pressure of falls by 4 mm. Hen (A) 6.173 molal	pure water is 40 mm. ce, molality of solutio (B) 3.0864 molal	If a non-volatile s on is - (C) 1.543 mo	solute is added to it value (D) 0.772 r	vapour pressure molal
Q.9	The vapour pressur added to the solven in the solution is	re of pure liquid solve t, its vapour pressure	ent A is 0.80 atm. drops to 0.60 atm	When a non-volatile ; mole fraction of th	e substance B is ne component B
	(A) 0.50	(B) 0.25	(C) 0.75	(D) 0.40	
Q.10	Vapour pressure of is dissolved in 100 [Given : De	CCl_4 at 25°C is 143 m ml CCl_4 , then the vap	m Hg. If 0.5 gm of our pressure of the g/cm ³ l	f non-volatile solute e solution at 25°C is	(mol. mass 65) -
	(A) 141.93 mm mm	(B) 94.39 r	nm (C) 19	9.34 mm	(D) 143.99
Q.11	Lowering of vapour of molar mass 40 g (A) 29.23 torr	pressure of 1.00 m so at its normal boiling (B) 30.4 torr	lution of a non-vol- point, is - (C) 35.00 torr	atile solute in a hypo (D) 40.00 t	thetical solvent orr

Q.12	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				
Q.13	The mole fraction of lowering of vapour p (A) 0.01	the solvent in the solution the solution of the solution of th	tion of a non-volatile (C) 0.02	solute is 0.980. The relative (D) 0.49	
Q.14	The vapour pressure pressure of the solve times the molecular v (A) 0.15	of a solution of a non-vent at the same tempera weight of the solute, weight of the solute, weight (B) 5.7	volatile solute B in a soluter. If the molecular hat is the weight ratio (C) 0.2	lvent A is 95% of the vapour weight of the solvent is 0.3 of solvent to solute. (D) none of these	
Q.15	The vapour pressure aqueous solution of s (A) 23.9 mm Hg	of water at room temp sucrose with mole fract (B) 24.2 mm Hg	berature is 23.8 mm Hg tion 0.1 is equal to – (C) 21.42 mm Hg	(D) 31.44 mm Hg	
Q.16	The vapour pressure i 20 g of A, its vapour the molecular mass of (A) 100 amu	of pure A is 10 torr and pressure is reduced to 9 of B is $-$ (B) 90 amu	at the same temperature 2.0 torr. If the molecula	re when 1 g of B is dissolved n r mass of A is 200 amu, then (D) 120 amu	
Q.17	The vapour pressure of solute per mole of ber of 167.0 Torr at 50°C (A) 0.305 mol	of pure benzene C_6H_6 and P_6	t 50°C is 260 Torr. How epare a solution of benz (C) 0.336 mol	(D) 120 and v many moles of nonvolatile ene having a vapour pressure (D) 0.663 mol	
Q.18	Lowering of vapour p (A) 13.44 Torr	pressure due to a solute (B) 14.12 Torr	e in 1 molal aqueous so (C) 312 Torr	olution at 100°C is - (D) 352 Torr	
Q.19	How many grams of 1.19 mmHg at a temp (A) 342 g	sucrose must be added perature at which press (B) 360 g	to 360 g of water to lo sure of pure water is 25 (C) 375 g	ower the vapour pressure by mm Hg ? (D) 380 g	

(ii) Vapour Pressure of a Solution Containing Two Volatile Liquids

Raoult's law states that the partial vapour pressure of a component of a solution of two miscible liquids A and B at a given temperature is equal to the product of the vapour pressure of the pure component at that temperature and its mole fraction in the solution.

Mathematical Expression: Let us assume that a solution has n_A moles of liquid A and n_B moles of liquid B. Let P_A° be the vapour pressure of the pure liquid A and P_B° is the vapour pressure of the pure liquid B.

Mole fraction of A, $X_A = \frac{n_A}{n_A + n_B}$, Mole fraction of B, $X_B = \frac{n_B}{n_A + n_B}$

 $P_A = P_A^{\circ} X_A$ (where P_A is the partial vapour pressure of liquid A in the solution)

Similarly, $P_B = P_B^{\circ} X_B$ (P_B - partial vapour pressure of B in the solution)

The total vapour pressure of an ideal solution containing components A and B is the sum of partial vapour pressures of all the components (Dalton's law of partial pressures)



1. Straight line I represents the plot of vapour pressure of liquid A (P_A) and its mole fraction (X_A) . According to Raoult's law this should be a straight line when

$$X_{A} = 0$$
 $P_{A} = 0$, $X_{A} = 1$, $P_{A} = P_{A}^{o}$

When mole fraction of liquid A is $X_A = 1$, the liquid A is pure and its vapour pressure is equal to P_A^o as shown by line (I)

2. Straight line II represents the plot of partial vapour pressure of liquid (B) P_B and its mole fraction

 $(X_{\scriptscriptstyle B}).$ According to Raoult's law, this should be a straight line. when

$$X_{B} = 0$$
 $P_{B} = 0$, $X_{B} = 1$, $P_{B} = P_{B}^{o}$

When mole fraction of liquid B is $X_B = 1$, the liquid B is pure and its vapour pressure is equal to P_B^o as shown by line (II).

3. Straight line (III) represents the total vapour pressure, P, of the solution for any composition and is given by the sum of the partial vapour pressure of liquids of A and B.

$$P = P_A + P_B$$

Illustration 7. An aqueous solution containing 28% by mass of a liquid A (mol. mass = 140) has a vapour pressure of 160 mm at 37°C. Find the vapour pressure of the pure liquid A. (The vapour pressure of water at 37°C is 150 mm.)

Solution : For two miscible liquids,

$$P_{total} = P_A + P_B = P_A^o X_A + P_B^o X_B$$
 $n_A = \frac{28}{140} = 0.2$

Liquid B is water. Its mass is (100–28), i.e. 72.

$$n_{\rm B} = \frac{72}{18} = 4.0$$

Total number of moles =
$$0.2 + 4.0 = 4.2$$
Given $P_{total} = 160$ mm, $P_B^0 = 150$ mm

So

$$160 = \frac{0.2}{4.2} \times P_A^0 + \frac{4.0}{4.2} \times 5.0$$
$$p_A^0 = \frac{17.15 \times 4.2}{0.2} = 360.15 \text{mm}$$

Dalton's Law v/s Raoult's Law:

The composition of the vapour in equilibrium with the solution can be calculated applying Daltons' law of partial pressures. Let the mole fractions of vapours A and B be Y_A and Y_B respectively. Let p_A and p_B be the partial pressure of vaours A and B respectively and total pressure P.



From Raoult's law $P = P_A^o X_A + P_B^o X_B$ $P_A = P_A^o X_A$ and $P_B = P_B^o X_B$ From Dalton's law,

Partial pressure = Mole fraction × Total pressure For A $P_A = y_A \times P$

$$P_A^o X_A = y_A \times P$$
 $\Rightarrow y_A = \frac{P_A^o X_A}{P}$ (1)

Above formula is used for calculation of mole fraction of A in vapour phase For B, $P_B = y_B \times P$

$$P_{B}^{\circ}X_{B} = y_{B} \times P \qquad \Rightarrow y_{B} = \frac{P_{B}^{\circ}X_{B}}{P} \qquad \dots (2)$$

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

From (1),
$$X_A = \frac{P \times y_A}{P_A^0}$$
 From (2) $X_B = \frac{P \times y_B}{P_B^0}$
on adding $X_A + X_B = \frac{P \times y_A}{P_A^0} + \frac{P \times y_B}{P_B^0} = 1$
 $\Rightarrow \frac{1}{P} = \frac{y_A}{P_A^0} + \frac{y_B}{P_B^0}$ (3)

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

Avoid confusion

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

 $\frac{1}{P} = \frac{y_A}{P_A^o} + \frac{y_B}{P_B^o} \implies \text{This formula is used to calculate total pressure when mole fraction}$

are given in vapour phase

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

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

Solution: No. of moles of $C_2H_5OH = \frac{60}{46} = 1.304$, No. of moles of $CH_3OH = \frac{40}{32} = 1.25$

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

'X_B' of methyl alcohol = $\frac{1.25}{1.304 + 1.25} = 0.4893$ Partial pressure of ethyl alcohol = X_A.P_A⁰ = 0.5107 × 44.5 = 22.73 mm Hg

Partial pressure of methyl alcohol = $X_B P_B^0 = 0.4893 \times 88.7 = 43.40$ mm Hg Total vapour pressure of solution = 22.73 + 43.40 = 66.13 mm Hg

Mole fraction of methyl alcohol in the vapour = $\frac{\text{Partial pressure of CH}_{3}\text{OH}}{\text{Total vapour pressure}}$

 $=\frac{43.40}{66.13}=0.6563$

Practice Problems II

Q.1	An aqueous solution vapour pressure of	on containing liqu water is 155 mm	aid A (M. wt. $= 12$) in then vapour pre-	28) 64% by wei essure of A at th	ght has a V. P. e same tempe	of 145 mm. If the rature will be -
	(A) 205 mm	(B) 105 mm	(C) 18:	5 mm	(D) 52.5 mm	
Q.2	 Q.2 The vapour pressure of pure ethylene bromide and propylene bromide are 170 and 127 mm a temperature. Find out : (i)The vapour pressure of ethylene bromide & propyline bromide in a 60% by weight solut ethylene bromide in propylene bromide at same temperature, is - 					
	(A) 52.4 m	m, 24.31 mm		(C) 52.4 mm, 4	52.4 mm, 48.63 mm	
(C) 104.9 mm, 48.63 mm (D) 104.9 mm, 24.31 mm					24.31 mm	
	(ii) Total vapour pressure of solution, is -					
	(A) 153.53	mm	(B) 76.71 mm	(C) 101	.03 mm	(D) 129.21 mm

Q.3	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					
Q.4	The vapour pressure mole fraction of B in (A) 3.3 and 2.1 cm o (C) 5.3 and 2.3 cm o	of two volatile liquid m mixture. What are var f Hg f Hg	nixture is $P_T = (5.3 - 2X_B)$ in cm of Hg; where X_B is pour pressure of pure liquids A and B? (B) 2.3 and 3.3 cm of Hg (D) 5.3 and 3.3 cm of Hg			
Q.5	A mixture contains 1 mole volatile liquid A ($P_A^o = 100 \text{ mg Hg}$) and 3 moles volatile liquid B($P_A^o = 80 \text{ mm}$). If solution be haves ideally, total vapour pressure of the solution is approximately(A) 80 mmHg(B) 85 mmHg(C) 90 mmHg(D) 92 mmHg					
Q.6	At 40°C the vapour pressure in torr of methanol and ethanol solution is P = 119 x + 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					
Q.7	Vapour pressure of p mole fraction of A is pressure of pure B at (A) 1 atm	ure A is 70 mm of Hg 0.8. If vapour pressur 25°C is - (B) 14 mm of Hg	at 25°C it forms an ide e of solution is 84 mm (C) 140 mm of Hg	cal solution with B in whichn of Hg at 25°C, the vapour(D) 56 cm of Hg		
Q.8	Vapour pressure (in to where X_A is the mole mixture of the two lie (A) 166	orr) of an ideal solution e fraction of A in the m quids will be - (B) 83	of two liquids A and B hixture. The vapour pre (C) 140	is given by : $P = 52 X_A + 114$ essure (in torr) of equimolar (D) 280		
Q.9	Solution of two volat that when the total va vapour phase is 0.45 the same temperature (A) 138.4 mm, 628.5 (C) 276.9 mm, 314.2	tile liquids A and B obe apour pressure above so and in liquid phase 0.6 will be - 7 mm 8 mm	y Raoult's law. At a cer olution is 400 mm of F 55 then the vapour pres (B) 276.9 mm (D) 138.4 mm	tain temperature, it is found Ig, the mole fraction of A in sources of two pure liquids at n, 628.57 mm n, 314.28 mm		
Q.10	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					
Q.11	The vapour pressure liquids is made. The	of two liquids are 1500 1 the mole fraction of A	0 and 30000 in a unit. A and B in vapour phase	When equimolar solution of e will be -		
	(A) $\frac{2}{3}, \frac{1}{3}$	(B) $\frac{1}{3}, \frac{2}{3}$	(C) $\frac{1}{2}, \frac{1}{2}$	(D) $\frac{1}{4}, \frac{3}{4}$		
Q.12	At 30°C, the vapour p the mole fraction of e of ether 0.50. Assum	pressure of pure ether is ach component in vapo e ideal behaviour.	s 646 mm and of pure a ur state for the solution	acetone is 283 mm. Find out of two having mole fraction		
	(A) 0.20, 0.80	(B) 0.799, 0.201	(C) 0.695, 0.305	(D) 0.535, 0.465		

Q.13	Benzene and toluene	form an ideal solution	on. The vapour pressure	of benzene and toluene are respectively		
	75 mm and 22 mm at 20°C. If the mole fraction of benzene and toluene in vapour phase are 0.63					
	(i) The vapour pressure of mixture is -					
	(A) 39.68 m	m (B) 79.32 1	mm (C) 58.56 1	mm (D) 29.24 mm		
	(ii) Mole fractio	n of benzene & tolue	ene in liquid phase is -			
	(A) 0.2, 0.8	(B) 0.63, 0	0.37 (C) 0.54, 0	.46 (D) 0.33, 0.67		
Q.14	At 90°C, the vapour liquid mixture that v	pressure of toluene i will boil at 90°C whe	is 400 mm and that of 1 n the pressure of mixture (C) 0.02 - 0.08	xylene is 150 mm. The composition of the is 0.5 atm, is - $(D) = 0.66 + 0.24$		
	(A) 0.8, 0.2	(B) 0.75, 0.25	(C) 0.92, 0.08	(D) 0.00, 0.34		
Q.15	V. P. of pure A	$p^{o}_{A} = 100 \text{ mmHg}$				
	V. P. of pure B Distillate of vapours approximately, on co (A) 135 mm	$p_{B}^{o} = 150 \text{ mmHg}$ s of a solution contain ondensation (B) 130 mm	ning 2 moles A and 3 m (C) 140 mm	oles B will have total vapour pressure, (D) 145 mm		
0.16	1 mala hanzana (De	-12 mm) and 2 mal	$(D^0 - 26)$) will have		
Q.10	(Λ) total variable	-42 mm) and 2 mole	es toluene ($P = 30 \text{ mm}$	i) will have		
	(A) total vapour (B) mole fraction	pressure 30 mm n of vapours of benze	ana ahaya liquid mixtu	re is $7/10$		
	(C) ideal behavior	our		all of the above		
	(C) Ideal bellavi	Jui	(D)			
Q.17	At a given temperature be the mole fraction fraction of A and B,	ure, the vapour press of B in the vapour pha under ideal behavior	ure of pure A and B is ase which is in equilibri ar conditions ?	108 and 36 torr respectively. What will um with a solution containing equimole		
	(A) 0.25	(B) 0.33	(C) 0.50	(D) 0.60		
Q.18	A solution of benze	one $(p^o = 120 \text{ torr})$ at	nd toluene ($p^{o} = 80$ tor	r) has 2.0 mol of each component. At		
	equilibrium the mol (A) 0.50	fraction of toluene in (B) 0.25	n vapour phase is - (C) 0.60	(D) 0.40		
Q.19	Liquids A and B form are the mole fraction	n an ideal solution ar ns of A in the solution	nd the former has strong n and vapour in equilib	ger intermolecular forces. If X_A and X'_A rium, then -		
	(A) $\frac{X'_A}{X_A} = 1$	(B) $\frac{X'_A}{X_A} > 1$	(C) $\frac{X'_{A}}{X_{A}} < 1$	(D) $X'_A + X_A = 1$		
Q.20	Mole fraction of a li component A in the $(P^o_A = vapour pressure)$	quid A in an ideal mit vapour in equilibriur ure of pure A ; P° _B = v	xture with another liqu n, the total pressure of vapour pressure of pure	id b is X_A . If X'_A is the mole fraction of the liquid mixture is - e B)		
	(A) $P^{o}{}_{A} \frac{X'{}_{A}}{X_{A}}$	(B) $\frac{P^{o}{}_{A}X_{A}}{X'_{A}}$	(C) $\frac{P^{o}_{B}X'_{A}}{X_{A}}$	(D) $\frac{P_B^o X_A}{X'_A}$		
Q.21	Two liquids A and $x_A : x_B = 1 : 3$, the m is-	B have $P_{A}^{o}: P_{B}^{o} =$ note fraction of A in v	1 : 3 at a certain tem vapour in equilibrium v	perature. If the mole fraction ratio of with the solution at a given temperature		
	(A) 0.1	(B) 0.2	(C) 0.5	(D) 1.0		
Q.22	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					
Q.23	Mole fraction of the $(p^{o} = 120)$ and tolue	toluene in the vapo ne ($p^o = 80$) having	our phase which is in e 2.0 moles of each, is –	quilibrium with a solution of benzene		
۱	(A) 0.50	(B) 0.25	(C) 0.60	(D) 0.40		

Q.24	The vapour pressure of pure liquid A at 300 K is 575 torr and that of pure liquid B is 390 torr.				
	These two compounds form ideal liquid and gaseous mix	xtures. The mole fraction of A in the vapour			
	phase is 0.35. Then :				
	(i) The total pressure of the inixture is (A) 526 torr (B) 965 torr (C)) 440 torr (D) 715 torr			
	(ii) composition of the liquid mixture is -				
	(A) $A = 27\%$, $B = 73\%$ (B)	A = 57 %, B = 43 %			
	(C) $A = 33\%$. $B = 67\%$ (D)	A = 30%, B = 70%			
Q.25	5 64 gm of methanol & 46 gm of ethanol forms in an idea of methanol and ethanol at 350 K are 8.1×10^4 and $4.5 \times$ of methanol in vapour phase is - (A) 0.62 (B) 0.22 (C) 0.80	al solution at 350 K. If the vapour pressure $< 10^4$ N m ⁻² respectively, then mole fraction (D) 0.78			
0.26	6 Two liquids A and B forms on ideal solution at tempe	prature T. When the total vanour pressure			
Q.20	above the solution is 400 torr, the mole fraction of A in phase 0.75. The vapour pressure of pure A and B respec (A) 165.54 torr, 772.00 torr (B) 240.24 (C) 213.33 torr, 960.00 torr (D) 312.15	the vapour phase is 0.40 and in the liquid ctively are - 4 torr, 840.00 torr 5 torr, 865.00 torr			
Q.27	7 Vapour pressure of a mixture of benzene and toluene is	given by $P = 179 x_p + 92$ where x_p is mole			
-	fraction of benzene. Determine :				
	(i) vapour pressure of the solution obtained by mi	ixing 936 gm of benzene and 736 gm of			
	toluene				
	(A) 199.4 mm (B) 271 mm (C)) 280 mm (D) 289 mm			
	(1) If vapours are removed and condensed into liquid	I then what will be the ratio of mole fraction			
	$(\Delta) 2.8$ (B) 1.5 (C)	- (D) 4 5			
	(iii) This condensed liquid again brought to the sam	temperature then what will be the mole			
	fraction of benzene in vapour phase -				
	(A) 0.07 (B) 0.93 (C)) 0.65 (D) 0.45			
Q.28	8 Benzene and toluene from nearly ideal solutions. If at 2 and pure benzene are 32.06 mm and 103.01 mm respe containing 0.60 mole fraction of toluene, is -	27°C the vapour pressures of pure toluene ectively, the vapour pressure of a solution			
	(A) 60.44 mm (B) 30.22 mm (C) 120.12	2 mm (D) 76.52 mm			
Q.29	 An aqueous solution containing 28% by mass of a liquid of 160 mm at 37°C. The vapour pressure of water at 3° liquid A, is - 	A (mol. mass = 140) has a vapour pressure 7°C is 150 mm, then the pressure of pure			
	(A) 180.22 mm (B) 300.32 mm (C)) 360.15 mm (D) 2/6.55 mm			
Q.30	0 The vapour pressure of ethyl alcohol and methyl alcohol	l are 45 mm and 90 mm. An ideal solution			
	is formed at the same temperature by mixing 60 g of C_2	$_{2}$ H ₅ OH with 40 g of CH ₃ OH. Total vapour			
(A)	pressure of the solution is approximately - (D) 25 mm (C) 105	(D) 140 mm			
<u>(A</u>	(C) 105 mm	(D) 140 mm			

Type of Solution

(i) Ideal Solution

An ideal solution may be defined as the one which obeys Raoult's law over all concentration ranges at a given temperature. The total vapour pressure of an ideal solution containing liquids A and B is given by the following equation.

 $\mathbf{P} = \mathbf{P}_{\mathbf{A}} + \mathbf{P}_{\mathbf{B}} = \mathbf{P}_{\mathbf{A}}^{\mathrm{o}} \mathbf{X}_{\mathbf{A}} + \mathbf{P}_{\mathbf{B}}^{\mathrm{o}} \mathbf{X}_{\mathbf{B}}$

In an ideal solution of two components A and B, all attractive forces between A and B molecules or between A and A molecules or between B and B molecules (A–B, A–A and B–B) must be identical so that the escaping tendency of an A or B molecule is independent of whether it is surrounded by A molecules, B, molecules or varying proportions of A and B molecules. The escaping tendency of pure liquid A in solution remains the same. Similarly the escaping tendency of B remains the same. Liquids form ideal solution only when they have nearly same molecular size and related constitution so that they have similar molecular environment in the pure state as well as in solution. A perfect ideal solution is rare but many liquids form nearly ideal solution. Liquid heptane and hexane form an ideal solution because the interaction between a hexane molecule and another hexane molecule is the same as the interaction between two heptane molecules other examples of **ideal solutions** are:

benzene + toluene,

ethyl bromde + ethyl iodide; ethyl alcohol + methyl alcohol chlorobenzene + bromobenzene; n-butyl chloride + n-butyl bromide

Conditions for Forming Ideal Solution: Two liquids on mixing form an ideal solution only when

- 1. both have similar structures and polarity so that they have similar molecular environment.
- 2. both have similar molecular sizes.
- 3. both have identical intermolecular forces.

Characteristics Of Ideal Solution:

Mixing of two substances results in an ideal solution only when:

- 1. They obey Raoult's Law
- 2. $\Delta H_{\text{mixing}} = 0 \Rightarrow$ that is no heat is absorbed or released during dissolution
- 3. $\Delta V_{\text{mixing}} = 0 \Rightarrow$ that is the total volume of the solution is equal to the sum of the volume of the pure liquids mixed to form the solution.

Graphical Representation of Vapour Pressure of Ideal Solutions:

Figure shows the relationship between partial vapour pressure and mole fraction of an ideal solution at constant temperature.



(ii) Non-Ideal Solutions

Solutions which do not obey Raoult's law over all concentration ranges at constant temperature are called non-ideal solutions.

Characteristic of nonideal solution

- $P_{A} \neq P_{A}^{o}X_{A} + P_{B} \neq P_{B}^{o}X_{B}, P \neq P_{A}^{o}X_{A} + P_{B}^{o}X_{B}$ (i)
- (ii)
- $\begin{array}{l} \Delta V_{mix} \neq 0 \ , \\ \Delta H_{mix} \neq 0 \end{array} ,$ (iii)

Types of Non-Ideal Solutions

- Non ideal solutions showing +ve deviation 1.
- 2. Non ideal solutions showing -ve deviation.

1. Non ideal solutions showing +ve deviation

Condition for forming non-ideal solution showing +ve deviation from Raoult's law.

- Tow liquids A and B on mixing form this type of solution when
- A—B attractive force should be weaker than A—A and B—B attractive forces. 1.
- 2. 'A' and 'B' have different shape, size and charater.
- 3. 'A' and 'B' escape easily showing higher vapour pressure than the expected value.

Characteristic of non-ideal solution showing +ve deviation

- Do not obey Raoult's law 1.
- 2. $\Delta H_{mix} > 0.$ (endothermic dissolution heat is absorbed.)
- $\Delta V \text{ mix} > 0.$ (Volume is increased after dissolution) 3.
- 4. $p_A > p_A^{0} X_A; p_B > p_B^{0} X_B, \qquad \therefore p_A + p_B > p_A^{0} X_A + p_B^{0} X_B$

Example :

acetone + ethanol	acetone + CS_2	water + methanol;
water + ethanol;	CCl_4 + toluene;	$CCl_4 + CHCl_3;$
acetone + benzene;	$CCl_4 + CH_3OH;$	cyclohexane + ethanol

Graphical representation of vapour of non-ideal solution showing +ve deviation



2. Non ideal solutions showing -ve deviation.

Condition for forming non-ideal solution showing +ve deviation from Raoult's law.

Two liquids A and B on mixing form this type of solution when

1.A—B attractive force should be greater than A—A and B—B attractive forces.

2.'A' and 'B' have different shape, size and character

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

Characteristic of non-ideal solution showing +ve deviation

- 1. Do not obey Raoult's law.
- 2. $\Delta H_{mix} < 0.$ (Exothermic dissolution; heat is evolved.)
- 3. $\Delta V mix < 0.$ (Volume is decreased during dissoluton)

4.
$$p_A < P_A^{0} X_A; p_B < p_B^{0} X_B, \qquad \therefore p_A + p_B < p_A^{0} X_A + p_B^{0} X_B$$

Example

acetone + aniline; chlorofrom + diethyl ether, chloroform + benzene water + HCl



Graphical representation of vapour of non-ideal solution showing +ve deviation



 $CH_{3}OH + CH_{3}COOH;$ acetic acid + pyridine;

 $H_2O + HNO_3;$

(iii) Azeotropes

The non-ideal solution showing large deviations from Raoult's law can not be purified by distillation. A solution at certain composition which continues to boil at constant temperature without change in the composition of the solution and its vapour is called an AZEOTROPE or constant boiling mixture. Azeotropes are of two types:

1. **Azeotropes with Max. vapour pressure and Min. BP :** When liquid in a solution do not have great chemical affinity for each other (+ve deviation from ideality) their higher escape tendencies increase the vapour pressure much more than expected on the basis of Raoult's law. In many cases, the deviations are so extreme as to lead to a maximum in the curve. The point of maximum vapour pressure means that the bp at this composition will be minimum and constant.

Example of Minimum Boiling Azeotrope

Components				Boiling poin	nt (K)
Α	В	Mass% of B	Α	В	Azeoterope
H_2O	C_2H_5OH	95.57	373	351.3	351.10
H_2O	C ₃ H ₇ OH	71.69	373	370.0	350.72
CHCl ₃	C_2H_5OH	67.00	334	351.3	332.30

2. Azeotropes with Min. vapour pressure and Max. bp : When liquids in solution form chemical bonds (-ve deviation from ideality), their escape tendencies and hence the vapour pressure decreases than expected on the basis of Raoult's law. In many cases, the maximum in the temperature composition curve is obtained. The point of minimum vapour pressure in the curve means that the bp of this composition will be max. and constant.

Examples of Max. Boiling Azeotrope

or

Components				oint (K)	
Α	В	Mass% of B	Α	В	Azeoterope
H_2O	HC1	20.3	373	188	383
H_2O	HNO ₃	58.0	373	359	393.5
H_2O	HClO ₄	71.6	373	383	476

Completely Immiscible Liquids : When they are distilled, they distil in the ratio of their vapor pressure

at that temperature. e.g. When A and B are distilled wt ratio
$$\frac{W_B}{W_A}$$
 is given as $\frac{W_B}{W_A} = \frac{P_B^{\circ} \cdot M_B}{P_A^{\circ} \cdot M_A}$

Completely Miscibile Liquids. They can be handled by Raoult's Law i.e.

$$y_i P = x_i P_i^{o}$$

where P = Total pressure of vapors in equilibrium with the liquid solution,

 P_i^{o} = vapor pressure of component *i* in pure state

 y_i = mole fraction of ith component *in vapor state*, x_i = mole fraction of ith component *in liquid state*

This most fundamental expression may be arranged in many useful forms. e.g. for binary solutions :

$$P = x_1(P_1^0 - P_2^0) + P_2^0$$

1/P = 1/P_2^0 + y_1(1/P_1^0 - 1/P_2^0)

Note : Vapor pressure of an ideal solution is always between P_1^0 and P_2^0 (Curve1 in Fig. 1 and 2)

Bubble Point. When the first bubble of vapor appears in liquid solution.

Dew Point. When the first drop of liquid condenses from a mixture of vapors. OR when the last drop of liquid remains and rest of the liquid is completely vaporised.

Colligative Properties

The property of a solution which depends upon the fraction of solute particles and solvent particles and not upon the chemical nature of solute is called a colligative property. Greater the no. of particles of solute in solution, greater is the extent to which colligative property is affected.

Type of colligative properties

- (i) Lowering of vapour pressure
- (ii) Elevation of Boiling point
- Depression of Freezing point (iv)
- iv) Osmotic Pressure
- **Factors that Affect the Colligative Property:** The no. of solute particles in solution. To be more accurate, the colligative property depends upon the fraction of solute and solvent particles in solution.
- (1) Nature of the solvent

(iii)

- (2) Independent of the nature of the solute
- (3) Extent of association and dissociation of solute particles in solution.
- (i) Lowering of Vapour Pressure: Vapour pressure lowering of a solution has already been explained under Raoult' Law. It was derived that the relative lowering of vapour pressure is given by the equation

$$\frac{P_{\rm A}^{\rm o} - P_{\rm A}}{P_{\rm A}^{\rm o}} = X_{\rm B} = \frac{n_{\rm B}}{n_{\rm A} + n_{\rm B}}$$

(ii) Elevation of Boiling Point: The boiling point of a liquid is the temperature at which its vapour pressure becomes equal to the atmospheric pressure. When the atmospheric pressure is 1 atm, boiling point is called the normal boiling point.



Plot of variation of vapour pressure elevation of boiling point

The vapour pressure of a liquid decreases when a non-volatile solute is dissolved in it. The decreased vapour-pressure means that the solution would have to be heated to a higher temperature so that its vapour pressure becomes equal to the atmospheric pressure. In other words, the boiling point of the solution T_b is higher than the boiling point of the pure solvent T_b^0 . The difference $T_b^s - T_b^0$ is called the boiling point elevation and denoted by ΔT_b .

 $\Delta T_{b} = T_{b} - T_{b}^{0}$

.....(1)

It is found that the elevation of boiling point is directly proportional to the number of moles of the solute in a given amount of the solvent (m).

 $\Delta T \propto m \implies \Delta T_b = K_b \cdot m$ (2) where m is the molality of the solution and K_b is a constant for a given solvent known as boiling-point elevation constant or molal boiling point elevation constant or ebullioscopic constant of solution.

Molal Elevation Constant or Ebullioscopic Constant: When molality of the solution is 1m, (1 mole of the solute is dissolved in 1 kg of the solvent) the above equation reduces to

 $\Delta T_{\rm b} = K_{\rm b} \times 1m = K_{\rm b}$

This indicates that molal elevation constant of a liquid (K_b) is equal to elevation of boiling point when molality of the solution is 1 m. the unit of K_b is Km^{-1} . $K (mol/kg)^{-1} = K \text{ kg mol}^{-1}$.

Determination of K_{h} of solvent :

$$K_{b} = \frac{RT_{b}^{2}}{1000L_{v}} \qquad(3)$$

where R is molar gas constant, T_b is the boiling point of the solvent on Kelvin scale and L_v the latent heat of vaporization of solvent in calories per gram.

For water $K_{b} = \frac{2 \times (373)^{2}}{1000 \times 540} = 0.515 \text{ K-kg/mol}$

Example:. Estimate the boiling point of a solution of 25.0g of urea NH_2CONH_2 plus 25.0g of thiourea NH_2CSNH_2 in 500g of chloroform, $CHCl_3$. The boiling point of pure chloroform is 61.2°C, K_b of chloroform = 3.63 Km⁻¹.

Solution: Moles of urea = $\frac{\text{Mass of urea}}{\text{Molecular mass of urea}} = \frac{25.0\text{g}}{60\text{g}/\text{mol}} = 0.42\text{mol}$

Moles of thiourea = $\frac{25.0}{76 \text{ g/mol}} = 0.33 \text{mol}$ \therefore Total moles of solute = 0.42 + 0.33 = 075

Molality, m = $\frac{\text{Moles of solute}}{\text{Mass of solvent in kg}} = \frac{0.75 \text{mol}}{(500 \text{g}/1000 \text{g})\text{kg}} = 1.50 \text{m}$ $\Delta T_{b} = T_{b} - T_{b}^{\ 0} = K_{b} \cdot \text{m} = 3.63 \times 1.50 = 5.44 \text{K} = 5.445^{\circ}\text{C}$ $T_{b} = 5.445^{\circ}\text{C} + T_{b}^{\ 0} = 5.445^{\circ}\text{C} + 61.2^{\circ}\text{C} = 66.645^{\circ}\text{C}$

(iii) **Depression in Freezing Point**: The freezing point of a liquid is the temperature at which it begins to freeze and the crystallized solid and liquid are in equilibrium. At freezing point, the vapour pressure of the solid is equal to the vapour pressure of the liquid. When a dilute solution is cooled to freezing point, it is assumed that crystals of pure solvent always separate out first.



Plot of variation of vapour pressure of a solution with temperature and depression in freezing point.

The vapour pressure of a liquid decreases when a non-volatile solute is dissolved in it. Therefore, a solid-liquid equilibrium exists only at a temperature lower than the freezing point of the pure solvent. In other words, for a solid to have the same vapour pressure as that of the solution, the freezing point should lower down. If T_f^0 is the freezing point of the pure solvent and T_f that of the solution, the difference $T_f^0 - T_f$ is called the freezing point depression and denoted by ΔT_s

$$\Delta T_s = T_f^0 - T_f$$
is found that the depression in freezing point is directly proportional to the number of moles

It is found that the depression in freezing point is directly proportional to the number of moles of the solute in a solute given amount of the solvent.

$$\Delta T_f = K_f \cdot m$$

.....(2)

where m is the molality of the solution and K_f is a constant for a given solvent known as molal depression constant or cryoscopic constant.

Molal Depression Constant or Cryoscopic Constant: When molality of the solution is 1m,

(1 mole of the solute is dissolved in 1 kg of the solvent) the above equation reduces to $\Delta T_f = K_f \times 1m = K_f$

This indicates that molal depression constant of a liquid (K_f) is equal to depression of freezing point when molality of the solution is 1 m. the unit of K_f is Km^{-1} . K (mol/kg)⁻¹ = K kg mol⁻¹.

Determination of K_r of solvent

 K_{f} is characteristic of a particular solvent and can be calculated from the thermodynamical relationship.

$$\mathbf{K}_{\mathbf{f}} = \frac{\mathbf{R}\mathbf{T}_{\mathbf{f}}^2}{\mathbf{1000L}_{\mathbf{f}}}$$

.....(3)

where T_f is the freezing point of solvent in absolute scale and L_f the latent heat of fusion in calories per gram of the solvent. For water,

$$K_{f} = \frac{0.002 \times (273)^{2}}{80} = 1.86$$
 K-kg/mole

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

Solution:
$$\Delta T_f = T_f^0 - T_f = K_f$$
. m
5.5°C - 3.5°C = 5.12 × m

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

: 1000g +

:. Mass of iodine needed for 1000g of benzene = m × molecular mass of iodine I_2 = 0.39 mol/kg × 254 g/mol = 99.06 g/kg

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

Practice Problems III

Q.1	A solution containing 0.52 g of $C_{10}H_8$ in CCl ₄ 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 ₄ produced an elevation by 0.65°C. Molecular weight of solute is -				
	(A) 85.53	(B) 181.51	(C) 94.38	(D) 160.62	
Q.2	0.65 g naphthalene (0 acetate solution was 0 will be -	C ₁₀ H ₈) was dissolved in 0.103°C. If b. pt. of pure	n 100 g methyl acetate. methyl acetate is 57°C,	Elevation of b. pt of methyl its molar heat of vaporisation	
	(A) 8.96 kcal mol ^{-1}	(B) 7.946 kcal mol ^{-1}	(C) $6.24 \text{ kcal mol}^{-1}$	(D) 15.65 kcal mol ^{-1}	
Q.3	When 174.5 mg of oct [Given K_b for Br_2 is 5 (A) 415.23 K	ta atomic sulphur is adde 5.2 K mol ⁻¹ kg and b. p (P) 220 K	ed to 78 g of bromine, th t. of Br_2 is 332.15 K]	(D) 222 10 K	
0.4	(A) 413.23 K	$(\mathbf{B}) 550 \mathbf{K}$	(C) 220.92 K	(D) 552.19 K	
Q.4	of another substance weights of the two su	B, depressed the f. pt. Ibstance -	by 0.2 °C. What is the	e relation between molecular	
	(A) $M_{A} = 4M_{B}$	$(B) M_{A} = M_{B}$	(C) $M_{A} = 0.5 M_{B}$	(D) $M_{A} = 2M_{B}$	
Q.5	An aqueous solution point of solution is $[I (A) = 2.049 C]$	containing 5% by weig K_f for H ₂ O is 1.86 K m	ght of urea and 10% by ol ⁻¹ kg]	weight of glucose. Freezing	
0 ((A) 3.04° C	(B) –3.04° C	(C) -5.96° C	(D) 5.96° C	
Q.6	g of water and is coo	at will separate out from led to -10°C, will be -	a solution containing \hat{L} [Given : K_f for	or $H_2O = 1.86 \text{ K mol}^{-1} \text{ kg}$	
	(A) 50.0 g	(B) 25.0 g	(C) 12.5 gm	(D) 30.0 gm	
Q.7	It has been found that glycerine to be added $= 6.01 \text{ kJ mol}^{-1}$]	t minimum temperature to 40 dm ³ water used in	e recorded in a hill stat n car radiator, so that it	tion is -10° C. The amount of does not freeze, is - [ΔH_{fusion}]	
	(A) 39.78 kg	(B) 22.45 kg	(C) 19.89 kg	(D) 42.66 kg	
Q.8	In winter, the normal aqueous solution of e	l temperature in Kullu ethylene glycol suitable	valley was found to be for a car radiator ? K_{f}	e -11° C. Is a 28% (by mass) for water = 1.86 K kg mol ⁻¹ .	
	(A) Yes	(B) No	(C) can't prec	lict	
Q.9	The temperature at w $(C_2H_6O_2)$ in water, is (A) 280.5 K	thich ice will begin to s - [K _f (w (B) 265.5 K	eparate from a mixture vater) = 1.86 K kg mol ⁻¹ (C) 276.5 K	of 20 mass percent of glycol ⁻¹] (D) 269.5 K	
Q.10	The amount of urea	to be dissolved in 500	ml of water ($K_f = 18$.6 K mol ⁻¹ 100 g solvent) to	
	produce a depression (A) 0.3 gm	of 0.186°C in freezing (B) 3 gm	g point is - (C) 6 gm	(D) 9 gm	
Q.11	The molal boiling po	oint constant of water i	s 0.53°C. When 2 mole	e of glucose are dissolved in	
	4000 gm of water, th (A) 100.53°C	e solution will boil at - (B) 101.06°C	(C) 100.265°C	(D) 99.47°C	

Q.12	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_{b} and K_{f} for (A) -0.544°C	or water are 0.512 and (B) -0.512°C	1.86 K molality ⁻¹] (C) -0.272°C	(D) -1.86°C	
Q.13	The freezing point of 271.9 K. If molar dep	a solution prepared fro ression constant is 1.86	m 1.25 gm of non-elect K molality ⁻¹ . Then mo	trolyte and 20 gm of water is lar mass of the solute will be	
	(A) 105.68	(B) 106.7	(C) 115.3	(D) 93.9	
Q.14	Elevation in b. p of a the same solution ? H (A) 0°	solution of non-electric $K_f(CCl_4) = 30.00 \text{ kg m}$ (B) 5.39 °	olyte in CCl ₄ is 0.60. W ol ⁻¹ K ; K _b (CCl ₄) = 5.0 (C) 3.59°	Vhat is depression in f. p. for D2 kg mol ⁻¹ K. (D) 2.49°	
Q.15	A solution of a non-v of water above this s [Given p_0 (water) = 0 (A) 0.18 atm	volatile solute in water l olution at 338 K is - 0.2467 atm at 338 K an (B) 0.23 atm	has a boiling point of 3' ad K_b for water =0.52 K (C) 0.34 atm	75. 3 K. The vapour pressure K kg mol ⁻¹] (D) 0.42 atm	
Q.16	Elevation in boiling mole fraction of urea (A) 0.982	point of an aqueous un a in this solution is - (B) 0.0567	rea solution is 0.52°. (k (C) 0.943	$K_{b} = 0.52 \text{K kg mol}^{-1}$). Hence (D) 0.018	
Q.17	Density of 1 M solut kg, solution freezes a (A) 1.58°C	ion of a non-electrolyto at - (B) -1.86°C	$c_{6}H_{12}O_{6}$ is 1.18 g/mL (C) -3.16°C	If K _f (H ₂ O) is 1.86 K mol ⁻¹ (D) 1.86°C	
Q.18	When a solution conseparated. If K_f for w (A) 4.8 g	ntaining w g of urea in vater is 1.86 K kg mol ⁻¹ (B) 12.0 g	1 kg of water is coole , w is - (C) 9.6 g	d to372°C, 200 g of ice is (D) 6.0 g	
Q.19	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° C at 1 atm. pressure) (A) 0.0188 (D) 0.188 (C) 0.548 (D) 0.028				
Q.20	Glucose is added to weight of glucose ad (A) 180 gm	1 litre water to such a ded is (B) 18 gm	n extent that $\Delta T_f/K_f$ be (C) 1.8 gm	(D) 0.18 gm	

Answer Key

1.	Practice Problem	Ι				
1. (A)	2. (C)	3. (A)	4. (B)	5. (C)	6. (B)	7. (A)
8. (A)	9. (B)	10. (A)	11. (A)	12. (C)	13. (C)	14. (B)
15. (C)	16. (B)	17. (B)	18. (A)	19. (A)		

2. Practice Problem II

1. (B)	2. (C)	3. (C)	4. (D)	5. (B)	6. (B)	7. (C)
8. (C)	9. (B)	10. (A)	11. (B)	12. (C)	13. (i) (A)	(ii) (D)
14. (C)	15. (A)	16. (D)	17. (A)	18. (D)	19. (C)	20. (B)
21. (A)	22. (A)	23. (D)	24. (A)	25. (D)	26. (C)	
27. (i) (A)	(ii) (D) (iii) (B)	28. (A)	29. (C)	30. (A)	

3. Practice Problem III

1. (C)	2. (B)	3. (D)	4. (D)	5. (B)	6. (B)	7. (C)
8. (A)	9. (B)	10. (B)	11. (C)	12. (A)	13. (A)	14. (C)
15. (B)	16. (D)	17. (B)	18. (C)	19. (C)	20. (D)	