LIQUID SOLUTION

1. SOLUTION

It is the homogeneous mixture of two or more components.

The substance which dissolve other substance is **solvent** & the substance which is dissolved is **solute**, independent of their quantity. If both are soluble in each other then the substance present in larger amount by mole is solvent.

* A solution may exist in any physical state.

Types of Solution:

	Solvent	Solute	Examples		
1.	Gas	Gas	Mixture of gases, eg. air.		
2.	Gas	Liquid	$CHCl_3(\ell) + N_2(g)$		
3.	Gas	Solid	Camphor (s) + $N_2(g)$.		
4.	Liquid	Gas	CO ₂ gas dissolve in water (aerated drink), soda water.		
5.	Liquid	Liquid	Mixture of miscible liquids e.g. alcohol in water.		
6.	Liquid	Solid	Salt in water, sugar in water.		
7.	Solid	Gas	hydrogen over palladium.		
8.	Solid	Liquid	Mercury in zinc, mercury in gold, i.e. all amalgams.		
9.	Solid	Solid	Alloys e.g. copper in gold, zinc in copper.		

2. SOLUBILITY

Maximum amount of solute which can be dissolved in a specified amount of solvent at constant temperature is to solubility. Solubility is affected by

- 1. nature of solute and solvent
- 2. temperature and
- 3. pressure

3. SOLUBILITY OF SOLID IN A LIQUID

Polar solutes are soluble in polar solvent and non polar solutes are soluble in non polar solvent due to similar intermolecular forces.

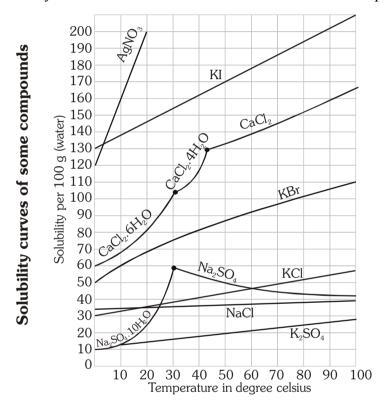
When solid solutes are dissolved in solvent, then following equilibrium exits.

Solute + Solvent $\xrightarrow{Dissolution}$ Solution.; ΔH may be positive or negative

Such a solution in which no more solute can be dissolved at the same temperature and pressure is called a **saturated solution**. An unsaturated solution is one in which more solute can be dissolved at the same temperature. The solution which is in dynamic equilibrium with undissolved solute is the saturated solution and contains the maximum amount of solute dissolved in a given amount of solvent.

3.1 Effect of temperature :

The solubility of a solid in a liquid is significantly affected by temperature changes, obeying *Le Chateliers Principle*. In general, if in a nearly saturated solution, the dissolution process is endothermic ($\Delta_{sol}H > 0$), the solubility should increase with rise in temperature and if it is exothermic ($\Delta_{sol}H < 0$) the solubility should decrease. These trends are also observed experimentally.



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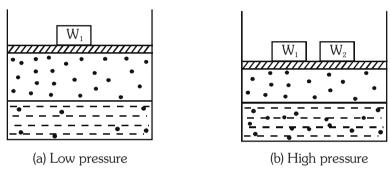
3.2 Effect of pressure :

Pressure does not have any significant effect on solubility of solids in liquids. It is so because solids and liquids are highly incompressible and practically remain unaffected by changes in pressure.

4. SOLUBILITY OF GASES IN LIQUID

Certain gases are highly soluble in water like NH_3 , HCl, etc, and certain gases are less soluble in water like O_2 , N_2 , He, etc. Solubility of gases is greatly effected by pressure and temperature. Increasing pressure increases solubility and increase in temperature decreases solubility since dissolution of any gas in any liquid is exothermic in nature.

4.1 Henry' Law:



Effect of pressure on the solubility of a gas. The concentration of dissolved gas is proportional to the pressure on the gas above the solution.

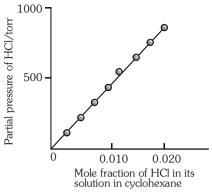
The partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution, at constant temperature

$$P = K_H X$$

 K_{H} = Henry's Law Constant

- * Henry's Law Constant depends on nature of gas and liquid as well as temperature.
- * K_H increases with increases in temperature.
- * Greater K_H means low solubility.

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Experimental results for the solubility of HCl gas in cyclohexane at 293 K. The slope of the line is the Henry's Law constant $K_{\scriptscriptstyle \rm H}$

Values of Henry's Law Constant for Some Selected Gases in Water

Gas	Temperature/K	K _H /kbar
Не	293	144.97
H_2	293	69.16
N_2	293	76.48
N_2	303	88.84
O_2	293	34.86
O_2	303	46.82
Argon	298	40.3
CO_2	298	1.67
Formaldehyde	298	1.83×10^{-5}
Methane	298	0.413
Vinyl chloride	298	0.611



4.2 Limitations of Henry' Law:

- (1) It is valid only for ideal behaviour of gas. As none of the gas is ideal, this law may be applied at low pressure and high temperature.
- (2) It gives better result when the solubility of gas in the liquid is low.
- (3) The gas should neither dissociate nor associate in the liquid.

4.3 Henry' Law application:

- (1) To increase the solubility of CO₂ in soft drinks and soda water, the bottle is sealed under high pressure.
- (2) Scuba divers must cope with high concentrations of dissolved gases while breathing air at high pressure underwater. Increased pressure increases the solubility of atmospheric gases in blood. When the divers come towards surface, the pressure gradually decreases. This releases the dissolved gases and leads to the formation of bubbles of nitrogen in the blood. This blocks capillaries and creates a medical condition known as bends, which are painful and dangerous to life. To avoid bends, as well as, the toxic effects of high concentrations of nitrogen in the blood, the tanks used by scuba divers are filled with air diluted with helium (11.7% helium, 56.2% nitrogen and 32.1% oxygen).
- (3) At high altitudes the partial pressure of oxygen is less than that at the ground level. This leads to low concentrations of oxygen in the blood and tissues of people living at high altitudes or climbers. Low blood oxygen causes climbers to become weak and unable to think clearly, symptoms of a condition known as anoxia.

4.4 Effect of Temperature :

Solubility of any gas in any liquid decreases with rise in temperature as dissolution is an exothermic process.

At constant pressure,
$$\ell n \frac{C_2}{C_1} = \frac{\Delta H_{sol}}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

where C = molar concentration of gas in solution

CLASS ILLUSTRATION - 01

- 1. If N_2 gas is bubbled through water at 293 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 bar. Given that Henry's law constant for N_2 at 293 K is 76.48 kbar.
- 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 are 3.30×10^7 mm and 6.51×10^7 mm respectively, calculate the composition of these gases in water.

5. VAPOUR PRESSURE :

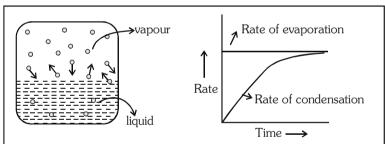
The Evaporation of a Liquid in a Closed Container

When a liquid is taken in a closed vessel at constant temperature, then there are two process which takes place.

- (i) evaporation
- (ii) condensation

In the constant evaporation from the surface particles continue to break away from the surface of the liquid

As the gaseous particles bounce around, some of them will hit the surface of the liquid again, and will be trapped there. This is called condensation. The rate of condensation increases with time, but rate of evaporation remain constant. There will rapidaly be an equilibrium set up in which the number of particles leaving the surface is exactly balanced by the number rejoining it.



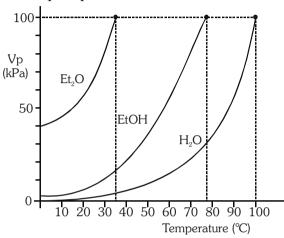
This pressure at equilibrium is called the **vapour pressure** (also known as **saturation vapour pressure**) of the liquid at that temperature.

5.1 Effect of Temperature on vapour pressure

When the space above the liquid is saturated with vapour particles, you have this equilibrium occuring on the surface of the liquid:

liquid
$$\rightleftharpoons$$
 vapour, $\Delta H > 0$

The forward change (liquid to vapour) is endothermic. It needs heat to convert the liquid into the vapour. According to Le Chatelier, increasing the temperature of a system in a dynamic equilibrium favours the endothermic change. That means increasing the temperature increase the amount of vapour present, and so increases the vapour pressure.



Effect of nature:

V.pr
$$\alpha$$
 Inter molecular attraction force(I.M.A.F.)

$$n-C_6H_{14} > n-C_7H_{16} > C_8H_{18}$$

The dependence of vapour pressure of a liquid on temperature is given by clausius-clapeyron

equation : ln
$$\frac{P2}{P_1} = \frac{\Delta H_{\rm vap.}}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

5.2 Nature of liquid: Weaker the intermolecular attraction, higher will be the vapour pressure.

6. VAPOUR PRESSURE OF LIQUID SOLUTION

6.1 Raoult's law:

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

6.2 Vapour pressure of liquid – liquid solution :

Let P_A and P_B be the partial vapour pressures of two constituents A and B in solution and P_A^0 and P_B^0 the vapour pressures in pure state respectivity.

Thus, according Raoult's law

$$\mathbf{P}_{\mathbf{A}} = \frac{\mathbf{n}_{\mathbf{A}}}{\mathbf{n}_{\mathbf{A}} + \mathbf{n}_{\mathbf{B}}} \mathbf{P}_{\mathbf{A}}^{0} = \mathbf{X}_{\mathbf{A}} \mathbf{P}_{\mathbf{A}}^{0} \qquad(1)$$

and
$$P_B = \frac{n_B}{n_A + n_B} P_B^0 = X_B P_B^0$$
(2)

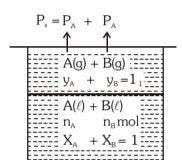
If total pressure be P_S, then

$$P_{S} = P_{A} + P_{B} = X_{A} P_{A}^{0} + X_{B} P_{B}^{0}$$

$$P_S = X_A P_A^0 + (1 - X_A) P_B^0$$
 [: $X_A + X_B = 1$]

$$P_{S} = X_{A}P_{A}^{0} - X_{A}P_{B}^{0} + P_{B}^{0}$$

$$P_{S} = X_{A} [P_{A}^{0} - P_{B}^{0}] + P_{B}^{0}$$



6.2.1 Relation between Dalton's Law and Raoult's Law:

The composition of the vapour in equilibrium with the solution can be calculated applying Dalton's law of partial pressures. Let the mole fraction of A and B in vapours be Y_A and Y_B respectively.

$$p_A = Y_A P_S = X_A P_A^0$$
(1)
 $p_B = Y_B P_S = X_B P_B^0$ (2)

Now,
$$X_A = \frac{Y_A \cdot P_S}{P_A^0}$$
 and $X_B = \frac{Y_B \cdot P_S}{P_B^0}$

As,
$$X_A + X_B = 1$$
, $\frac{Y_A \cdot P_S}{P_A^0} + \frac{Y_B \cdot P_S}{P_B^0} = 1$

$$\therefore \qquad \frac{1}{P_S} = \frac{Y_A}{P_A^0} = \frac{Y_B}{P_B^0}$$

Hence, the total vapour pressure of solution may be calculated from liquid composition at equilibrium as

$$P_S = X_A \cdot P_A^0 + X_B \cdot P_B^0$$

and from vapour composition at equilibrium at

$$\frac{1}{P_{S}} = \frac{Y_{A}}{P_{A}^{0}} + \frac{Y_{B}}{P_{B}^{0}}$$

6.2.2 Comparision between liquid and vapour composition:

$$\frac{Y_{A}}{Y_{B}} = \frac{P_{A}/P_{S}}{P_{B}/P_{S}} = \frac{P_{A}}{P_{B}} = \frac{X_{A} \cdot P_{A}^{0}}{X_{B} \cdot P_{B}^{0}}$$

If A is more volatile than B $\left(P_A^0>P_B^0\right)$, then $\frac{Y_A}{Y_B}>\frac{X_A}{X_B}$

It means that the mole-fraction of A is vapour form is relatively greater than that in liquid form, relative to B. Hence, in any ideal solution, vapour is always more richer in the more volatile component.

6.2.3 Raoult's law as a special case of Henry's law:

From Raoult's law, the vapour pressure of volatile component in the solution is $P = P^0 \cdot X$.

In the solution of gas in liquid, one component is so volatile that it exist as gas and its pressure is given by Henry's law as $P = K_{H}X$

In both laws, the partial pressure of volatile component is directly proportional to its mole-fraction is solution. Only the proportionality constant K_H differs from P^0 . Hence, Raoult's law becomes a special case of Henry's law in which K_H becomes P^0 .

6.3 Vapour pressure of solution of solids in liquid:

Let us assume A = non volatile solid & B = volatile liquid

According to Raoult's law -

$$P_s = X_A P_A^{0} + X_B P_B^{0}$$
for $A, P_A^{0} = 0$

for A,
$$P_A^{\ 0} = 0$$

$$P_{s} = X_{B} P_{B}^{0} \qquad \dots (5)$$

Let $P_B^0 = P^0 = V$ apour pressure of pure state of solvent.

here X_{R} is mole fraction of solvent

$$P_{S} = \frac{n_{B}}{n_{A} + n_{B}} P^{0}$$
(6)

$$P_S \propto \frac{n_B}{n_A + n_B}$$
 i.e. vapour pressure of solution \propto mole fraction of solvent

$$\Rightarrow P_{S} = X_{B}P_{B}^{0} \Rightarrow P_{S} = (1 - X_{A})P_{B}^{0}$$

$$\Rightarrow P_S = P_B^0 - X_A P_B^0$$

$$\Rightarrow \frac{P_B^0 - P_S}{P_R^0} = X_A$$

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

$$\frac{\mathbf{P}^0 - \mathbf{P_S}}{\mathbf{P}^0} = \frac{\mathbf{n_A}}{\mathbf{n_A} + \mathbf{n_B}} \qquad \dots (8)$$

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

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

$$\frac{P_S}{P^0 - P_S} = \frac{n_B}{n_A}$$

$$\boxed{\frac{\mathbf{P}^{0} - \mathbf{P}_{S}}{\mathbf{P}_{S}} = \frac{\mathbf{n}_{A}}{\mathbf{n}_{B}} = \frac{\mathbf{w}_{A} \cdot \mathbf{m}_{B}}{\mathbf{m}_{A} \cdot \mathbf{w}_{B}}} \dots (9)$$

CLASS ILLUSTRATION - 02

- 3. 1 mole heptane (V.P. = 92 mm of Hg) is mixed with 4 mole Octane (V.P. = 31 mm of Hg), form an ideal solution. Find out the vapour pressure of solution.
- 4. At 88°C, benzene has a vapour pressure of 900 torr and toluene has a vapour pressure of 360 torr. What is the mole fraction of benzene in the mixture with toluene that will be boil at 88°C at 1 atm pressure, benzene toluene form an ideal solution.
- 5. 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 mole of B is 550 mm of Hg. At the same temperature, if one more 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.
- 6. Liquids 'A' and 'B' form an ideal solution. Calculate the molar-fraction of 'A' in vapour form above the liquid solution containing 25 mole-percent of 'A' at equilibrium $\left(P_A^0=0.2atm,\,P_B^0=0.5atm\right)$

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7. Liquids 'A' and 'B' form an ideal solution. Calculate the vapour pressure of solution having 40 mole-percent of A in the vapour at equilibrium. $(P_A^0 = 80 \text{cm}\,\text{Hg}, P_B^0 = 30 \text{cm}\,\text{Hg})$

8. Using the following information determine the boiling point of a mixture contains 1560 gm benzene and 1125 gm chlorobenzene, when the external pressure is 1000 torr. Assume the solution is ideal.

Temperature (0°C)	Vapour pressure	Vapour pressure of		
	of benzene(torr)	chlorobenzene(torr)		
80	750	120		
90	1000	200		
100	1350	300		
110	1800	400		
120	2200	540		



6.4 Ideal and Non ideal solutions:

The solutions which obey Raoult's law over the entire range of concentration are known as ideal solutions.

Table: Comparison between Ideal and Non-ideal solutions

	Ideal solutions	Non-ideal solutions			
		+ve deviation from Raoult's law	- deviation from Raoult's law		
1.	Obeys Raoult's law at every	Do not obey Raoult's law.	Do not obey Raoult's law.		
	concentrations.				
2.	$\Delta H_{\text{mix}} = 0$; Neither heat is	$\Delta H_{mix} > 0$. Endothermic dissolution;	$\Delta H_{mix} < 0$; exothermic dissolution		
	evolved nor absorbed during	heat is absorbed.	heat is evolved.		
	dissolution.				
3.	$\Delta V_{mix} = 0$; total volume of	$\Delta V_{mix} > 0$. Volume is increased after	$\Delta V_{mix} < 0$; volume is decreased		
	solution is equal to sum of	dissolution.	during dissolution.		
	volumes of the components.				
4.	$P = p_A + p_B = p_A^0 X_A + p_B^0 X_B$	$P_{A} > p_{A}^{0} X_{A}; \ p_{B} > p_{B}^{0} X_{B}$	$P_{A} < p_{A}^{0} X_{A}; \ p_{B} < p_{B}^{0} X_{B}$		
	i.e., $P_A = p_A^0 X_A; p_B = p_B^0 X_B$	$\therefore (P_{A} + p_{B}) > (p_{A}^{0}X_{A} + p_{B}^{0}X_{B})$	$\therefore (P_{A} + p_{B}) < (p_{A}^{0}X_{A} + p_{B}^{0}X_{B})$		
5.	A - A, A - B, B - B	A — B, attraction force should be	A — B, attraction force should be		
	interactions should be same,	weaker than A — A and B — B	greater than A — A and B — B attractive		
	i.e., 'A' and 'B' are identical	attractive forces. 'A' and 'B' have	forces. 'A' and 'B' have different shape,		
	in shape, size and character.	different shape, size and character.	size and charater.		
_	Essening tondency of IAI and	IAI and IDI assama assilts showing	Econing tondonor of both commercial		
6.	Escaping tendency of 'A' and 'B' should be same in pure	'A' and 'B' escape easily showing high vapour pressure than the	Escaping tendency of both components A and B is lowered showing lower		
	liquids and in the solution.	expected value.	vapour pressure than expected ideally.		
	nquius and in the solution.	expected value.	vapour pressure man expected ideally.		

Example:

dilute solutions;

benzene + toluene ;

n-hexane + n-heptane;

chlorobenzene + bromobenzene ;

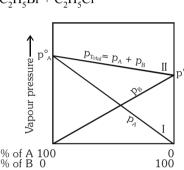
ethyl bromide + ethyl iodide;

n-butyl chloride + n-butyl bromide

 $CCl_4 + SiCl_4$;

 $C_2H_4Br_2 + C_2H_4Cl_3$

 $C_2H_5Br + C_2H_5Cl$



Example:

acetone + ethanol;

acetone + CS₂;

water + methanol;

water + ethanol;

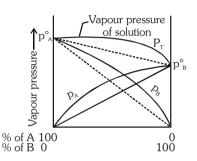
CCl₄ + CHCl₃;

 CCl_4 + toluene;

acetone + benzene

 $CCl_4 + CH_3OH$;

cyclohexane + ethanol



Example:

acetone + aniline;

acetone + chloroform;

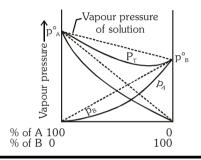
 $CH_2OH + CH_2COOH$;

 $H_2O + HNO_3$;

water + HCl;

acetic acid + pyridine;

HNO₃ + CHCl₃



Graphs for ideal Binary solution of liquid A & liquid B:

(Assume $P_A^0 < P_B^0$)

I. Vapour pressure V/s liquid composition

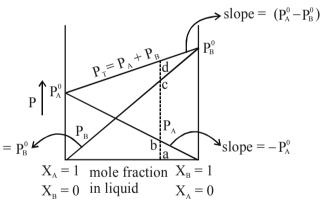
$$P_{A} = X_{A}P_{A}^{0} = (1 - X_{B})P_{A}^{0}$$

$$\mathbf{P}_{\mathbf{A}} = \mathbf{P}_{\mathbf{A}}^{0} - \mathbf{X}_{\mathbf{B}} \mathbf{P}_{\mathbf{A}}^{0}$$

$$P_{B} = X_{B}P_{B}^{0}$$

$$\therefore \qquad P_{\mathrm{T}} = P_{\mathrm{A}}^{0} + X_{\mathrm{B}} \Big(P_{\mathrm{B}}^{0} - P_{\mathrm{A}}^{0} \Big)$$

As
$$P_T = P_A + P_B$$
, $ad = ab + ac$



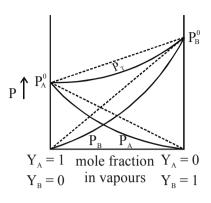
II. Vapour pressure V/s vapour composition

$$\frac{1}{P_{T}} = \frac{Y_{A}}{P_{A}^{0}} + \frac{Y_{B}}{P_{B}^{0}}$$

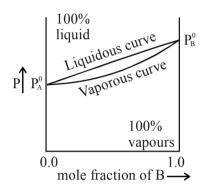
$$\frac{1}{P_{T}} = \frac{1}{P_{A}^{0}} + Y_{B} \left(\frac{1}{P_{B}^{0}} - \frac{1}{P_{A}^{0}} \right)$$

$$\frac{1}{y} = c + mx$$

So curve will be rectangular hyperbola.



III. Vapour pressure V/s composition



- (i) The V.P. of ideal solution always lie in between the V.P. of pure components.
- (ii) Below vapourous curve, the system will by 100% vapour & above liquidous and curve, 100% liquid. Both the physical states exists only in between the curves.
- (iii) At any composition, the physical state of system may be changed by changing the pressure.
- (iv) At any pressure in between P_A^0 and P_B^0 , the physical state of system may be changed by changing the composition.

,

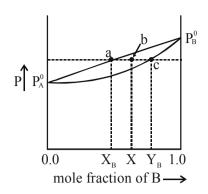
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(v) Length $ab \propto total moles of vapour$

Length cb ∞ total moles of liquid

$$\frac{ab}{cb} = \frac{\text{total moles of vapour}}{\text{total moles of liquid}}$$

or
$$\frac{X - X_B}{Y_B - X} = \frac{n_{A(g)} + n_{B(g)}}{n_{A(\ell)} + n_{B(\ell)}} \text{ (Lever's rule)}$$



6.6 Boiling point:

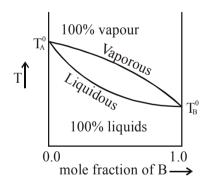
Boiling point of a liquid is the temperature at which the vapour pressure of the liquid become equal to the atmospheric pressure.

Ex. Liquid 'A' and 'B' form an ideal solution. At 27°C, the vapour pressure of pure liquids 'A' and 'B' are 0.6 atm and 1.2 atm, respectively. What the coposition of liquid solution boiling at 27°C?

Sol.
$$P_{T} = X_{A} \cdot P_{A}^{0} + X_{B} \cdot P_{B}^{0}$$

or
$$I = X_A \times 0.6 + (1 - X_A) \times 1.2 \implies X_A = \frac{1}{3}$$

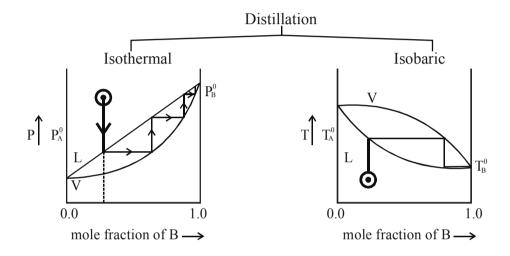
6.7 Boiling point curves for ideal binary solution:



- (i) The boiling point of ideal solution always lie in between the boiling points of pure liquids.
- (ii) Below liquidus curve, the system in 100% liquid and above vapourus curve, the systm is 100% vapour. Both the physical states exists only in between the curves.
- (iii) At any composition, the physical state of system may be changed by changing the temperature.
- (iv) At any temperature in between T_A^0 and T_B^0 , the physical state of system may be changed by changing the composition.

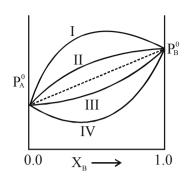
6.8 Distillation

It is the method of seperation of liquids by converting them into vapours (boiling).



- (i) The seperation of liquid by distillation occurs because at any T or P, the composition of distillate or condensate is different than the composition of original liquid.
- (ii) With the elemination of vapour above the liquid, the boiling point of residual liquid increases.
- (iii) The boiling point of distillate is less than that of original liquid.

6.9 Graphs for Non-ideal solutions and azeotropic mixture

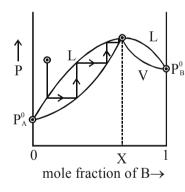


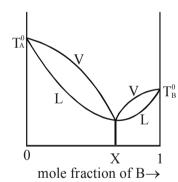
- (I) Large positive deviation : $(V.P.)_{solution} > P_B^0$ at some composition
- (II) Small positive deviation : $P_A^0 < (V.P.)_{solution} < P_B^0$
- (III) Small negative deviation : $P_A^0 < (V.P.)_{solution} < P_B^0$
- (IV) Large negative deviation : $(V.P.)_{solution} < P_A^0$ at some composition

6.9.1 Konowaloff's rule:

In ideal or non-idal solution the vapour is always more rich in the component, addition of which in liquid, increase the vapour pressure of solution.

6.9.2 Large (+)ve derivation (Minimum boiling azeotrope)





The solution of large positive deviation can not be seperated by distillation becasue at composition 'x', the liquid & vapour composition becomes identical.

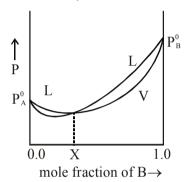
Such solution which can not be saperated by distillation are called **azeotropic mixture or constant boiling solution.**

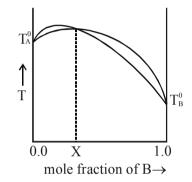
At any composition less than X, traces of pure A may be obtained but not pure B. Similarly at composition greater than X, traces of pure B may be obtained but not pure A.

Minimum boiling point Azeotropic

Mixture	% Composition of	Boiling point	
	azeotrope	(pressure = 1atm)	
1. Water-Ethanol	96 Ethanol	78.15℃	
2. Pyridine-Water	57.00 Pyridine	92.60℃	
3. Ethanol-Benzene	32.4 Ethanol	67.80℃	
4. Acetic acid-Toluene	28.0 Acetic acid	105.40℃	

5.9.3 Large (–)ve derivation (Maximum boiling azeotrope)





Maximum boiling point Azeotropic

Mixture	% Composition of	Boiling point	
	azeotrope	(pressure = 1atm)	
1. Nitric acid-Water	68% Nitric acid	125.5℃	
2. Acetic acid-Pyridine	65% Pyridine	139.0℃	
3. Chloroform-Acetone	80% Chloroform	65.0℃	
4. Hydrogen chloride-Water	79.8 Water	108.6℃	

Note: Azeotrope is not formed in ideal solution or solution of small deviations.

Space for Notes

CLASS ILLUSTRATION - 03

- 9. Liquids 'A' and 'B' form an ideal solution. At 80° C, $P_{A}^{0} = 0.4$ bar and $P_{B}^{0} = 0.8$ bar. All the vapour above the liquid solution containing equal moles of both the liquids at equilibrium is collected in another empty vessel and condensed. Now, the condesate is heated to 80° C and all the vapours above the liquid solution at equilibrium is again collected in another empty vessel and condensed. What is the mole-fraction of 'B' is new condensate?
- 10. Liquid A & B form an ideal solution. In a cylinder piston arrangement, 2 moles of vapours of liquid A & 3 moles of vapours of liquid B are taken at 0.3 atm. $P_A^0 = 0.4$ atm, $P_B^0 = 0.6$ atm.
 - (i) Predict whether vapours will condense or not?
 - (ii) If the vapours are compressed slowly & isothermly, at what pressure Ist drop of liquid will form
 - (iii) If the initial volume of vapours was 10L, at what volume I^{st} drop of liquid will form?
 - (iv) What is the composition of I^{st} drop of liquid formed?
 - (v) If the vapours are further compressed slowly & isothermally, at what P almost complete condensation will occur?
 - (vi) What is the composition of last traces of vapours remained?
 - (vii) What is the composition of system at 0.58 atm?
 - (viii) What is the composition of system at 0.51 atm? Also calculate moles of A & B in liquid & vapour form.
 - (ix) At what P, half of the total amount of vapours will condense?



7. COLLIGATIVE PROPERTIES

Properties of a solution which depends on the number of solute particles irrespective of their nature, relative to the total number of particles present in solution are called colligative properties.

The following properties are colligative properties of solution:

- (i) Relative lowering of vapour pressure.
- (ii) Elevation in boiling point.
- (iii) Depression in freezing point.
- (iv) Osmotic pressure.

7.1 Lowering of vapour pressure :

When a non-volatile solute 'A' is dissolved in a pure solvent 'B', the vapour pressure of the solvent is lowered i.e. the vapour pressure of a solution is always lower than that of pure solvent, because the escaping tendency of solvent molecules decreases.

If at a certain temperature P° is the vapour pressure of pure solvent, and P_{s} is the vapour pressure of solution then

Lowering of vapour pressure = $P^{\circ} - P_{s}$

Relative lowering of vapour pressure = $\frac{P^0 - P_s}{P^0}$

from equation (8)

$$\frac{\mathbf{P}^0 - \mathbf{P_S}}{\mathbf{P}^0} = \frac{\Delta \mathbf{P}}{\mathbf{P}^0} = \frac{\mathbf{n_A}}{\mathbf{n_A} + \mathbf{n_B}} = \mathbf{X_A}$$

For a very dilute solution $n_A < < < n_B$

SO
$$\frac{\mathbf{P}^0 - \mathbf{P_S}}{\mathbf{P}^0} = \frac{\mathbf{n_A}}{\mathbf{n_B}} = \frac{\mathbf{w_A}}{\mathbf{m_A}} \times \frac{\mathbf{m_B}}{\mathbf{w_B}}$$

7.1.1 Measurement of Lowering in Vapour Pressure by Dynamic Method (Ostwald and Walker Method)

The apparatus used is shown in Fig. It consists of two sets of bulbs. The first set of three bulbs is filled with solution to half of their capcity and second set of another three bulbs is filled with the pure solvent.

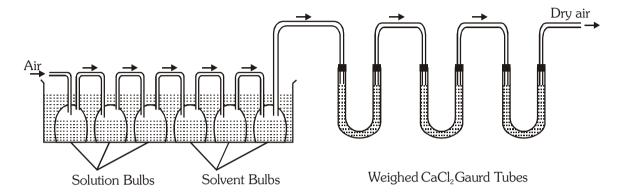


Fig. Ostwald and Walker method

Each set is separately weighed accurately. Both sets are connected to each other and then with the accurately weighed set of guard tubes filled with anhydrous calcium chloride or some other dehydrating agents like P_2O_5 , conc. H_2SO_4 etc. The bulbs of solution and pure solvent are kept in a thermostat maintained at a constant temperature.

A current of pure dry air is bubbled through the series of bulbs as shown in fig. The air gets saturated with the vapour in each set of bulbs. The air takes up an amount of vapours proportional to the vapour pressure of the solution first and then it takes up more amount of vapours from the solvent which is proportional to the difference in the vapour pressure of the solvent and the vapour pressure of solution, i.e., $p_0 - p_s$.

The two sets of bulbs are weighed again. The guard tubes are also weighed.

Loss in mass in the solution bulbs $\propto p_{s}$

Loss in mass in the solvent bulbs $\propto (p_0 - p_s)$

Total loss in both sets of bulbs $\propto [p_s + (p_0 - p_s)] \propto p_0$

Total loss in mass of both sets of bulbs is equal to gain in mass of guard tubes.

Thus,
$$\frac{p_0 - p_s}{p_0} = \frac{Loss \text{ in mass in solvent bulbs}}{Total loss \text{ in mass in both sets of bulbs}} = \frac{Loss \text{ in mass in solvent bulbs}}{Gain \text{ in mass of guard tubes}}$$

Further, we know from Raoult's law,

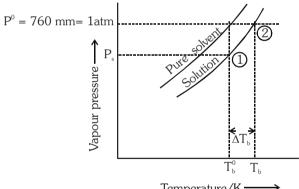
$$\frac{p_0 - p_s}{p_0} = \frac{w_A / m_A}{w_A / m_A + w_B / m_B}$$

.
$$\frac{\text{Loss in mass of solvent bulbs}}{\text{Gain in mass of gaurd tubes}} = \frac{w_A / m_A}{w_A / m_A + w_B / m_B}$$

CLASS ILLUSTRATION - 04

- Calculate the vapour pressure lowering caused by addition of 50 g of sucrose 11. (molecular mass = 342) to 500 g of water if the vapour pressure of pure water at 25°C is 23.8 mm Hg.
- The vapour pressure of benzene at 90°C is 1020 torr. A solution of 5 g of a solute in *12*. 58.5 g benzene has vapour pressure 990 torr. What is the molecular weight of solute?
- *13*. The vapour pressure of water is 17.54 mm Hg at 293 K. Calculate vapour pressure of 0.5 molal solution of a solute in it.
- 7.2 **Elevation in boiling point (Ebullioscopy):**

 $solvent(\ell) \Longrightarrow solvent(g)$



Temperature/K-

The vapour pressure curve for solution lies below the curve for pure solvent .

 ΔT_b denotes the elevation of boiling point of a solution.

When a non-volatile solute A is dissolved in a pure solvent B, its vapour pressure decreases and hence the boiling point increases. The difference ΔT_b of boiling points of the solution and pure solvent is called elevation in boiling point.

If T_b^0 is the boiling point of pure solvent and T_b is the boiling point of the solution then, $T_b > T_b^0$

and the elevation in boiling point $\Delta T_b = T_b - T_b^0$

Experiments have shown that for dilute solutions, the elevation of boiling point (ΔT_b) is directly proportional to the molal concentration of the solute in a solution. Thus

or
$$\Delta T_{\rm b} \propto m$$
$$\Delta T_{\rm b} = K_{\rm b}.m$$

where K_b = boiling point elevation constant or molal elevation constant or ebulioscopic constant. Molal elevation constant is characteristic of a particular solvent and can be calculated from the thermodynamical relationship.

$$\boldsymbol{K}_{b} = \frac{\boldsymbol{R}\boldsymbol{T}_{b}^{2}.\boldsymbol{M}}{\boldsymbol{1000} \ \Delta\boldsymbol{H}_{vap}}$$

where, R is molar gas constant = 2 cal/mol–K , M = molar mass of solvent T_b is the boiling point of the pure solvent (in K) and ΔH_{vap} is the latent heat of vaporisation of pure solvent

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

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

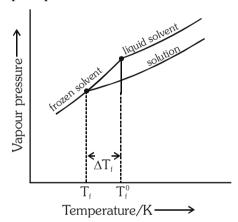
Solvent	B.P. (° C)	Molal elevation constant
Water	100.0	0.52
Acetone	56.0	1.70
Chloroform	61.2	3.63
Carbon tetrachloride	76.8	5.03
Benzene	80.0	2.53
Ethyl alcohol	78.4	1.20

CLASS ILLUSTRATION - 05

- 14. 0.15 g of a substance dissolved in 15 g of solvent boiled at a temperature higher by 0.216°C than that of the pure solvent. What is the molecular weight of the substance. $[K_b$ for solvent = 2.16 K-kg/mol]
- 15 The rise in boiling point of a solution containing 1.8 g glucose in 100 g of a solvent is 0.1°C. The molal elevation constant of the liquid is –
- 16. When 10.6 g of a nonvolatile substance is dissolved in 740 g of ether, its boiling point is raised 0.284°C. What is the molecular weight of the substance? Molal boiling point constant for ether is 2.11°C·kg/mol.

7.3 Depression in freezing point (Cryoscopy):

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



When a non-volatile non-electrolyte is dissolved in a pure solvent, the vapour pressure of the solvent is lowered and it become equal to that of solid solvent at lower temperature.

If T_f^0 is the freezing point of pure solvent and (T_f) is the freezing point of its solution then,

$$T_{\rm f} < T_{\rm f}^0$$

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

$$T_{\rm f}^0 - T_{\rm f} = \Delta T_{\rm f}$$

Similar to elevation in boiling point, depression in freezing point for dilute solution is directly proportional to its molality,

$$\Delta T_f \propto m$$

or

$$\Delta T_f = K_f m$$

where $K_{_{\rm f}}$ is called freezing point depression constant or molal depression constant or cryoscopic constant.

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

$$K_{f} = \frac{R \cdot T_{f}^{0^{2}} \cdot M}{1000 \cdot \Delta H_{fus}}$$

where, T_f^0 is the freezing point of pure solvent in (Kelvin) and ΔH_{fus} is the latent heat of fusion pure solvent. For water,

$$K_f = \frac{0.002 \times (273)^2}{80} = 1.86 \text{ K-kg/mol}$$

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

Solvent	F.P. (° C)	Molal depression solvents
Water	0.0	1.86
Ethyl alcohol	-114.6	1.99
Chloroform	-63.5	4.79
Carbon tetrachloride	-22.8	31.8
Benzene	5.5	5.12
Camphor	179.0	39.70

Space for Notes



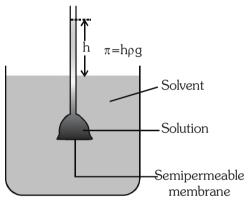
CLASS ILLUSTRATION - 06

- 17. If freezing point of a solution prepared from 1.25 g of a non electrolyte and 20 g of water is 271.9 K, the molar mas of the solute will be $-(K_f \text{ of water} = 1.86 \text{ K-kg/mol})$
- 18. Molal depression constant for water is 1.86. What is freezing point of a 0.05 molal solution of a non electrolyte in water? $(K_f \circ f \text{ water} = 1.86 \text{ K-kg/mol})$
- 19. The cryoscopic constant for acetic acid is 3.6 K kg/mol. A solution of 1 g of a hydrocarbon in 100 g of acetic acid freezes at 16.14°C instead of the usual 16.60°C. The hydrocarbon contains 92.3% carbon. What is the molecular formula?
- 20. 2m aqueous urea solution is cooled to -7.44° C. Calculate the mass percent of water present in solution, which will separate as ice, (K_c of water = 1.86 K-kg/mol)

7.4 Osmosis and osmotic pressure:

7.4.1 Osmosis:

Osmosis is defined as the spontaneous flow of solvent molecules through semipermeable membrane from a pure solvent to solution.



Level of solution rises in the funnel due to osmosis of solvent

7.4.2 Semi-permeable membrane (SPM):

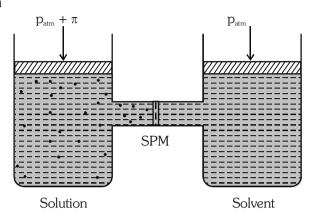
There are the membranes (substances) which allow selective movement of particles across them. For a solution of solid solute in a liquid solvent, ideal SPM allow free movement of solvent particles across it, but not solute particles. These membranes contain a network of submicroscopic holes or pores through which small solvent molecules may pass but not the bigger solute particle.

28

7.4.3 Osmotic presssure (π) : It is the pressure which should be applied on the solution to just prevent osmostis or The hydrostatic pressure built up on the solution which just stops the osmosis.

osmotic pressure = hydrostatic pressure

$$\pi = \rho gh$$



The excess pressure equal to the osmotic pressure must be applied on the solution side to prevent osmosis

7.4.4 Van't Hoff laws:

- (i) The osmotic pressure (π) of a solution is directly proportional to its molar concentration(C), when the temperature is kept constant. (Van't Hoff-Boyle's law) thus $\pi \propto C$ (when temperature is constant)
- (ii) Concentration remaining same, the osmotic pressure of a dilute solution is directly proportional to its absolute temperature (T). (Van't Hoff-Charle's law)

$$\pi \propto T$$
 (when C is constant)

Combining the two laws, i.e., when concentration and temperature both are changing, the osmotic pressure will be given by :

$$\pi \propto C.T$$
 or $\pi = CRT$

Where R = Universal gas constant.

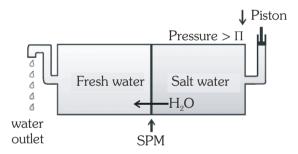
7.4.5 Isotonic or iso-osmotic solution:

Solutions which have the same osmotic pressures at a given temperature are called isotonic or isoosmotic solutions

When isotonic solutions are separated by semipermeable membrane, no osmosis occurs between them. For example, the osmotic pressure associated with the fluid inside the blood cell is equivalent to that of 0.9% (mass/volume) sodium chloride solution, called normal saline solution and it is safe to inject intravenously. On the other hand, if we place the cells in a solution containing more than 0.9% (mass/volume) sodium chloride, water will flow out of the cells and they would shrink. Such a solution is called **hypertonic**. If the salt concentration is less than 0.9% (mass/volume), the solution is said to be **hypotonic**. In this case, water will flow into the cells if placed in this solution and they would swell.

7.5 Reverse Osmosis and water purification:

If external pressure greater than osmotic pressure is applied, the flow of solvent molecules can be made to proceed from solution towards pure solvent, i.e., in reverse direction of the ordinary osmosis. Reverse osmosis is used for the desalination of sea water for getting fresh drinking water.



Reverse osmosis occurs when a pressure larger than the osmotic pressure is applied to the solution.

CLASS ILLUSTRATION - 07

- 21. A cane sugar solution has an osmotic pressure of 2.46 atm at 300 K. What is the molarity of the solution.
- A solution containing 8.6 g urea in one litre was found to be isotonic with 0.5% (wt./vol.) solution of an organic, non-volatile solution. The molecular weight of latter is
- 23. Find the freezing point of a glucose solution whose osmotic pressure at $25^{\circ}C$ is found to be 30 atm. $K_f(water) = 1.86 kg.mol^{-1}.K$.
- 24. 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?

8 Abnormal colligative properties:

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

Van't Hoff in 1880, introduced a factor, called Van't Hoff factor (i). The factor 'i' is defined as

 $i = \frac{observed\,colligative\,property}{Calculated\,colligative\,property} = \frac{Normal\,molecular\,mass}{observed\,molecular\,mass}.$

 $= \frac{\text{total number of particles after dissociation / association}}{\text{Number of particles initially taken}}$

In case of association of solute particles in solution, the observed molecular weight of solute being more than the normal, the value of factor 'i' is less than unity (i.e. i < 1), while for dissociation the value of i is greater than unity (i.e. i > 1), because the observed molecular weight has lesser value than normal molecular weight.

8.1 Calculation of 'i' in case of dissociation

$$A_x B_y \longrightarrow x A^{y+} + y B^{x-}$$

Initial mol

after dissociation $1 - \alpha$

Total no. of solute particles = $1 - \alpha + x\alpha + y\alpha = 1 - \alpha + \alpha(x + y)$

or
$$i = 1 - \alpha + n\alpha$$
 [where $x + y = n$ (total ions.)]

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

For strong electrolytes : $\alpha = 1$ or 100%, so i = n (total no. of ions)

$$NaCl \rightarrow Na^+ + Cl^-$$
 (i = 2)

$$K_2SO_4 \rightarrow 2K^+ + SO_4^{2-} (i=3)$$

For complex compound

$$K_4[Fe(CN)_6] \rightarrow 4K^+ + [Fe(CN)_6]^{4-} \Rightarrow n = 5$$

_			,			
S. No.	Solute type	Example	Ionisation	No. of particles in the solution from 1 mole solute (n)	van't Hoff factor ('i')	Abnormal molecular mass
1.	Non-electrolyte	Urea, sucrose, glucose, fructose	_	1	1	m _{normal}
2.	Binary electrolyte AB type	NaCl, KCl, HCl CH ₃ COOH NH ₄ OH, NaOH etc.	$AB \rightleftharpoons A^{+} + B^{-}$ $1 - \alpha \qquad \alpha \qquad \alpha$	2	1 + α	$\frac{m_{normal}}{1+\alpha}$
3.	Ternary electrolyte AB_2 type or A_2B type	CaCl ₂ , BaCl ₂ H ₂ SO ₄ , K ₂ [PtCl ₆]	$AB_{2} \rightleftharpoons A^{2+} + 2B^{-}$ $1 - \alpha \qquad \alpha \qquad 2\alpha$ $A_{2}B \rightleftharpoons 2A^{+} + B^{-}$ $1 - \alpha \qquad 2\alpha \qquad \alpha$	3 3	$1 + 2\alpha$ $1 + 2\alpha$	$\frac{m_{normal}}{1+2\alpha}$ $\frac{m_{normal}}{1+2\alpha}$
4.	Quanternary electrolyte AB_3 or A_3B type	AlCl ₃ , K ₃ [Fe(CN) ₆]	$AB_{3} \rightleftharpoons A^{3+} + 3B^{-}$ $1 - \alpha \qquad \alpha \qquad 3\alpha$ $A_{3}B \rightleftharpoons 3A^{+} + B^{3-}$ $1 - \alpha \qquad 3\alpha \qquad \alpha$	4	$1 + 3\alpha$ $1 + 3\alpha$	$\frac{m_{normal}}{1+3\alpha}$ $\frac{m_{normal}}{1+3\alpha}$
5.	General electrolyte AB_{n-1}	One mole of solute giving 'n' ions in the solution	$AB_{n-1} \rightleftharpoons A^{+(n-1)} + (n-1)B^{-1}$ $1 - \alpha \qquad \alpha \qquad (n-1)\alpha$	n	$1+(n-1)\alpha$	$\frac{m_{normal}}{\left[1+(n-1)\alpha\right]}$

8.2 Calculation of 'i' in case of assocation

Initial mol
$$1 \longrightarrow (A)_n$$
 after dissociation
$$1 - \alpha \quad \alpha/n$$

$$i = \frac{1 - \alpha + \frac{\alpha}{n}}{n} , \quad \alpha = \text{degree of assocation}$$

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

CLASS ILLUSTRATION - 08

- 25. Determine the amount of $CaCl_2$ (i = 2.47) dissolved in 2.5 litre of water such that its osmotic pressure is 0.75 atm at $27^{\circ}C$.
- 26. 19.5 g of CH₂FCOOH is dissolved in 500 g of water. The depression in the freezing point of water observed is 1.0°C. Calculate the van't Hoff factor and dissociation constant of fluoroacetic acid.
- 27. Phenol associates in benzene to a certain extent to form a dimer. A solution containing 18.8×10^{-3} kg phenol in 1 kg of benzene has its freezing point depressed by 0.768 K. Calculate the fraction of phenol that has dimerised. K_f for benzene = 5.12 kg mol⁻¹K.
- 28. Cane sugar underoges the inversion as follow

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

If solution of 0.025 moles of sugar in 200 gm of water show depression in freezing point 0.372°C, then what % sucrose has inverted. $(K_f(H_2O) = 1.86 \text{ K kg mol}^{-1})$

29. When $0.1 \, M \, Pb(NO_3)_2$ solution is titrated with $0.1 \, M \, KI$ solution then what will be the osmotic pressure (in atm) of solution when equivalence point is reached at 300 K.

(Take : R = 0.08 atm L/mol-k)

ANSWER KEY

CLASS ILLUSTRATION - 01

- Ans. 0.716 m mol 1.
- **Ans.** $X_{02} = 4.61 \times 10^{-5}$ and $X_{N2} = 9.22 \times 10^{-5}$ 2.

CLASS ILLUSTRATION - 02

- *3*. 43.2 mm of Hg. Ans.
- x = 0.744. Sol.
- **Sol.** $p_B^0 = 600 \text{ mm of Hg} = \text{vapour pressure of pure B}$ *5*. $p_A^0 = 400 \text{ mm of Hg} = \text{vapour pressure of pure A}$
- Ans. 2/17 6.
- **Sol.** 40 cm Hg *7*.
- Ans. $(100^{\circ}C)$ 8.

CLASS ILLUSTRATION - 03

- 9. Ans. 0.8
- *10.* Ans.
 - (i) no condensation
- (ii) 0.5 atm.
- (iii) 6L

(iv) 0.5

(v) 0.52 atm

(vi) 4/13

- (vii) 3 mole
- (viii) $X_A = 0.45$, $Y_A = 0.35$, Moles of A in liquid = 1.09; Moles of B in liquid = 1.33
- (ix) 0.5104 atm

CLASS ILLUSTRATION - 04

- 11. Ans. 0.124 mm Hg
- 12. Ans.. 220
- *13*. 3 17.38
- **CLASS ILLUSTRATION 05**

Ans. 100 *14*.

- 15. Ans. 1.0
- 106 g/mol
- **CLASS ILLUSTRATION 06**
- *17*. Ans. 105.68 mol/kg
- 18. Ans. $-0.093^{\circ}C$
- 19. Ans. 50%

20. Ans. C_6H_6

CLASS ILLUSTRATION - 07

- 21. Ans. 0.1M
- 22 Ans. 34.89 gm/mol
- Ans. 13.8 atm 23
- Ans. $T_f = -2.28^{\circ}C$ *24*.

26.

- 25. Ans. 3.42 g
- 27. Ans. 0.50
- 29. 5. Ans.(3.2)
- **CLASS ILLUSTRATION 08** Sol. i = 1.0753, $k = 3.07 \times 10^{-3}$

 - Ans (60%) *28*.

PREVIOUS YEARS SOLVED EXAMPLES

- 1. In the depression of freezing point experiment, it is found that
 - (I) The vapour pressure of the solution is less than that of pure solvent.
 - (II) The vapour pressure of the solution is more than that of pure solvent.
 - (III) Only solute molecules solidify at the freezing point.
 - (IV) Only solvent molecules solidify at the freezing point.
 - (A) I, II
- (B) II, III
- (C) I, IV
- (D) I, II, III

[JEE 1999]

Ans. (C)

Sol. $P_s < P_0$

& Equilibrium exists.

IEE-Chemistry

- 2. The van't Hoff factor for 0.1 M Ba(NO₃)₂ solution is 2.74. The degree of dissociation is
 - (A) 91.3%
- (B) 87%
- (C) 100%
- (D) 74%

[JEE 1999]

Sol. $i = 1 + 2 \infty$

$$\alpha = \frac{1.74}{2} = 0.87 \text{ or } 87\%$$

- 3. To 500 cm³ of water, 3×10^{-3} 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⁻¹ mol⁻¹ and 0.997 g cm⁻³ respectively. [JEE 2000]
- Ans. 0.23 K

Sol.
$$\Delta T_f = i K_f \cdot m$$

$$= (1.23) \times 1.86 \times \frac{3/60}{500 \times 0.997/1000}$$

$$= 0.23 \text{ K}$$

4. The vapour pressure of two miscible liquids (A) and (B) are 300 and 500 mm of Hg respectively. In a flask 10 mole of (A) is mixed with 12 mole of (B). However, as soon as (B) is added, (A) starts polymerising into a completely insoluble solid. The polymerisation follows first-order kinetics. After 100 minute, 0.525 mole of a solute is dissolved which arrests the polymerisation completely. The final vapour pressure of the solution is 400 mm of Hg. Estimate the rate constant of the polymerisation reaction. Assume negligible volume change on mixing and polymerisation and ideal behaviour for the final solution. [JEE 2001]

Ans. (1.0×10^{-4}) min⁻¹

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

$$400 = 300 \times \frac{(10-x)}{(22.525-x)} + 500 \times \frac{12}{(22.525-x)}$$

$$9010 - 400 x = 9000 - 300 x$$

 $x = 0.1$

$$k = \frac{1}{100} \ln \frac{10}{10 - 0.1} = \frac{1}{100} \ln \frac{10}{9.9} = 1 \times 10^4 \text{ min}^{-1}$$

- 5. 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

Ans. (A)

Sol. Equilibrium exists between liquid solvent & solid solvent.

6. 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

Ans.
$$K_b(x) = 0.68, K_b(y) = 0.53, K_b(z) = 0.98$$

Sol. $K_b \propto T_b^2$

- 7. 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]

Ans. (a)122, (b) It means that benzoic acid remains as it is in acetone while it dimerises in benzene

Space for Notes

Sol. (a)

(i)
$$\Delta T_b = i K_b \cdot m$$

$$0.17 = i \times 1.7 \times \frac{1.22/122}{0.1}$$

$$i = 1 = \frac{\left(\text{mol wt}\right)_{\text{Th}}}{\left(\text{mol wt}\right)_{\text{ACt}}}$$

$$(\text{mol wt})_{\text{ACt}} = \frac{122}{1} \text{ gm/mol}$$

(ii)
$$\Delta T_b = i \times K_b$$
. m

$$0.13 = i \times 2.6 \times \frac{1.22/122}{0.1}$$

$$i = 0.5 = \frac{\text{(mol wt)}_{Th}}{\text{(mol wt)}_{ACt}} \Rightarrow \text{(mol ut)}_{ACl} = \frac{122}{0.5}$$

$$= 244 \text{ gm/mol}$$

but in benzene it is in dimenc form

8. A 0.004 M solution of Na_2SO_4 is isotonic with a 0.010 M solution of glucose at same temperature. The apparent degree of dissociation of Na_2SO_4 is

(A)
$$25\%$$

$$(C)75\%$$

Ans. (C)

$$\textbf{Sol.} \hspace{0.5cm} \pi_{Na_2So_4} = \pi_{g10C^{\circ}}$$

$$i \times 0.004 = 0.010$$

$$i = 2.5 = 1 + 2 \infty \implies \infty = 0.75 \text{ or } 75\%$$

Space for Notes

- 9. The elevation in boiling point, when 13.44 g of freshly prepared $CuCl_2$ are added to one kilogram of water, is [Some useful data, K_b (H_2O) = 0.52 kg K mol⁻¹, mol. wt. of $CuCl_2$ = 134.4 gm] (A) 0.05 (B) 0.1 (C) 0.16 (D) 0.21 [JEE 2005]
- Ans. (C)

Sol.
$$\Delta T_b = i K_b \cdot m$$

= $3 \times 0.52 \times \frac{13.44/134.4}{1}$
= $0.156 K$
 $\approx 0.16 K$

10. 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**]

Ans. 35% (degree of asso = 70%)

Sol.
$${}^{2} \underset{\scriptscriptstyle{0.77\,\text{mol}}}{\text{PhOH}} \Longrightarrow (\text{PhOH})_{2}$$
 $0.77(1-\infty)$
 $0.77 \propto /2$
 $i = 1-\infty/2$
 $\Delta T_{f} = i \quad K_{f} \cdot m$
 $7 = (1-\infty) \times 14 \times \frac{72.5/94}{1}$
 $0.649 = 1-\infty/2$
 $\infty/2 = 0.35$
 $\infty = 0.70$

% of phenol in dimeric form

$$= \frac{0.77 \times /2}{0.77} \times 100 = \frac{\infty}{2} \times 100 = 35\%$$

- 11. When 20 g of naphtholic acid $(C_{11}H_8O_2)$ is dissolved in 50 g of benzene $(K_f = 1.72 \text{ K kg mol}^{-1})$, 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

Ans. (A)

Sol.
$$\Delta T_f = i K_f \cdot \frac{n}{W/1000}$$

 $2 = i \times 1.72 \times \frac{20/172}{50/1000}$
 $i = 0.5$

Paragraph for Question No. Q.12 to Q.14

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 $(K_f^{\text{water}}) = 1.86 \text{ K kg mol}^{-1}$

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

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

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

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^{-1}

Molecular weight of ethanol = 46 g mol⁻¹

In answering the following questions, consider the solutions to be ideal dilute solutions and solutes to be non-volatile and non-dissociative.

12. 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

Ans. (D)

Space for Notes

$$(T_f')_{Alc.sol^n} = (T_f)_{EtoH} - (K_f)_{etoh} .m$$

= 115.7 - 2 × $\frac{0.1}{0.9 \times 46/1000}$
= 155.7 - 2 × 2.415 = 150.9 K

13. The vapour pressure of the solution M is

[JEE 2008]

- (A) 39.3 mm Hg
- (B) 36.0 mm Hg
- (C) 29.5 mm Hg
- (D) 28.8 mm Hg

Ans. (B)

Sol.
$$P^s = (p^\circ)_{solvent} \cdot X_{solvent}$$

= $40 \times 0.9 = 36.0 \text{ mm Hg}$

- **14.** 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

Ans. (B)

Sol.
$$(T_b')_{Aqsol^n} = (T_b)_{solventH_2O} + K_b$$
. m
 $= 373 + 0.52 \times \frac{0.1}{0.9 \times 18/1000}$
 $= 373 + 0.52 \times 6.173 = 376.2 \text{ K}$

- 15. The Henry's law const ant for the solubility of N_2 gas in water at 298 K is 1.0×10^5 atm. The mole fraction of N_2 in air is 0.8. The number of moles of N_2 from air dissolved in 10 moles of water at 298 K and 5 atm pressure is-
 - (A) 4.0×10^{-4}
- (B) 4.0×10^{-5}
- (C) 5.0×10^{-4}
- (D) 4.0×10^{-5}

Ans. (A)

Sol.
$$P_{N_2} = K_H X_{N_2}$$

 $Y_{N_2}.P_T = K_H \times N_2$
 $0.8 \times 5 = 1 \times 10^5 \times \frac{n}{n+10}$
 $4 = 10^5 \times \frac{n}{10}$
 $n = 4 \times 10^{-4}$

Space for Notes

EXERCISE # S-I

(Raoult's law)

1. At 25°C, the vapour pressure of methyl alcohol is 96.0 torr. What is the mole fraction of CH₃OH in a solution in which the (partial) vapor pressure of CH₃OH is 24.0 torr at 25°C?

LS0001

2. The vapour pressure of ethanol and methanol are 44.0 mm and 88.0 mm Hg respectively. An ideal solution is prepared at the same temperature by mixing 69 g of ethanol with 40 g of methanol. Calculate total vapour pressure of the solution.

LS0002

3. Liquide 'A' and 'B' form an ideal solution. The vapour pressure of solution containing equal moles of both liquids is 80 cm Hg. At the same temperature, the vapour pressure of solution containing 25 mole percent of liquid 'A' is 70 cm Hg. Calculate P_A⁰ and P_B⁰.

LS0003

4. Liquids 'A" and 'B' form an ideal solution. Calculate the mole-fraction of 'A' in the vapours above the liquid solution containing the liquids 'A' and 'B' in 2 : 3 mole ratio, at equilibrium.

[Given :
$$P_A^0 = 0.4$$
 atm, $P_B^0 = 0.8$ atm]

LS0004

5. Liquids 'P' and 'Q' form an ideal solution. At equilibrium, the vapours contain 40% molecules of 'P'. Calculate the vapour presure of solution.

[Given :
$$P_P^0$$
 = 0.4 bar, P_Q^0 = 0.6 bar]

LS0005

6. Liquids 'X' and 'Y' form an ideal solution. The vapour pressure of solution may be expressed as: P[/cmHg] = (80 - 25x), where 'x' is the mole-fraction of liquid 'X' in the liquid solution at equilibrium. Calculate the vapour pressures of pure liquids 'X' and 'Y'.

LS0006

7. Liquid 'R' and 'S" form an ideal solution. The mole-fraction of 'R' in liquid and vapour phases at equilibrium are 0.25 and 0.40, respectively. If the vapour pressure of solution is 0.50 bar, calculate P_R^0 and P_S^0

LS0007

Colligative properties

8. The vapour pressure of pure liquid solvent A is 0.80 atm. When a nonvolatile substance B is added to the solvent its vapour pressure drops to 0.60 atm. What is the mole fraction of component B in the solution?

LS0008

9. Calculate the relative lowering in vapour pressure if 100 g of a nonvolatile solute (mol.wt.100) are dissolved in 432 g water.

LS0009

10. The vapour pressure of pure benzene at 30° C is 640 mm of Hg and the vapour pressure of a solution of a solute in C_6H_6 at the same temperature is 624 mm of Hg. Calculate molality of solution.

The vapour pressure of pure benzene at a certain temperature is 640 mm of Hg. A nonvolatile nonelectrolyte 11. solid weighing 2.175 g is added to 39.0 of benzene. The vapour pressure of the solution is 600 mm of Hg. What is molecular weight of solid substance?

LS0011

12. The vapour pressure of water is 17.54 mm Hg at 293 K. Calculate vapour pressure of 0.5 molal solution of a solute in it.

LS0012

13. When 10.5 g of a nonvolatile substance is dissolved in 742 g of ether, its boiling point is raised 0.25°C. What is the molecular weight of the substance? Molal boiling point constant for ether is 2.12°C·kg/mol. LS0013

Calculate the molal elevation constant, K_b for water and the boiling point of 0.1 molal urea solution. 14. Latent heat of vaporisation of water is 9.72 kcal mol⁻¹ at 373.15 K. $[(373.15)^2 = 258 \times 540]$

LS0014

Pure benzene freeze at 5.45°C. A solution containing 6.72 g of C₂H₂Cl₄ in 120 g of benzene was observed 15. to freeze at 3.75°C. What is the molal freezing point constant of benzene?

LS0015

16. The freezing point of a solution containing 2.40 g of a compound in 60.0 g of benzene is 0.10°C lower than that of pure benzene. What is the molecular weight of the compound? (K_s is 5.12°C/m for benzene) LS0016

17. A 6.84% solution (w/v) of cane-sugar (Mol. weight = 342) is isotonic with 0.8% (w/v) solution of nonvolatile solute. Find molecular weight of solute.

LS0018

18. Calculate the osmotic pressure of 12% (w/v) aq. urea solution at 27°C.

LS0019

19. Calculate the osmotic pressure of a solution containing 18 gm glucose and 17.1 gm canesugar $(C_{12}H_{22}O_{11})$ per litre, at 27°C.

LS0020

A storage battery contains a solution of H_2SO_4 38% by weight. What will be the Van't Hoff factor if the 20. $\Delta T_{\text{f(experiment)}}$ is 22.8K. [Given $K_f = 1.86 \text{ mol}^{-1} \text{ Kg}$]

LS0021

21. A certain mass of a substance, when dissolved in $100 \,\mathrm{g} \,\mathrm{C}_6 \,\mathrm{H}_6$, lowers the freezing point by $1.28 \,\mathrm{^{\circ}}\mathrm{C}$. The same mass of solute dissolved in 100g water lowers the freezing point by 1.40°C. If the substance has normal molecular weight in benzene and is completely ionized in water, into how many ions does it dissociate in water? K_f for H_2O and C_6H_6 are 1.86 and 5.12K kg mol⁻¹.

LS0022

22. **2.0** g of benzoic acid dissolved in 25.0g of benzene shows a depression in freezing point equal to 1.96K. Molal depression constant (K_s) of benzene is 4.9 K.kg.mol⁻¹. What is the percentage association of the acid? LS0023

23. A decimolar solution of potassium ferrocyanide is 50% dissociated at 300K. Calculate the osmotic pressure of the solution. (R=8.314 JK⁻¹ mol⁻¹)

LS0024

A 1.2% solution (w/v) of NaCl is isotonic with 7.2% solution (w/v) of glucose. Calculate degree of 24. ionization and Van't Hoff factor of NaCl.

LS0025

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Henry's law

25. How many gm O_2 gas will disolve in 100 gm water at 9 bar and 27°C? ($K_H = 40 \text{ Kbar}$)

LS0026

26. The Henry law constant for dissolution of a gas in aqueous medium is 3×10^2 atm. At what partial pressure of the gas (in atm), the molality of gas in aqueous solution will be $\frac{5}{9}$ m.

EXERCISE # S-II

1. At 90°C, the vapour pressure of toluene is 400 torr and that of σ -xylene is 150 torr. What is the composition of the liquid mixture that boils at 90°C, when the pressure is 0.50 atm? What is the composition of vapour produced?

LS0028

2. The vapour pressure of an aqueous solution of glucose is 750 mm Hg at 373 K. Calculate molality and mole fraction of solute.

LS0029

Calculate the amount of ice that will separate out of cooling a solution containing 50g of ethylene glycol in 200 g water to -9.3 °C. (K_r for water = 1.86 K mol⁻¹ kg)

LS0030

4. How many grams of sucrose (mol.wt. = 342) should be dissolved in 100 gm water in order to produce a solution with 105°C difference between the freezing point & boiling point temperature at 1 atm?

(Unit:
$$K_f = 2 \text{ K.kg mol}^{-1}$$
; $k_h = 0.5 \text{ K.kg mol}^{-1}$)

LS0033

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 101.36°C at 1.00 atmospheric pressure. What is the molecular formula? $K_h(H_2O) = 0.52 \text{ K mol}^{-1} \text{ kg}$

LS0034

6. A complex is represented as $CoCl_3 \cdot xNH_3$. It's 0.1 molal solution in a solution shows $\Delta T_f = 0.558$ °C. K_f for H_2O is 1.86 K mol⁻¹ kg . Assuming 100% ionisation of complex and coordination no. of Co is six, calculate formula of complex.

LS0035

7. Normal boiling point of diethyl ether is 327° and at 190 mmHg boiling points in 27°C. What is the value of ΔH_{van}° in kJ/mole.

(Use:
$$R = 8.3 \text{ J/K-mole}, \ln 2 = 0.7$$
)

ALLEN

EXERCISE # O-I

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Duigu	COLLECT	•

Ding	ic correct.					
1.	The boiling point of C_6H_6 , CH_3OH , $C_6H_5NH_2$ and $C_6H_5NO_2$ are $80^{\circ}C$, $65^{\circ}C$, $184^{\circ}C$ and 212 respectively which will show highest vapour pressure at room temperature :					
	$(A) C_6 H_6$	(B) CH ₃ OH	$(C) C_6 H_5 NH_2$	(D) $C_6H_5NO_2$	T C00.42	
2.	Mole fraction of A vap	pours above the solution	in mixture of A and B (X	$X_A = 0.4$) will be	LS0042	
	[Given: $P_A^{\circ} = 100 \text{ mg}$	m Hg and $P_{\rm B}^{\circ} = 200 \text{ mm}$	Hg]			
	(A) 0.4	(B) 0.8	(C) 0.25	(D) none of these		
3.	At a given temperature by	, total vapour pressure in	Torr of a mixture of volati	le components A and	LS0043 B is given	
	- 7	$P_{Total} = 120 - 75 X_B$				
		re of pure A and B resp	- · · · · · · · · · · · · · · · · · · ·			
	(A) 120, 75	(B) 120, 195	(C) 120, 45	(D) 75, 45	LS0044	
4.	Two liquids A & B for	n an ideal solution. What	t is the vapour pressure of	Solution containing		
••	_					
	A and 3 moles of B at 300 K? [Given : At 300 K, Vapour pr. of pure liquid A (P_A^o) = 100 torr, Vapour					
	pr. of pure liquid B (]	$(P_B^o) = 300 \text{ torr }]$				
	(A) 200 torr	(B) 140 torr	(C) 180 torr	(D) None of these		
_	10D 10 1 1 1	1.4		. 11	LS0045	
5.			of the solvent in a solutio		ional to	
	(A) Mole fraction of the	ne solvent and solute	(B) Mole fraction of the(D) The volume of the			
	(C) Wolc fraction of the	ic sorvein and sorute	(D) The volume of the	Solution	LS0046	
6.	1 mole of heptane (V.	P = 92 mm of Hg) was m	nixed with 4 moles of oct	ane (V. P. = 31mm o		
	vapour pressure of resi	ulting ideal solution is:				
	(A) 46.2 mm of Hg	(B) 40.0 mm of Hg	(C) 43.2 mm of Hg	(D) 38.4 mm of H		
7.	Mala fraction of A year	nours shows solution in r	mixture of A and D (V =	- 0 4) will bo	LS0047	
7.	($P_A^{\circ} = 100 \text{mm}, P_R^{\circ} =$		mixture of A and B $(X_A =$	- 0.4) WIII be		
	(\mathbf{A}) 0.4	(B) 0.8	(C) 0.25	(D) None		
	(11) 0.1	(B) 0.0	(0) 0.23	(B) I tone	LS0048	
8.	The vapour pressure o	f a pure liquid 'A' is 70 to	err at 27°C. It forms an ide	eal solution with ano	ther liquid	
		•	ur pressure of the solution	n is 84 torr at 27^{0} C. T	he vapour	
	pressure of pure liquid		(0) 140	(D) 7 0		
	(A) 14	(B) 56	(C) 140	(D) 70	LS0049	
					LOUVE	

A	LLEN			Liquid solu	tion 47
9.		s a vapour pressure of 90 fbenzene in the mixture weal solution:			
	(A) 0.416	(B) 0.588	(C) 0.688	(D) 0.740	LS0050
10.	The exact mathemat	ical expression of Raoul	t's law is (n = moles of	solute; $N = moles of s$	
	$(A) \frac{P^0 - P_s}{P^0} = \frac{n}{N}$	$(B) \frac{P^0 - P_s}{P^0} = \frac{N}{n}$	$(C) \frac{P^0 - P_s}{P_s} = \frac{n}{N}$	$(D) \frac{P^0 - P_s}{P^0} = n$	×N
11.	the solvent. The mol	e of a solvent decreased be e fraction of solute in solutes or essure is 20 mm of Hg	-		
	(A) 0.2	(B) 0.4	(C) 0.6	(D) 0.8	
12.	The vanour pressure	of a solution having soli	d as solute and liquid a	s solvent is :	LS0052
13.	(B) Inversely propor(C) Directly propor(D) Inversely propar	ional to mole fraction of the retional to mole fraction of the tional to mole fraction of the tional to mole fraction of the atile solute is dissolved in	of the solvent of the solute The solute	he vapour pressure of	LS0053 the solution
	relative to that of w	ater is			
	(A) $\frac{2}{3}$	(B) $\frac{1}{3}$	(C) $\frac{1}{2}$	(D) $\frac{3}{2}$	
14.		e of pure A is 10 torr and ressure is reduced to 9.0 to	-	-	
	(A) 100 amu	(B) 90 amu	(C) 75 amu	(D) 120 amu	
15.		e of a pure liquid solvent	* *		LS0055 on addition
	of a non volatile su (A) 0.20	bstance (Y). The mole f (B) 0.25	raction of (Y) in the s $(C) 0.5$	(D) 0.75	LS0056
16.	Among the following	g, that does not form an io	deal solution is:		250050
	(A) C_6H_6 and C_6H_5 (C) C_6H_5Cl and C_6H_5	CH_3 $I_5Br(D) C_2H_5Br$ and C_2H_3	(B) C_2H_5Cl and C_3H_5I	C ₆ H ₅ OH	
17					LS0057
17.	(A) Nature of the sol	es of the solution depend tution	upon (B) Nature of the s	olvent	
	(C) Number of solut		(D) Number of mo		

(A) 274.76 K

(B) 377 K

18.	Elevation of boiling potential (A) K _b	int of 1 molar aqueous gl (B) 1.20 K _b	ucose solution (density = (C) 1.02 K _b	= 1.2 g/ml) is (D) 0.98 K _b
	(11) 11 _b	(B) 1.20 R _b	(C) 1.02 II _b	LS0059
19.	When common salt is d (A) Melting point of the (C) Boiling point of the	e solution increases	(B) Boiling point of the (D) Both Melting point	and Boiling point is decrease
20	Wile at all and die atte a free	-in a maint of a success and	utian aantainina 17 am a	LS0060
20.	(water $K_f = 1.86 \text{ deg}$	- kg mol ⁻¹)		fC_2H_5OH in 1000 gm of wate
	(A) - 0.69°C	(B) -0.34 °C	(C) 0.0°C	(D) 0.34°C LS006 1
21.	If mole fraction of the s	solvent in solution decrea	ses then:	
	(A) Vapour pressure of	solution increases	(B) B. P. decreases	
	(C) Osmotic pressure in	ncreases	(D) All are correct	7 000 0
22.	5% (w/v) solution of suc of compound 'A' is -	rose is isotonic with 1% (v	v/v) solution of a compour	LS0062 and 'A' then the molecular weigh
	(A) 32.4	(B) 68.4	(C) 121.6	(D) 34.2
	,	` '		LS0063
23.	Osmotic pressure of a super litre is:	ugar solution at 24 ⁰ C is 2.	5 atmosphere. The conce	ntration of the solution in mol
	(A) 10.25	(B) 1.025	(C) 1025	(D) 0.1025
24.			_	LS0064 and to have an osmotic pressure
	-	cury at 27° C. The molec	-	
	(A) 14.97	(B) 149.7	(C) 1697	(D) 1.497 LS006 5
25.	If a 6.84% (wt. / vol.) so	olution of cane-sugar (mo	ol. wt. 342) is isotonic wi	th 1.52% (wt./vol.) solution o
	· · · · · · · · · · · · · · · · · · ·	molecular wight of thioc		
	(A) 152	(B) 76	(C) 60	(D) 180
		. ,	` '	LS0060
26.	Which of the following	aqueous solution will sh		essure at 300 K?
	(A) 1 M NaCl	(B) 1 M CaCl ₂	(C) 1 M AlCl ₃	(D) 1 M C ₁₂ H ₂₂ O ₁₁ LS006 7
27.		nip between the boiling ne same molar concentra		solution of AlCl ₃ (T ₁ K) and
	(A) $T_1 = T_2$	(B) $T_1 > T_2$	(C) $T_2 > T_1$	(D) $T_2 \le T_1$ LS0068
28.	1.0 molal aqueous solu	tion of an electrolyte A.F	B, is 60% ionised. The bo	oiling point of the solution at
			3 - 22, 22, 22, 210, 210, 210, 210, 210, 21	Or
	atm is $(K_{b(H_2O)} = 0.55)$	2 K kg mol ')		

(C) 376.4 K

(D) 374.76 K

ALLEN Liquid solution 49 29. The freezing point depression of a 0.1 M a solution of weak acid (HX) is -0.20°C. What is the value of equilibrium constant for the reaction? $HX (aq) \rightleftharpoons H^+(aq) + X^-(aq)$ **[Given**: K_s for water = 1.8 kg mol⁻¹ K. & Molality = Molarity] (B) 1.35×10^{-3} (C) 1.21×10^{-2} (A) 1.46×10^{-4} (D) 1.35×10^{-4} LS0070 The Vant Hoff factor (i) for a dilute solution of $K_3[Fe(CN)_6]$ is (Asuming 100% ionsation): **30.** (A) 10 (B)4(C) 5 (D) 0.25LS0071 31. The substance A when dissolved in solvent B shows the molecular mass corresponding to A₃. The vant Hoff's factor will be -(C) 3 (A) 1 (B)2(D) 1/3LS0072 32. The value of observed and calcutated molecular wieght of silver nitrate are 92.64 and 170 respectively. The degree of dissociation of silver nitrate is: (A) 60% (B) 83.5 % (C) 46.7% (D) 60.23% LS0073 33. The freezing point of 1 molal NaCl solution assuming NaCl to be 100% dissociated in water is: $(K_f = 1.86 \text{ K Molality}^{-1})$ $(A) -1.86 \, ^{\circ}C$ (B) -3.72 °C $(C) +1.86 \, ^{\circ}C$ (D) $+ 3.72 \, ^{\circ}\text{C}$ LS0074 What is the freezing point of a solution containing 8.1 gm. of HBr in 100gm. water assuming the acid to 34. be 90% ionised ($K_{\rm s}$ for water=1.86 K molality⁻¹):-(C) 0°C (A) 0.85° C (B) -3.53°C (D) -0.35°C LS0075 **35.** If a ground water contains H₂S at concentration of 2 mg/l, determine the pressure of H₂S in head space of a closed tank containing the ground water at 20°C. Given that for H_2S , Henry's constant is equal to 6.8×10^{-2} 10³ bar at 20°C. (A) 720 Pa (B) $77 \times 10^2 \text{ Pa}(\text{C}) 553 \text{ Pa}$ (D) $55 \times 10^2 \text{ Pa}$ LS0076 A pressure cooker reduces cooking time for food because -[AIEEE-2003] 36. (A) The higher pressure inside the cooker crushes the food material (B) Cooking involves chemical changes helped by a rise in temperature (C) Heat is more evenly distributed in the cooking space

(D) Boiling point of water involved in cooking is increased

EXERCISE # O-II

Single correct:

1. An ideal solution was obtained by mixing (MeOH) methanol and (EtOH) ethanol. If the partial vapour pressure of methanol and ethanol are 2.619 K Pa and 4.556 K Pa respectively, the composition of vapour (in terms of mole fraction) will be -

(A) 0.635 MeOH, 0.365 EtOH

(B) 0.365 MeOH, 0.635 EtOH

(C) 0.574 MeOH, 0.326 EtOH

(D) 0.173 MeOH, 0.827 EtOH

LS0078

2. Molar volume of liquid A(d = 0.8 gm/ml) increase by factor of 2000 when it vapourises at 200K. Vapour pressure of liquid A at 200K is [R = 0.08 L-atm/mol-K]

(Molar mass of A = 80g/mol)

(A) 0.4 atm

(B) 8 atm

(C) 0.8 atm

(D) 0.08 atm

LS0079

3. Assuming each salt to be 90 % dissociated, which of the following will have highest boiling point?

- (A) Decimolar Al₂(SO₄)₃
- (B) Decimolar BaCl₂
- (C) Decimolar Na₂SO₄
- (D) A solution obtained by mixing equal volumes of (B) and (C)

LS0080

4. A solution has a 1:4 mole ratio of pentane to hexane. The vapour pressures of the pure hydrocarbons at 20°C are 440 mmHg for pentane and 120 mmHg for hexane. The mole fraction of pentane in the vapour phase would be:-

(A) 0.200

(B) 0.478

(C) 0.549

(D) 0.786

LS0082

5. For which of the following vant' Hoff's factor is not correctly matched -

	Salt	Degree of dissociation (α)	i
(A)	Na ₂ SO ₄	50 %	2
(B)	$K_3[Fe(CN)_6]$	75%	3.25
(C)	$[Ag(NH_3)_2]Cl$	80 %	1.8
(D)	[Cr(NH ₃) ₅ Cl]SO ₂	90 %	2.8

LS0083

6. Statement-1: Addition of ethylene glycol (non-volatile) to water lowers the freezing point of water hence used as antifreeze.

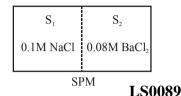
Statement-2: Addition of any substance to water lowers its freezings point of water.

- (A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
- (B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
- (C) Statement-1 is true, statement-2 is false.
- (D) Statement-1 is false, statement-2 is true.

More than one may be correct

- 7. Which of the following is correct for a non-ideal solution of liquids A and B, showing negative deviation?
 - (A) $\Delta H_{mix} = -ve$
- (B) $\Delta V_{\text{mix}} = -ve$
- (C) $\Delta S_{mix} = +ve$
- (D) $\Delta G_{\text{mix}} = -ve$

- 8. Two solutions S₁ and S₂ containing 0.1M NaCl(aq.) and 0.08M BaCl₂(aq.) are separated by semipermeable membrane. Which among the following statement(s) is/are correct -
 - (A) S_1 and S_2 are isotonic
 - (B) S_1 is hypertonic and S_2 is hypotonic
 - (C) S_1 is hypotonic and S_2 is hypertonic
 - (D) Osmosis will take place to from S_1 to S_2



For an ideal binary liquid solution with $P_A^{\circ} > P_B^{\circ}$, which relation between X_A (mole fraction of A in liquid 9. phase) and Y_A (mole fraction of A in vapour phase) is correct?

- (A) $Y_A < Y_B$ (B) $X_A > X_B$ (C) $\frac{Y_A}{Y_B} > \frac{X_A}{X_B}$ (D) $\frac{Y_A}{Y_B} < \frac{X_A}{X_B}$

LS0090

Match the column:

(A)

10. Column-I

(Colligative properties)

$\Delta T_f = 0.3 \times K_f$

(B)
$$\Delta T_b = 0.28 \times K_b$$

(C)
$$\pi = 0.19 \times RT$$

(D)
$$\frac{P^0 - P}{P^0} = \frac{\left(\frac{\Delta T_f}{K_f}\right)}{\left(\frac{1000}{18}\right) + \left(\frac{\Delta T_f}{K_f}\right)}$$

Column-II

(Aqueous solution)

(Assume m = M)

(P)
$$0.1 \text{ m} - \text{Ca}(\text{NO}_3)_2$$

(Q)
$$0.14 \text{ m} - \text{NaBr}$$

(R)
$$0.1 \text{ m} - \text{MgCl}_2(\alpha = 0.9)$$

(T) 0.1 m - HA (monobasic acid, $K_a = 0.81$)

[AIEEE-2011]

E

expression:-

1.

EXERCISE # (J-MAIN)

The degree of dissociation (1) of a weak electrolyte, A_xB_y is related to van't Hoff factor (i) by the

	(1) $\alpha = \frac{x + y - 1}{i - 1}$	(2) $\alpha = \frac{x + y + 1}{i - 1}$	(3) $\alpha = \frac{i-1}{(x+y-1)}$	(4) $\alpha = \frac{i-1}{x+y+1}$
			, ,	LS0095
2.	•	= -	=	of water, how many grams of of the solution lowered to [AIEEE-2012]
	(1) 27 g	(2) 72 g	(3) 93 g	(4) 39 g
				LS0096
3.	dissociation of the salt	is:	[JI	23°C. The apparent degree of EE (MAIN)-2012 ONLINE]
	$(k_f \text{ for water} = 1.86 \text{ K })$	kg mol-1, atomic mass; Z	Zn = 65.3 and $Cl = 35.5$)	
	(1) 1.36%	(2) 2.47%	(3) 73.5%	(4) 7.35%
				LS0097
4.	1 mol of A and 2 moles	s of B is 250 mm Hg. Th	ne total vapour pressure	sure of a solution containing becomes 300 mm Hg when 1 of pure A and B at the same
	temperature are		[JE	E (MAIN)-2012 ONLINE]
	(1) 450, 150 mm Hg	(2) 250, 300 mm Hg	(3) 125, 150 mm Hg	(4) 150, 450 mm Hg LS0098
5.		.00 m aqueous solution or g mol ⁻¹ . The percentage		C. The freezing point constant concentration is
				E (MAIN)-2012 ONLINE]
	(1) 2.7%	(2) 30%	(3) 10%	(4) 5.2%
				LS0099
6.	• •	ethyl alcohol should be ad		er to prevent its freezing at 268
	K?	1 1 1	[JE	E (MAIN)-2013 ONLINE]
	$(K_f \text{ for water is } 1.86 \text{ K})$		(2) 9(9 0(-	(4) 990 07 -
	(1) 899.04 g	(2) 886.02 g	(3) 868.06 g	(4) 880.07 g LS0100
7.	Vapour pressure of pure	benzene is 119 torr and t	hat of toluene is 37.0 torr	at the same temperature. Mole
		pour phase which is in equ	uilibrium with a solution o	f benzene and toluene having a E (MAIN)-2013 ONLINE]
	(1) 0.137	(2) 0.205	(3) 0.237	(4) 0.435
		()		LS0101
8.	A molecule M associates	s in a given solvent accord	ing to the equation $M \rightleftharpoons 0$	M) _n . For a certain concentration
				eiated molecules was 0.2. The
	value of n is:			EE (MAIN)-2013 ONLINE]
	(1) 2	(2) 4	(3) 5	(4) 3
	(1)2	(2)	(3)3	I C0102

53

9.		e solute dissolved in 108g of mass of the solute is:	<u> </u>	ive lowering of vapour p [JEE (MAIN)-2013 C			
	(1) 60	(2) 80	(3) 40	(4) 20			
					LS0103		
10.	The molarity of a s	solution obtained by mix	ing 750 mL of 0.5(M)H0	Cl with 250 mL of 2(M)HCl will		
	be:-			[JEE (MAI	N)-2013]		
	(1) 0.875 M	(2) 1.00 M	(3) 1.75 M	(4) 0.975 M			
					LS0104		
11.	The observed osm	notic pressure for a 0.10	M solution of $Fe(NH_4)_2$	$(SO_4)_2$ at 25°C is 10.8	atm. The		
	expected and exper	rimental (observed) values	of Van't Hoff factor (i) w	ll be respectively:			
	$(R = 0.082 L atm k^{-1})$	mol ⁻¹)		[JEE (MAIN)-2014 C)NLINE]		
	(1)3 and 5.42	(2) 5 and 3.42	(3) 4 and 4.00	(4) 5 and 4.42	T C010#		
10	For an ideal Calatia	on oftens common anta A an	dD which of the fallowing	maiatma 9	LS0105		
12.		on of two components A ar		_	NIT TNIET		
	$(1) \Delta H_{\text{mixing}} < 0 \text{ (ze}$			[JEE(MAIN)-2014 O	NLINE		
		 (2) A – A, B – B and A – B interactions are identical (3) A – B interaction is stronger than A – A and B – B interactions 					
		_	A and D – D interactions				
	$(4) \Delta H_{\text{mixing}} > 0 \text{ (ze}$	ero)			LS0106		
13.	Consider separate	solution of 0.500 M C ₂ H	₅ OH(aq), 0.100 M Mg ₃ ($(PO_4)_2(aq), 0.250 \text{ M KB}$			
		aq) at 25°C. Which staten	•	· =			
	strong electrolytes			[JEE (MAI			
		$O_4(aq)$ has the highest os	motic pressure.	- `	· -		
	-	OH (aq) has the highest o					
		he same osmotic pressure	_				
	$(4) 0.100 \mathrm{MMg}_{3}(\mathrm{P}$	$(O_4)_2$ (aq) has the highest of	osmotic pressure.				
		7,2 (D	•		LS0107		
14.	Determination of the	ne molar mass of acetic acid	d in benzene using freezir	g point depression is aff	fected by:		
			[J]	EE (MAIN)-2015 ON	LINE]		
	(1) association	(2) dissociation	(3) complex formation	on (4) partial ionizatio			
1.5	A 1.1: 4200C	. 1 61 5 1	Cl 12.5 1 C	4 1 1041	LS0108		
15.		is composed of 1.5 mol o					
	_	oure toluene at this temper					
	vapour pressure of	the solution and the benzer	_	_	-		
	(1) 20 0 40 10	590	_	EE (MAIN)-2015 ON	NLINE		
	(1) 38.0 torr and 0		(2) 30.5 torr and 0.				
	(3) 35.8 torr and 0	.400	(4) 35.0 torr and 0.	+0U	LS0109		
					100107		

nodeO6/B0B0-BA/Kota/JEE(Advanced)/Leader/Che/Sheet/Liquids/

ALLEN

16.		sure of acetone at 20°C is	_		
	in 100 g of acetor	ne at 20°C, its vapour pres	ssure was 183 torr. The r	nolar mass (g mol ⁻¹) o	f the substance
	is:			[JEE (N	MAIN)-2015]
	(1)128	(2) 488	(3) 32	(4) 64	
					LS0110
17.	-	ation of a salt MX ₂ at cer	tain temperature has a v		•
		this solution of the salt is:		[JEE (MAIN2016	-ONLINE]
	(1)0.50	(2) 0.80	(3) 0.67	(4) 0.33	7 00444
40		N	500 · · · · · · · · · · · · · · · · · ·	: 0.01 x 1 m 1	LS0111
18.		N_2 in water at 300 K and	500 torr partial pressure		
	1) at 750 torr par	rtial pressure is:		[JEE (MAIN2016	-ONLINE]
	(1) 0.02	$(2) \ 0.005$	(3) 0.015	(4) 0.0075	
					LS0112
19.	18 g glucose (C _e	$_{5}H_{12}O_{6}$) is added to 178.2	g at 100°C water. The v	apour pressure of wat	er (in torr) for
	this aqueous solu	ution is:		[JEE (MAIN	N)-2016]
	(1)759.0	(2) 7.6	(3) 76.0	(4) 752.4	
	(1)/03.0	(2) 7.0	(3) 70.0	(1) 702.1	LS0113
20.	The freezing point	nt of benzene decreases by	0.45°C when 0.2 g of a	cetic acid is added to 20	
		ociates to form a dimer in l	-		-
	be :-		,1		MAIN)-2017]
	(K _f for benzene	$= 5.12 \text{ K kg mol}^{-1}$			
	(1) 64.6%	(2) 80.4%	(3)74.6%	(4) 94.6%	
	_				LS0114
21.		vas dissolved in x g of H ₂	O. The change in freez	= =	
	- '	% ionised, the value of x		[JEE (MAIN2017	-ONLINE]
	•	1.86°C kg mol ⁻¹) is app	=		
		$S = 32 \text{ g mol}^{-1}$ and that		(4) 25 ~	
	(1) 45 g	(2) 65 g	(3) 15 g	(4) 25 g	LS0115
22.	A solution is pre	pared by mixing 8.5 g of	CH ₂ Cl ₂ and 11.95 g of 0	CHCl. If vanour press	
,		98 K are 415 and 200 n		_	
	-	mass of $Cl = 35.5$ g mo		[JEE (MAIN2017	-
	(1) 0.486	(2) 0.325	(3) 0.162	(4) 0.675	_
					LS0116
23.	For 1 molal aque	ous solution of the following	ng compounds, which or	ne will show the highest	freezing point
	?			[JEE (MAIN)	-2018]
	(1) $[Co(H_2O)_5C]$		$(2) \left[\text{Co(H}_2\text{O)}_4\text{C} \right]$		
	$(3) \left[\text{Co(H}_2\text{O)}_3\text{C} \right]$	l_3].3 H_2 O	$(4) \left[\text{Co(H}_2\text{O)}_6 \right] \text{C}$	Cl_3	
					LS0117

LS0149

				Liquiu soiuii	
24.			_	lyte non-volatile solute separa are M_X and M_Y , respective	=
	$M_X = \frac{3}{4} M_Y$. The re	elative lowering of vapou	r pressure of the solu	tion in X is "m" times that of the	ne solution
	in Y. Given that the "m" is -	e number of moles of sol	ute is very small in co	omparison to that of solvent, the [JEE (MAIN-2018-ONL)	
	$(1) \frac{3}{4}$	(2) $\frac{4}{3}$	(3) $\frac{1}{2}$	(4) $\frac{1}{4}$	
25.		-volatile, non-electrolyteduce its vapour pressur (2) 37.5 g		= 50 g mol ⁻¹) needed to be di [JEE (MAIN-2018-ONL) (4) 150 g	
26.	550 mm of Hg. At	the same temperature, if oution increases by 10 mr	ne more mole of n-he	of n-hexane and 3 moles of n- eptane is added to this solution, to vapour pressure in mm Hg of [JEE (MAIN-2020-C	the vapour n-heptane
					LS0146
27.	non-volatile solut	tes A, B and C. The relationship the order [Given, m	ative lowering of va	as a solvent and 10 g of pour pressure in the presence 100 g mol ⁻¹ ; B = 200 [JEE (MAIN-2020-C	e of these g mol ⁻¹ ;
	(1) A > B > C	(2) $A > C > B$	(3) $C > B >$	A (4) B > C > A	
28.	CaCl ₂ solution. The [Assume 100% io	he value of x is nisation of the complex a	and CaCl ₂ , coordina	lution is two times that of 0.051 [JEE (MAIN-2020-C) tion number of Cr as 6, and the	ONLINE]
	molecules are pres	sent inside the coordinati	ion spherej		LS0148
29.	1	f water in equilibrium w ded to the beaker of wa		n a sealed container. When a f ch water molecules:	
	(1) leaves the vap			[JEE (MAIN-2020-O	NLINE]
	(2) leaves the solu				-
	(3) leaves the solu				

(4) leaves the vapour decreases

30. If 250 cm³ of an aqueous solution containing 0.73 g of a protein A is isotonic with one litre of another aqueous solution containing 1.65 g of a protein B, at 298 K, the ratio of the molecular mases of A and B is _______ × 10⁻² (to the nearest integer). [JEE (MAIN-2020-ONLINE]

LS0150

31. Henry's constant (in kbar) for four gases α , β , γ and δ in water at 298 K is given below:

(density of water = 10^3 kg m⁻³ at 298 K)

[JEE (MAIN-2020-ONLINE]

This table implies that:

- (1) The pressure of a 55.5 molal solution of γ is 1 bar
- (2) The pressure of a 55.5 molal solution of δ is 250 bar
- (3) Solubility of γ at 308 K is lower than at 298 K
- (4) α has the highest solubility in water at a given pressure

LS0151

32. The osmotic pressure of a solution of NaCl is 0.10 atm and that of a glucose solution is 0.20 atm. The osmotic pressure of a solution formed by mixing 1 L of the sodium chloride solution with 2 L of the glucose solution is $x \times 10^{-3}$ atm. x is _____. (nearest integer) :- [JEE (MAIN-2020-ONLINE]

EXERCISE # (J-ADVANCED)

1.	For a dilute solution containing 2.5 g of a non-volatile non-electrolyte solute in 100 g of water	r, 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-(take $K_b = 0.76 \text{ K kg mol}^{-1}$)	[JEE 2011]

- (A) 724
- (B) 740
- (C) 736
- (D) 718

LS0137

2. The freezing point (in °C) of a solution containing 0.1 g of K₃[Fe(CN)₆] (Mol. Wt. 329) in 100 g of water $(K_f = 1.86 \text{ K kg mol}^{-1})$ is -[JEE 2011]

 $(A) - 2.3 \times 10^{-2}$

(B) -5.7×10^{-2}

 $(C) - 5.7 \times 10^{-3}$

(D) -1.2×10^{-2}

LS0136

3. 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 (take $K_b = 0.76 \text{ K kg mol}^{-1}$)

[JEE 2012]

- (A) 724
- (B) 740
- (C) 736
- (D) 718

LS0137

4. Benzene and naphthalene form an ideal solution at room temperature. For this process, the true statement(s) is(are) [J-Adv. 2013]

- (A) ΔG is positive
- (B) ΔS_{system} is positive (C) $\Delta S_{\text{surroundings}} = 0$.
- (D) $\Delta H = 0$

LS0138

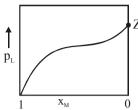
5. If the freezing point of a 0.01 molal aqueous solution of a cobalt (III) chloride-ammonia complex (which behaves as a strong eletrolyte) is -0.0558° C, the number of chloride (s) in the coordination sphere of the complex is- $[K_f \text{ of water} = 1.86 \text{ K kg mol}^{-1}]$ [JEE-Adv. 2015]

LS0139

- **6.** Mixture(s) showing positive deviation from Raoult's law at 35°C is (are)
- [JEE-Adv. 2016]

- (A) carbon tetrachloride + methanol
- (B) carbon disulphide + acetone
- (C) benzene + toluene
- (D) phenol + aniline

7. For a solution formed by mixing liquids L and M, the vapour pressure of L plotted against the mole fraction of M in solution is shown in the following figure, Here x_L and x_M represent mole fractions of L and M, respectively, in the solution. the correct statement(s) applicable to this system is(are)

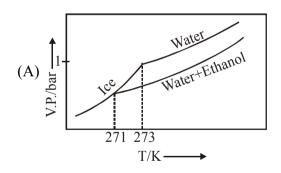


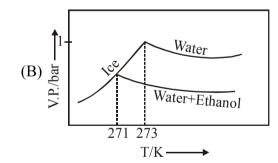
- (A) Attractive intramolecular interactions between L–L in pure liquid L and M–M in pure liquid M are stronger than those between L–M when mixed in solution [JEE-Adv. 2017]
- (B) The point Z represents vapour pressure of pure liquid M and Raoult's law is obeyed when $x_L \to 0$
- (C) The point Z represents vapour pressure of pure liquid L and Raoult's law is obeyed when $x_r \to 1$
- (D) The point Z represents vapour pressure of pure liquid M and Raoult's law is obeyed from $x_L = 0$ to $x_L = 1$

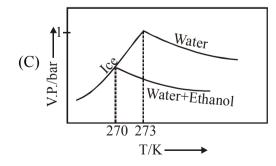
LS0141

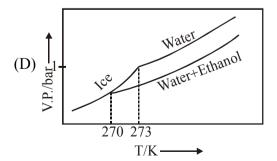
8. Pure water freezes at 273 K and 1 bar. The addition of 34.5 g of ethanol to 500 g of water changes the freezing point of the solution. Use the freezing point depression constant of water as 2 K kg mol⁻¹. The figures shown below represents plots of vapour pressure (V.P.) versus temperature (T). [Molecular weight of ethanol is 46 g mol⁻¹]

Among the following, the option representing change in the freezing point is - [JEE-Adv. 2017]





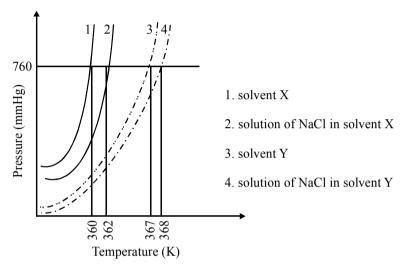




Liquids A and B form ideal solution over the entire range of composition. At temperature T, equimolar binary solution of liquids A and B has vapour pressure 45 Torr. At the same temperature, a new solution of A and B having mole fractions x_A and x_B, respectively, has vapour pressure of 22.5 Torr. The value of x_A/x_B in the new solution is _____. [JEE-Adv. 2018]
 (given that the vapour pressure of pure liquid A is 20 Torr at temperature T)

LS0143

10. The plot given below shows P–T curves (where P is the pressure and T is the temperature) for two solvents X and Y and isomolal solutions of NaCl in these solvents. NaCl completely dissociates in both the solvents.



On addition of equal number of moles a non-volatile solute S in equal amount (in kg) of these solvents, the elevation of boiling point of solvent X is three times that of solvent Y. Solute S is known to undergo dimerization in these solvents. If the degree of dimerization is 0.7 in solvent Y, the degree of dimerization in solvent X is ____. [JEE-Adv. 2018]

LS0144

11. Liquids **A** and **B** form ideal solution for all compositions of **A** and **B** at 25°C. Two such solutions with 0.25 and 0.50 mole fractions of A have the total vapor pressures of 0.3 and 0.4 bar, respectively. What is the vapor pressure of pure liquid **B** in bar?

[JEE-Adv. 2020] LS0153 **3.**

ANSWER KEY

EXERCISE # S-I

6.

- 1. Ans. 0.25
 - 2.

Ans. $P_A^0 = 100 \text{ cmHg}, P_B^0 = 60 \text{ cmHg}.$

- **5.** Ans. 0.5 bar
- **Ans.** $P_R^0 = 0.8$ bar, $P_S^0 = 0.4$ bar 7.
- 9. **Ans.0.04**
- Ans. 65.25 11.
- **13.** Ans.120 g/mol
- **15.** Ans.5.1 K-kg/mol
- **17.** Ans. 40 g/mol
- **19.** Ans. 3.69 atm
- 21. Ans. 3 ions
- 23. Ans. 7.482 ×105 Nm⁻²
- 25. Ans. 0.04

4. Ans. 0.25

Ans. $P_{x}^{0} = 55$ cmHg, $P_{y}^{0} = 80$ cmHg

Ans. 64.0 mm Hg

- 8. **Ans.0.25**
- 10. Ans.0.32 m
- Ans.17.38 mm Hg **12.**
- Ans. $K_b = 0.516$ kg mol K^{-1} , $T_b = 373.20$ K 14.
- **16.** Ans.2048 g/mol
- Ans. 49.26 atm 18.
- 20. Ans. Ans.1.96
- 22. Ans.78 %
- 24. Ans.0.95; 1.95
- **26.** Ans.(3)

EXERCISE # S-II

- Ans. 92 mol% toluene; 96.8 mol % toluene 1.
- 2. Ans. 0.741 m, 0.0136
- 4. Ans (68.4)
- 6. Ans. [Co(NH₂)₅Cl]Cl₂

- 38.71 g **3.** Ans.
- 5. $C_{40}H_{80}O_{40}$ Ans.
- 7. Ans. (6.972)

EXERCISE # O-I

- Ans.(B) 1.
- Ans.(C) 2.
- 3. Ans.(C)
- 4. Ans.(D)

- 5. Ans.(A)
- 6. Ans.(C)
- 7. Ans.(C)
- 8. Ans.(C)

- 9. Ans.(D)
- **10.** Ans.(C)
- Ans.(C) 11.
- **12.** Ans.(A)

- 13. Ans.(A)
- 14. Ans.(B)
- **15.** Ans.(B)

- **17.** Ans.(C)
- **18.** Ans.(D)

Ans.(B)

Ans.(D)

16. Ans.(B)

- Ans.(C)
- 22. Ans.(B)
- 23. Ans.(D)

19.

31.

20. Ans.(A)

Ans.(B)

Ans.(B)

24.

32.

- 21.

26.

- 27. Ans.(B)
- 28. Ans.(D)

- 25. Ans.(B) 29.
- **30.** Ans.(B)

Ans.(D)

Ans.(B)

Ans.(B)

33.

- **34.** Ans.(B)
- **35.** Ans.(A)
- **36.** Ans.D)

EXERCISE # O-II

- 1. Ans.(B)
- 2. Ans.(D)
- 3. Ans.(A)
- 4. Ans.(B)

- 5. Ans.(D)
- **6. Ans.**(**C**)
- 7. Ans.(A, B, C, D) 8.
- 8. Ans.(C, D)

- 9. **Ans.**(C)
- 10. Ans.(A) \rightarrow P; (B) \rightarrow Q, R, S; (C) \rightarrow T; (D) \rightarrow P, Q, R, S, T

EXERCISE # (J-MAIN)

- $1. \quad Ans.(3)$
- 2. Ans.(3)
- $3. \quad Ans.(3)$
- 4. Ans.(1)

- 5. Ans.(1)
- 6. Ans.(3)
- 7. Ans.(3)
- 8. Ans.(1)

- 9. Ans.(4)
- 10. Ans.(1)
- 11. Ans.(4)
- 12. Ans.(2)

- 13. Ans.(3)
- 14. Ans.(1)
- 15. Ans.(1)
- 16. Ans. (4)

- 17. Ans. (1)
- 18. Ans. (3)
- 19. Ans. (4)
- 20. Ans.(4)

- 21. Ans.(1)
- 22. Ans.(2)
- 23. Ans.(3)
- 24. Ans.(1)

- 25. Ans.(4)
- 26. Ans.(600)
- 27. Ans. (1)
- 28. Ans.(5.00)

- 29. Ans.(1)
- 30. Ans.(177)
- 31. Ans.(2)
- 32. Ans.(167)
- EXERCISE # (J-ADVANCED)
- $1 \quad Ans.(A)$
- 2. **Ans.(A)**
- 3. **Ans.(A)**
- 4. Ans.(B,C,D)

- 5. Ans.(1)
- 6. Ans.(A, B)
- 7. Ans.(A,C)
- 8. Ans.(D)

- 9. Ans.(19)
- 10. Ans.(0.05)
- 11. Ans.(0.20)

JEE-Chemistry ALLEN

Important Notes