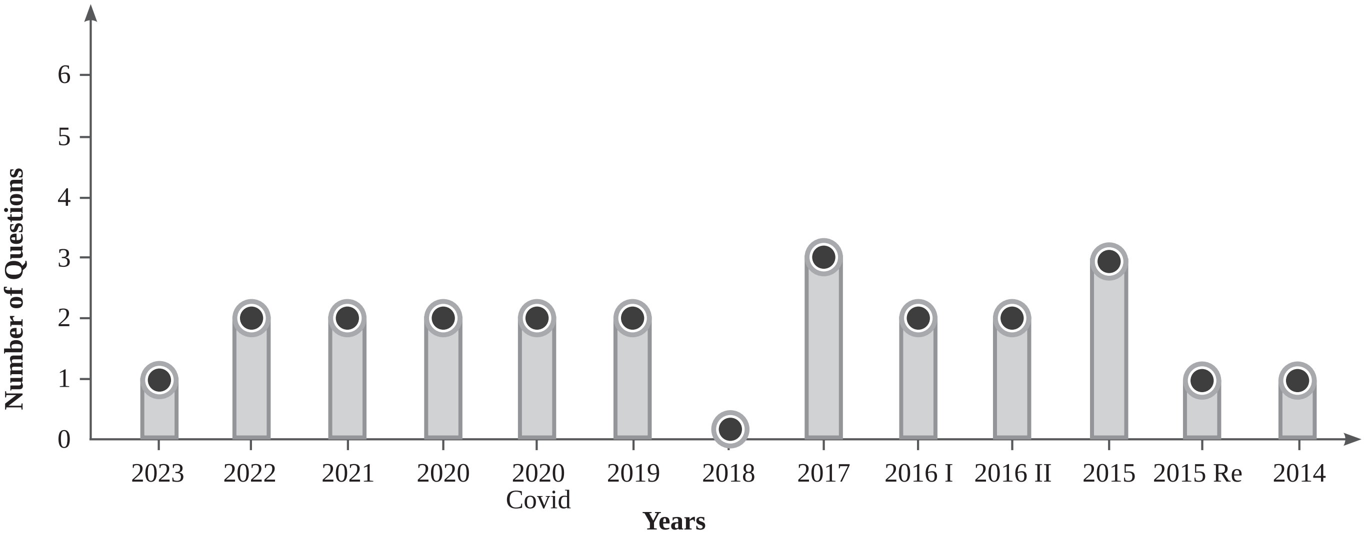
CHAPTER

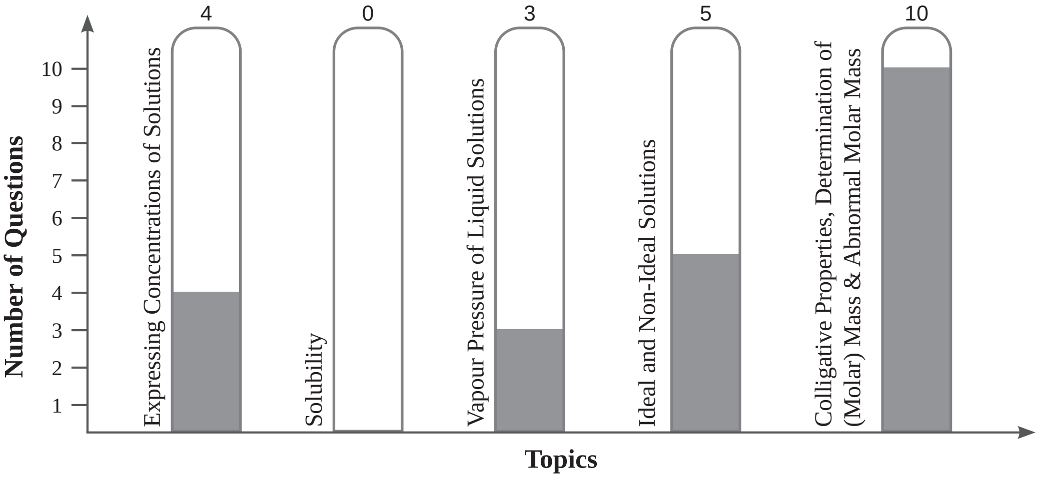
1

Solutions

Year Wise Number of Questions Analysis (2023-2014)

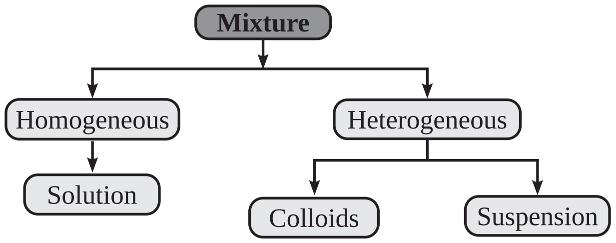


Topicwise Number of Questions Analysis (2023-2014)



SOLUTION

A homogeneous mixture of two or more substances which are chemically non-reacting.



Characteristics of Solution

(*i*) It is homogeneous in nature, yet retaining the properties of its constituents.

(*ii*) It is made of two parts i.e., solute and solvent.
Which component to take as solute and which component to take as solvent depends on physical state of the components.

(*iii*) The component which has the same physical state in pure form as the solution is called solvent and the other is called solute. Example, in case of solution of sugar and water, sugar is the solute and water is solvent.

(*iv*) If both the components have same state as the solution, the one component which is in excess is called solvent and the other is called solute. Example, alcohol in water, benzene in toluene etc.

Solvent

- Generally, component that is present in the largest quantity (by mole).
- Determines the physical state in which solution exists.

Solute

- Components present in the solution other than solvent.

TYPES OF SOLUTIONS

Solutions may be classified as:

Table: Types of Solutions

Types of Solutions		
Classification based on number of components		
Binary	Ternary	Quaternary
Classification based on concentration of solute		
Dilute		Concentrated
Classification of solution based on physical state of solute and solvent		
Gaseous solutions	Liquid solutions	Solid solutions

1. Based on the number of components present, solutions may be classified into different types

Table: Classification of solution based on number of components present

Solution Type	Number of Components	Example
Binary	Two (1 solute + 1 solvent)	Salt dissolved in water
Ternary	Three (2 solute + 1 solvent)	Salt and Sugar both dissolved in water
Quaternary	Four (3 solute + 1 solvent)	Salt, Sugar and Copper sulphate dissolved in water

2. Based on physical state of solute and solvent, solutions may be classified into different types

Table: Classification of solution based on physical state of solute and solvent

Types of Solutions	Solute	Solvent	Some Common Examples
Gaseous Solutions	Gas	Gas	Mixture of non-reacting gases
	Liquid	Gas	Chloroform mixed with $N_2(g)$
	Solid	Gas	Camphor in $N_2(g)$
Liquid Solutions	Gas	Liquid	Ammonia dissolved in water
	Liquid	Liquid	Ethanol dissolved in water
	Solid	Liquid	Salt dissolved in water
Solid Solutions	Gas	Solid	Solution of hydrogen in platinum
	Liquid	Solid	Amalgams
	Solid	Solid	Steel

EXPRESSING CONCENTRATION OF SOLUTIONS

There are several ways by which we can describe the concentration of the solution quantitatively.

Percent by Weight (%w/w)

Amount of solute (g) dissolved per 100 g of solution.

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

For example, if a solution of HCl contains 36 % (w/w) HCl by weight, it has 36 g of HCl in 100 g of solution.

Percent by Volume (%V/V)

Amount of solute (mL) dissolved per 100 mL of solution.

$$\%\text{ by volume} = \frac{\text{volume of solute (mL)}}{\text{volume of solution (mL)}} \times 100$$

For example, if we have 35% (V/V) C_2H_5OH solution by volume means 35 mL C_2H_5OH is present per 100 ml of the solution.

Percent by Weight/Volume (%w/V)

Amount of solute (g) dissolved per 100 mL of solution.

$$\%\frac{\text{w}}{\text{V}} = \frac{\text{weight of solute (gm)}}{\text{volume of solution (mL)}} \times 100$$

i.e., 30% HCl solution, means 30 g of HCl is present per 100 mL (w/V) of solution

Mole Fraction (χ)

- A binary solution is made of two substances; one is the solute and the other is solvent. Mole fraction, χ, of solute is defined as the ratio of the number of moles of solute and the total number of moles of solute and solvent. Thus,

$$\chi_{\text{solute}} = \frac{\text{moles of solute}}{(\text{moles of solute} + \text{moles of solvent})}$$

If n represents moles of solute and N number of moles of solvent,

$$\chi_{\text{solute}} = \frac{n}{n+N}$$

Notice that mole fraction of solvent would be

$$\chi_{\text{solvent}} = \frac{N}{n+N}$$

Mole fraction is unitless and $(\chi_{\text{solute}} + \chi_{\text{solvent}}) = 1$

Molarity (M)

- In current practice, concentration is most often expressed as molarity. Molarity is defined as the number of moles of solute per litre of solution.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in litres}}$$

$$\text{or } M = \frac{w/M'}{V/1000} = \frac{w \times 1000}{M'V}$$

w = Mass of solute in grams
M´ = Molecular weight of solute in gm/mol.
V = Volume of solution in mL.

- Its unit is mol/L.

Key Note

When a solution is diluted then $M_1V_1 = M_2V_2$

Molality (m)

- Molality of a solution is defined as the number of moles of solute per kilogram of solvent.

$$\text{Molality} = \frac{\text{moles of solute}}{\text{mass of solvent in kilograms}}$$

$$\text{or } M = \frac{\frac{w}{M}}{\frac{W}{1000}} = \frac{w \times 1000}{MW}$$

where,
w = mass of solute in grams
M = molecular wt of solute in g/mol.
W = mass of solvent in gram.

Parts per Million (ppm)

Parts per million (ppm) is defined as the number of parts by mass of solute present in one million (10^6) parts by mass of the solution.

$$\text{ppm} = \frac{\text{Number of parts of the component}}{\text{Total number of parts of all components of the solution}} \times 10^6$$

Table: Difference between ppm and ppb

Parts per Million (ppm)	Part per Billion (ppb)
ppm is the number of parts of a solute in 10^6 parts of solution.	ppb is the number of parts of a solute in 10^9 parts of solution.
Concentration in ppm can also be expressed as w/w, v/v and w/v.	Concentration in ppb can also be expressed w/w, v/v and w/v

Normality (N)

It is a number of gram equivalents of solute dissolved per litre of solution.

Unit = gram equivalents/litre

Normality decreases as temperature increases.

$$N = \frac{\text{No. of gram equivalents of solute}}{\text{Volume of solution in litres}}$$

Number of gram equivalents

$$= \frac{\text{Weight of the substance in grams (w)}}{\text{Gram equivalent weight (EW)}}$$

$$N = \frac{W}{E.W} \times \frac{1}{V_{lits}}$$

$$N = \frac{W}{E.W} \times \frac{1000}{V_{ml}}; \; W = \frac{N \times E.W \times V}{1000}$$

Key Note

When a solution is diluted or two solutions of different substances react, then $V_1N_1 = V_1N_2$

Equivalent Weight (E)

It is the number of parts by weight of a substance that combine or displace 1.008 parts by weight of hydrogen or 35.5 parts by weight of chlorine or 8 parts by weight of oxygen.

It is represented by E.

It is a relative value, number units.

Equivalent weight expressed in grams in known as gram equivalent weight or gram equivalent.

Equivalent weight of acids

$$E_{acids} = \frac{M.Wt}{\text{Basicity}}$$

Basicity is the number replaceable hydrogen atoms by metal ions in a inoculate of an acid.

Equivalent weight of Base

$$E_{base} = \frac{M.Wt}{\text{Acidity}}$$

Acidity is the number of hydroxyl groups present in a molecule of the base.

Key Note

Relation between Molarity and Normality

Normality = n_{factor} × Molarity
Molecular Wt. = n_{factor} × Equivalent weight

Where n_{factor} = Valency (or) Basicity (or) Acidity (or) number of electrons transferred.

Formality (F)

This is the concentration unit for ionic compounds that dissolve in polar solvent to give pair of ions. This represents number of gram formula weight of the substance dissolved per litre of the solution. It is almost the same as molarity. It describes the solute that is mixed in a liquid rather than the solute present in solution after the dissolution process.

$$\text{Formality} = \frac{\text{Moles of substance added to solution}}{\text{Volume of solution (in litres)}}$$

Train Your Brain

Example 1: If we have 6% w/w urea solution with density 1.060 g/mL, then calculate its strength in g/L.

Sol. 6 g in 100 g solution.

$$6\,g \text{ in } \frac{100}{1.060}\text{mL} \Rightarrow \frac{100}{1.060}\text{mL} \rightarrow 6 \text{ g}$$

$$\therefore\ 1000\,\text{mL} = \frac{6}{100}\times 1.060\times 1000$$

$$= 10.6 \times 6 = 63.6 \text{ g/L}$$

Example 2: Calculate molality of 1.2 M H_2SO_4 solution if its ρ = 1.4 gm/mL.

Sol. $$\text{Molality} = \frac{(\text{molarity})\times 1000}{1000\times d - (\text{molarity})\times M_{\text{solute}}}$$

$$\text{Molality} = \frac{1.2\times 1000}{1000\times 1.4 - 1.2\times 98} = 0.935$$

Example 3: If we have 10 molal urea solution calculate mole fraction of urea in this solution and also calculate % w/w of urea.(MW = 60)

Sol. (*i*) 10 moles urea in 1000 gm of water

$$X_{\text{urea}} = \frac{10}{10+\frac{1000}{18}} = \frac{10}{65.55} = 0.152$$

(*ii*) % *w*/*w* weight of urea $= \frac{10\times 60}{10\times 60+1000}\times 100$

$$= 37.5\%$$

Concept Application

1. One litre of sea water weighs 1030 g and contains about 6×10^{-3}g of dissolved O_2. Calculate the concentration of dissolved oxygen in ppm.
2. The density of a 3M sodium thiosulphate solution ($Na_2S_2O_3$) is 1.25 g/mL. Calculate
   - (*a*) The percentage by mass of sodium thiosulphate.
   - (*b*) The mole fraction of sodium thiosulphate and
   - (*c*) Molalities of Na^+ and $S_2O_3^{2-}$ ions.

SOLUBILITY

Solubility of Solid in Liquid

The amount of solute that is dissolved in specified amount of solvent (generally 100 g) to form a saturated solution at a given temperature is known as the solubility of solute.

$$\text{Solute (s)} + \text{Solvent (l)} \rightleftharpoons \text{Solution(aq)};\ \Delta_{\text{sol}}H$$

Effect of nature of solvent and solute

The solubility of a solute in a solvent depends on the nature of both the solute and the solvent. A polar compound dissolves in a polar solvent. E.g., common salt dissolves in water. A polar compound is less soluble (or insoluble) in a non-polar solvent.

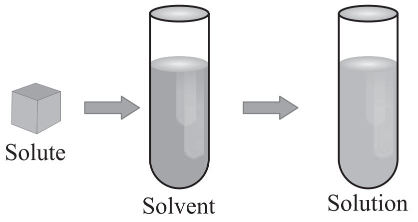
Effect of Temperature

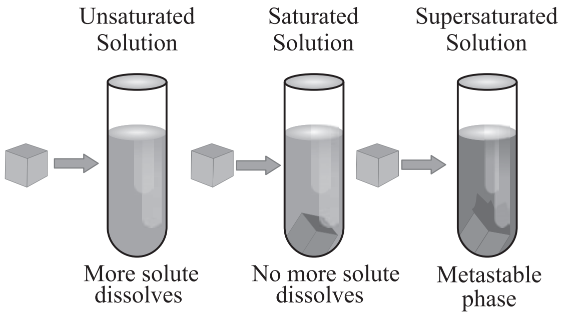
According to the Le Chatelier's principle:

- If the dissolution is endothermic ($\Delta_{\text{sol}}H > 0$) - Temperature ↑, solubility ↑.
- If the dissolution is exothermic ($\Delta_{\text{sol}}H < 0$) - Temperature ↑, solubility ↓.
- Generally the solubility of solid solute in liquid solvent increases with increase in temperature.

Effect of Pressure

- No significant effect on solubility of solids in liquids.
- Solids and liquids are highly incompressible and practically remain unaffected by changes in pressure.





Solubility of Gas in a Liquid

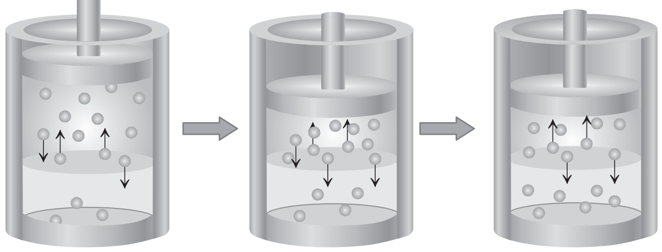
- **Effect of pressure on solubility of Gas in a liquid:**

  $$\text{Solute(g)} + \text{Solvent(l)} \rightleftharpoons \text{Solution(aq)}$$

  On increasing the pressure on a gas-liquid mixture at equilibrium

  (*i*) The gas concentration over the solution increases.

  (*ii*) Thus, according to the Le-Chatelier's principle, reaction shifts forward to dissolve more gas, i.e., solubility increases



Le Chatelier's principle

Le Chatelier's principles, sometimes known as the equilibrium law, are used for predicting how changes in temperature or pressure will affect a system that is in chemical equilibrium.

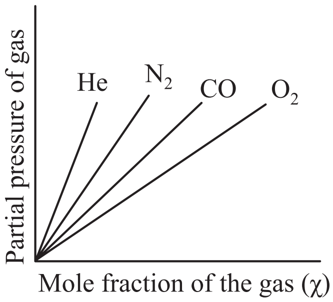
According to Le Chatelier's Principle, equilibrium changes the forward and backward reactions in order to accept the effect of a change that affects the equilibrium conditions.

Changes in concentration, pressure, temperature, and inert gases are examples of factors that may influence equilibrium and lead it to change in a way that cancels their effects.

- In exothermic equilibrium, an increase in temperature decreases product formation, and a decrease in temperature increases product formation.
- In endothermic reactions, an increase in temperature increases the product formation, and a decrease in temperature decreases the product formation.
- For example in general, if in a nearly saturated solution, the dissolution process is endothermic ($\Delta_{sol} H>0$), the solubility should be increased with rise in temperature and if it is exothermic ($\Delta_{sol} H<0$), the solubility should decrease.
- The solubility of a gas in solution decreases with increase in temperature.

HENRY'S LAW

- Solubility of a gas in a liquid solvent increases in direct proportion to the partial pressure of the gas above the solution. (i.e. P_{gas})
- Mathematically: $P_{gas} = K_H \chi_{gas}$
  (Here K_H, is the Henry's law constant, χ_{gas} = mole fraction of gas in solution phase)
  The slope of the line is the Henry's Law Constant, K_H.



Effect of Nature of Gas On Solubility of Gas in Liquid

At a constant temperature, $\chi \propto (1/K_H)$

Thus, a more soluble gas will have lesser value of K_H.

Gas	Temperature/K	K_H/k bar
He	293	144.97
N_2	293	76.48

Effect of nature of solvent on solubility of gas in liquid

Gases that are capable of forming ions in aqueous solution are more soluble in water than in other solvents. For example, HCl, NH_3.

Effect of Temperature On Solubility of Gas in Liquid

$T \uparrow \Rightarrow K_H \uparrow \Rightarrow$ solubility $\downarrow$

For eg. Solubility of O_2 is higher in water at lower T, so aquatic species are more comfortable in cold waters.

Gas	Temperature/K	K_H/k bar
O_2	293	34.86
O_2	303	46.82
N_2	293	76.48
N_2	303	88.84

Application of Henry's Law

- To increase the solubility of CO_2 in soft drinks.
- To avoid bends, the tanks used by scuba divers are filled with air diluted with helium.
- Low blood oxygen at high altitudes causes climbers to become weak and unable to think clearly, symptoms of a condition known as anoxia.

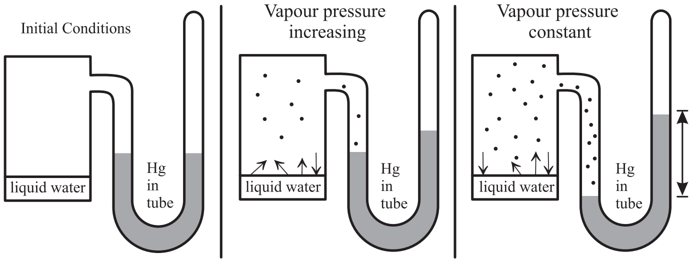
Limitations of Henry's Law

Henry's law is valid only for following conditions:

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

VAPOUR PRESSURE

- The vapour pressure of a liquid is the pressure exerted by its vapour over the liquid surface when the liquid and vapour are in dynamic equilibrium.
- $VP = K_p$ for $A_{(l)} \rightleftharpoons A_{(vap)}$. Thus, it depends only on temperature for a given liquid.



Definition of Boiling Point

The boiling point is the temperature at which the vapour pressure of a liquid becomes equal to the external pressure surrounding the liquid.

Volatile liquids have high Vapour Pressure and low Boiling Point.
Eg: - Ether, Methyl alcohol, acetone, benzene, Carbon tetrachloride, Carbon disulphide.

Less volatile liquids have low vapour pressure and .high boiling point.

Eg: - H_2O, Aniline, Nitrobenzene

Factors affecting vapour pressure

Nature of liquid:

One of the most significant factors affecting vapour pressure is the nature of liquid. Based on the intermolecular forces, the effect of the liquid's nature can be explained. With an increase in the force of the intermolecular interactions, the vapour pressure decreases. The liquid's vapour pressure increases as intermolecular forces become weaker. For instance, at a certain temperature, glycerol has a lower vapour pressure than isopentane. This is due to the fact that glycerol has stronger intermolecular forces throughout.

Boiling point of liquid:

The boiling point has a significant effect on the vapour pressure as well. Boiling point and vapour pressure have an inversely proportionate relationship. It means that if one liquid's boiling point is higher than another liquid's boiling point, the liquid with the higher boiling point will have a lower vapour pressure. When ether and ethyl alcohol's vapour pressures are compared, for instance, ether has a larger vapour pressure due to its lower boiling point.

Effect of temperature:

Vapour pressure is most significantly influenced by temperature. The kinetic energy of a liquid's molecules increases as it is heated to a high temperature. Higher kinetic energy molecules have a tendency to leave the liquid surface more quickly, which raises the vapour pressure because more molecules are vaporized. As a result, we can draw the conclusion that a liquid's vapour pressure is directly proportional to its temperature. To be precise, as the temperature increases, the vapour pressure increases as well, and vice versa.

Concentration of solute:

The vapour pressure of the liquid decreases when a solute is added to a solvent. When comparing the vapour pressure of a pure solvent and one with a solute added, the pure solvent will show a higher vapour pressure. Thus, it may be claimed that the concentration of solute added also influences a liquid's vapour pressure.

Vapour pressure of solid-liquid solutions

In a pure liquid, the entire surface is occupied by molecules of the liquid. In a solution, the surface has molecules of both, i.e., solute and solvent. Hence, the fraction of the surface covered by solvent molecules gets reduced. As a consequence, the number of solvent molecules escaping from the surface gets reduced. Thus, vapor pressure is reduced.

The decrease in vapor pressure of the solvent depends on the quantity of non-volatile solute present in the solution, irrespective of its nature.

Vapour Pressure of Liquid-Liquid Solution

Raoult's Law for volatile Solute

The partial pressure of a volatile component of a solution is directly proportional to its mole fraction in solution at any temperature.

$P_A \propto X_A$ and $P_B \propto X_B$ and

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

Where P_A = partial vapour pressure of component A,

P_A^0 = vapour pressure of component A in pure form,

X_A = mole fraction of component A in solution

$P_T = P_A + P_B = P_A^0.X_A + P_B^0.X_B$

$$\left.\begin{array}{l} P_A = \gamma_A\, P_T \\ P_B = \gamma_B\, P_T \end{array}\right\} \Rightarrow \frac{\gamma_A}{\gamma_B} = \frac{P_A}{P_B} = \frac{P_A^0 \cdot X_A}{P_B^0 \cdot X_B}$$

Where, γ_A and γ_B are the mole fraction of components A and B in vapour phase respectively.

Particle Concentration of Ions/Molecules of Solute in Solution

Molar concentration of solution × number of ions formed from one molecule of Solute

Eg: (1) In 0.01M Aqueous solution of $Al_2(SO_4)_3$

$\left[Al^{3+}\right] = 0.02; [SO_4^{2-}] = 0.03\ M$

Total particle concentration = 0.05M

Particle concentration of 0.01M glucose solution is 0.01M

Limitations of Raoult's Law

It is applicable for very dilute solutions only.

It is applicable for solutions containing solutes, which neither associate nor dissociate.

It is applicable for ideal solutions only (Solutions in which solute and solvent do not have Interaction).

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

When K_H equals p_1^0 in Henry's law, Raoult's law becomes a special instance of Henry's law.

According to Raoult's law

$p = p^0x$

Where p is the partial pressure, x is the mole fraction and p^0 is the vapour pressure of the pure component.

According to Henry's law:

$p = K_Hx$

Where p is the partial pressure, x is the mole fraction and K_H is the proportionality constant (Henry's constant).

We can see that the partial pressure of the volatile component or gas is directly proportional to its mole fraction in solution by comparing the above equations. As a result, where $K_H = p^0$, Raoult's law is a particular instance of Henry's law.

Train Your Brain

Example 4: Which of the following statement(s) is/are incorrect?

(1) In a nearly saturated solution, if the dissolution process is endothermic, then the solubility of solids in liquids should decrease with rise in temperature.

(2) In a nearly saturated solution, if the dissolution process is exothermic, then the solubility of solids in liquids should increase.

(3) Pressure has very little effect on the solubility of a solid in a liquid.

(4) Both (1) and (2)

Sol. In a nearly saturated solution, if the dissolution process is endothermic, then the solubility of solids in liquids should increase with rise in temperature and if the dissolution process is exothermic, then the solubility of solids in liquids should decrease.

Example 5: If two components A and B have $P_A^0 : P_B^0 = 1 : 2$ and have mole fraction in solution 1 : 2 then mole fraction of A in vapour is:

(1) 0.33 (2) 0.25

(3) 0.52 (4) 0.2

Sol. Mole fraction of component 'A' in vapour phase

$$= \frac{\text{Partial pressure of 'A'}}{\text{Total Vapour pressure}} = \frac{P_A}{P_A + P_B}$$

$$\text{but; } P_A = P_A^0 x_A$$

$$P_B = P_B^0 x_B = \frac{P_A^0 x_A}{P_A^0 x_A + P_B^0 x_B}$$

$$P_A^0 = 1,\ x_A = 1,\ \ P_B^0 = 2,\ x_B = 2$$

on substituting the values, we get

mole fraction of component 'A' in vapour phase

$$= \frac{1 \times 1}{1 \times 1 + 2 \times 2} = \frac{1}{1+4} = \frac{1}{5} = 0.2$$

Concept Application

3. Two liquids A and B have $P_A^0 : P_B^0 = 1:3$ at a certain temperature. If the mole fraction ratio of $X_A : X_B = 1:3$, the mole fraction of A in vapour at equilibrium with the solution at a given temperature is:

(1) 0.1 (2) 0.2

(3) 0.5 (4) 1.0

4. Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 25°C are 200 mmHg and 41.5 mmHg respectively. Vapour pressure of the solution obtained by mixing 25.5 g of $CHCl_3$ and 40 g of CH_2Cl_2 at the same temperature will be: (Molecular mass of $CHCl_3$ = 119.5 u and molecular mass of CH_2Cl_2 = 85 u)

(1) 173.9 mmHg (2) 615.0 mmHg

(3) 347.9 mmHg (4) 90.63 mmHg

5. Vapour pressure of methyl alcohol and ethyl alcohol solution is represented by $P = 115 X_A + 140$, X_A is the mole fraction of methyl alcohol.

The value of $\lim_{x_A \to 0} \frac{P_B^0}{x_B}$ is:

(1) 255 (2) 115

(3) 140 (4) 135

IDEAL AND NON-IDEAL SOLUTIONS

Ideal Solutions

1. The solution that obey Raoult's law at all temperatures and concentrations is known as ideal solution.
2. $\Delta H_{mix} = 0$ i.e., no heat is evolved or absorbed when components are mixed to form the solution.
3. $\Delta V_{mix} = 0$ i.e., no change in volume. In ideal solution the A - B intermolecular interactions are the same as A - A and B - B inter molecular interactions.

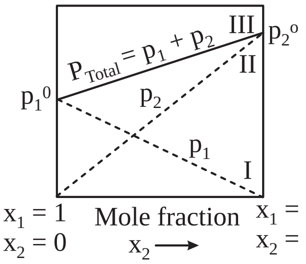


Fig.: The plot of vapour pressure and mole fraction of an ideal solution at constant temperature

In an ideal solution of two components A and B, all interactions, i.e., (A - A, B - B and A - B) must be identical.

Two liquids on mixing will form an ideal solution if the following conditions are satisfied:

(*i*) Both have similar structures.

(*ii*) Both have similar molecular sizes.

(*iii*) Both have identical intermolecular forces strictly there is no new attraction and repulsions upon mixing.

The following pairs almost behave as ideal solutions:

(*a*) Benzene and toluene

(*b*) Ethyl bromide and ethyl chloride

(*c*) n - Heptane and n - hexane

(*d*) Chlorobenzene and bromobenzene

(*e*) Ethyl iodide and ethyl bromide

Non-ideal Solutions

1. Solutions which do not obey Raoult's law over the entire range of concentration is known as non ideal solution
2. $\Delta H_{mix} \neq 0$
3. $\Delta V_{mix} \neq 0$

3D Model

Scan this QR code to understand Non-ideal solution through 3D model. To learn more download the Physics Wallah App.

Types of non ideal solutions

They are of two types

(I) Showing positive deviations from Raoult's law

For such solutions

(*a*) A - B inter - molecular interactions are weaker than either A - A or B - B intermolecular interactions.

(*b*) ΔH_{mix} is +ve and ΔV_{mix} is +ve

(*c*) $P_{total} > P_A^o.x_A + P_B^o.x_B$

$P_A > P_A^o X_A ; P_B > P_B^o \cdot X_B$

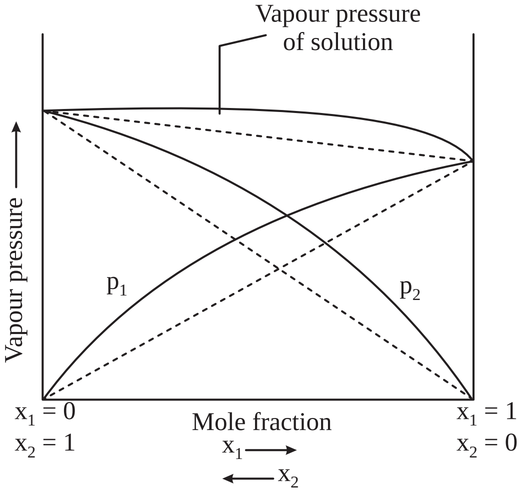


Fig.: A solution that shows +ve deviation from Raoult's Law

Examples:

(*i*) Carbon tetrachloride +benzene

(*ii*) Carbon tetrachloride + chloroform

(*iii*) Carbon tetrachloride + Toluene

(*iv*) Acetone + Carbon disulphide

(*v*) Acetone +Ethyl alcohol

(*vi*) Acetone + Benzene

(*vii*) Methyl alcohol + Water

(*viii*) Ethyl alcohol + Water

(II) Showing negative deviations from Raoult's law

For such solutions

(*a*) A-B intermolecular interactions are stronger than both A-A and B-B intermolecular interactions.

(*b*) ΔH_{mix} is –ve and ΔV_{mix} is –ve

(*c*) $P_{total} < P_A^o.x_A + P_B^o.x_B ; P_A < P_A^o \cdot X_A ; P_B < P_B^o \cdot X_B$

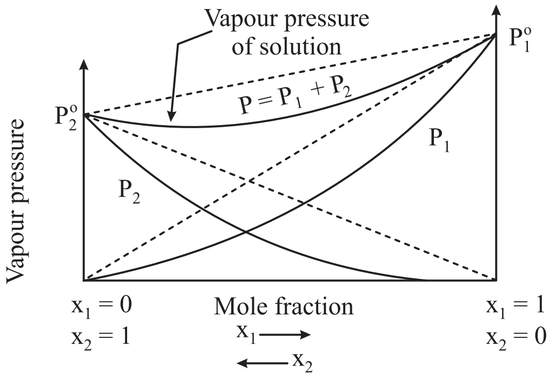


Fig.: A solution that show negative deviation from Raoult's Law

Examples:

(*i*) Chloroform + Acetone

(*ii*) Chloroform + Benzene

(*iii*) Chloroform + Diethyl ether

(*iv*) Acetone + Aniline

(*v*) HCl + Water

(*vi*) HNO_3 + Water

Azeotropic Mixture or Constant Boiling Mixture

Azeotropes are binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature. Non-ideal solutions form azeotropes.

There are two types of Azeotropes.

Maximum boiling Azeotrope

Non-ideal solutions showing –ve deviations from Raoult's law form maximum boiling azeotrope which boil at temperature greater than boiling points of its components.

For example, Water and HNO_3 (HNO_3 68% + H_2O 32%) constant boiling point 393.5K

Minimum boiling Azeotrope

Non ideal solutions showing large +ve deviations from Raoult's law form minimum boiling azeotrope which boil at temperature lower than boiling point of its components.

For example, Rectified spirit (ethanol 95.5% + H_2O 4.50%) constant boiling point 351.15K.

COLLIGATIVE PROPERTIES

The properties of dilute solutions that depend on the (relative) number of particles (ions or molecules) and not on the nature of particle of the solute dissolved in the solution are called **colligative properties**.

1. Relative Lowering of Vapour Pressure

Lowering of vapour pressure

When a non volatile solute is added to a solvent, the vapour pressure decreases.

In a solution, the surface is not only occupied by solvent molecules but also by solute molecules.

The number of molecules of solvent present on surface are relatively less in solution than that of pure solvent as some solvent molecules on the surface are displaced by solute molecules.

Raoult's law for non volatile solute

The relative lowering of vapour pressure of a dilute solution containing a non-volatile solute is equal to mole fraction of solute.

$$\frac{P^o - P}{P^o} = x_2 \qquad \frac{P^o - P}{P^o} = \frac{n_2}{n_1 + n_2}$$

For very dilute solutions

$$\frac{P^o - P}{P^o} = \frac{n_2}{n_1} \Rightarrow \frac{P^o - P}{P^o} = \frac{W_2 \times M_1}{M_2 \times W_1}$$

Where P^o = V.P of pure solvent

P = V.P of pure solution

W_1 = Wt. of solute

M_1 = M.Wt of solute

W_2 = Wt. of solvent

M_2 = M.Wt of solvent

Train Your Brain

Example 6: 12g of urea is dissolved in 1 L of water and 68.4 g of sucrose is separately dissolved in another 1 L of water. The lowering of vapour pressure of first solution is:

(1) Equal to second (2) Greater than second
(3) Less than second (4) Double that of second

Sol. No. of moles of urea = $\frac{12}{60} = 0.2\,\text{mol}$

No. of moles of sucrose = $\frac{68.4}{342} = 0.2\,\text{mol}$

Mole fraction of solute is same, therefore lowering of vapour pressure is same.

Example 7: The amount of solute (molar mass 60 g mol^{-1}) that must be added to 180 g of water so that the vapour pressure of water is lowered by 10% is:

(1) 30 g (2) 60 g
(3) 120 g (4) 12 g

Sol. If p° = 100 mm, $p_s = 100 - 10 = 90$ mm

$$\frac{p^\circ - p_s}{p^\circ} = \frac{w_2 / M_2}{w_1 / M_1} = \frac{w_2}{M_2} \times \frac{M_1}{w_1}$$

$$\frac{100-90}{100} = \frac{w_2}{60} \times \frac{18}{180}$$

$$\text{or} \quad w_2 = \frac{10}{100} \times 60 \times 10 = 60 \text{ g}$$

Example 8: 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?

Sol. $\frac{P_A^\circ - P_A}{P_A^0} = X_{\text{solute}} = \frac{n_B}{n_A + n_B}$

$$\frac{59.2 - 51.3}{59.2} = X_{\text{solute}} = \frac{7.9}{59.2} = 0.1334$$

$X_{\text{solvent}} = 0.8666$

$$\text{Molality (m)} = \frac{X_{\text{solute}} \times 1000}{X_{\text{solvent}} \times M_{\text{solvent}}}$$

$$= \frac{0.1334 \times 1000}{0.8666 \times 46} = 3.34 \text{ m}$$

Concept Application

6. Which of the following solutions have more relative lowering in vapour pressure at a certain temperature?
(1) 90 grams of glucose in 900 grams of H_2O
(2) 34.2 grams of sucrose in 450 grams of H_2O
(3) 20 grams of urea in 900 grams of H_2O
(4) 45 grams of glucose in 900 grams of H_2O

7. A solution is obtained by dissolving 0.2 moles of urea in a litre of water. Another solution is obtained by dissolving 0.4 moles of cane-sugar in a litre of water at the same temperature. The lowering of vapour pressure to the first solution is:
(1) Same as that of the second solution
(2) Half to that of the second solution
(3) Double to that of the second solution
(4) None of these

8. At a certain temperature, the vapour pressure of water is 90 mm. At the same temperature the vapour pressure of a solution containing a non-volatile solute is 81mm. The relative lowering of vapour pressure is:
(1) 9 (2) 0.9
(3) 10 (4) 0.1

2. Elevation in Boiling Point

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

The vapour pressure (P) of a dilute solution of the non-volatile solute is less than the vapour pressure of the pure solvent (P^o) in which the non-volatile solute is dissolved.

Boiling point of solution (T_b) is greater than the boiling point of solvent (T_b^o).

$(T_b - T_b^o) = \Delta T_b$, where ΔT_b is elevation of Boiling point.

For dilute solution, elevation of boiling point (ΔT_b) is directly proportional to the molal concentration of the solute in a solution.

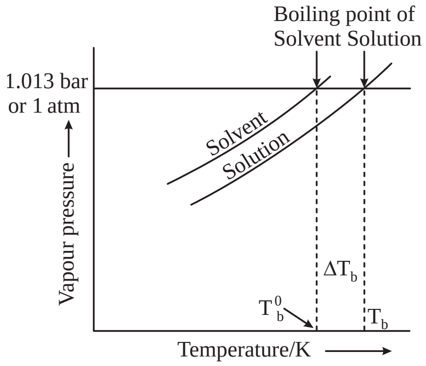


Fig.: The vapour pressure curve for solution lies below the curve for pure water

ΔT_b and K_b are related by the equation

$$\boxed{\Delta T_b = K_b \times m} \text{ or } \boxed{\Delta T_b = K_b \times \frac{w}{M} \times \frac{1000}{W}}$$

M → molar mass of solute
w → mass of solute
W → mass of solvent

Where, m is molality and K_b is molal elevation constant.

The elevation in boiling point observed in one molal solution of a non-volatile solute is called molal elevation constant (K_b) or Ebullioscopic constant.

$$K_b = \frac{RT_b^2}{1000L_{vap}} = \frac{MRT_b^2}{1000\Delta H^\circ_{vap}}$$

ΔH°_{vap} = standard enthalpy of vapourisation

The molal elevation constant of a solvent does not change with the change in the nature of solute dissolved in it.

Train Your Brain

Example 9: Estimate the boiling point of a solution (in C°) 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}).

Sol. Molar mass of urea, NH_2CONH_2

$= 2 \times 14 + 12 + 16 + 4 \times 1 = 60$ g/mol

Molar mass of Thiourea, NH_2CSNH_2

$= 2 \times 14 + 12 + 32 + 4 \times 1 = 76$ g/mol

Moles of urea

$$= \frac{\text{Mass of urea}}{\text{Molar mass of urea}} = \frac{25.0\text{g}}{60\text{g/mol}} = 0.42\text{mol}$$

$$\text{Moles of thiourea} = \frac{25.0}{76\text{ g/mol}} = 0.33\text{mol}$$

Moles of solute = 0.42 + 0.33 = 0.75

Molality,

$$m = \frac{\text{Moles of solute}}{\text{Mass of solvent in kg}} = \frac{0.75\text{mol}}{(500\,\text{g}/1000\,\text{g})\text{kg}} = 1.50\text{m}$$

$\Delta T_b = T_b - T_b^0 = K_b.m = 3.63 \text{ K m}^{-1} \times 1.50\text{m} = 5.445\text{K}$

$T_b = 5.445°\text{C} + T_b^0 = 5.445°\text{C} + 61.2°\text{C} = 66.645°\text{C}$

Example 10: The boiling point of $CHCl_3$ was raised by 0.323°C when 0.5143 g of anthracene was dissolved in 35 g $CHCl_3$. Calculate the molar weight of anthracene. K_b for $CHCI_3$ = 3.9 K mol^{-1} kg.

Sol. Given that, w = 0.5143 g, W = 35 g

$K_b = 3.9 \text{ K mol}^{-1}$ kg, $\Delta T_b = 0.323°\text{C}$

$$\because \ \Delta T_b = \frac{1000 K_b w}{MW}$$

$$\therefore \ 0.323 = \frac{1000 \times 3.9 \times 0.5143}{M \times 35}$$

M = 177.42 g/mol

Example 11: A solution containing 0.2563g of naphthalene (molecular mass = 128) in 50g of carbon tetrachloride yields a boiling point elevation of 0.201°C while a solution of 0.6216g of an unknown solute in the same mass of the solvent gives a boiling point elevation of 0.647°C. Find the molar mass of the unknown solute.

Sol. We know that

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

$$\text{For } CCl_4,\ K_b = \frac{0.201 \times 50 \times 128}{1000 \times 0.2563} = 5.019$$

$$\text{and } M = \frac{1000 \times K_b \times w}{\Delta T_b \times W}$$

$$= \frac{1000 \times 5.019 \times 0.6216}{0.647 \times 50} = 96.44 \text{ g/mol}$$

Concept Application

9. Calculate K_b of water if L_{vap} = 540 Cal/gm T_b = 100°C.

10. When 10g of a non-volatile solute is dissolved in 100g of benzene, it raises boiling point by 1°C then molecular mass of the solute is (K_b for benzene = 2.53 Km^{-1}):

(1) 223 g (2) 233 g

(3) 243 g (4) 253 g

11. The rise in the boiling point of a solution containing 1.8g of glucose in 100g of solvent is 0.1°C. The molal elevation constant of the liquid is:

(1) 0.01°C/m (2) 0.1°C/m

(3) 1°C/m (4) 10°C/m

3. Depression of Freezing Point

Freezing point is the temperature at which the vapour pressure of the substance in its liquid phase becomes equal to its vapour pressure in the solid phase. At this temperature, solid and liquid will be in equilibrium.

When a non-volatile solute is dissolved in a solvent, the freezing point decreases.

For dilute solutions, the curves are considered almost linear.

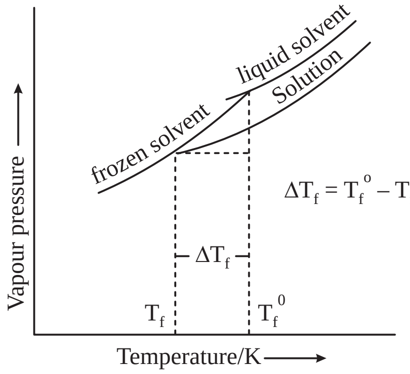


Fig.: Diagram showing ΔT_f depression of the freezing point of a solvent in a solution

ΔT_f and K_f are related by the equation

$$\boxed{\Delta T_f = K_f \times m} \text{ or } \boxed{\Delta T_f = K_f \times \frac{w}{M} \times \frac{1000}{W}}$$

$$\text{or } \boxed{K_f = \frac{MRT_f^2}{1000(\Delta H^o_{fus})}} \quad K_f = \frac{R(T_f^o)^2}{1000\, l_{fus}}$$

ΔH^o_{fus} = standard enthalpy of fusion.

The depression of freezing point observed in 1 molal solution of a non volatile solute is known as K_f.

K_f depends on chemical nature of solvent but not solute in the solution.

Rast method is used for measuring depression in freezing point.

Key Note

- Colligative property $\propto \dfrac{1}{\text{Molar mass of solute}}$

Train Your Brain

Example 12: 1kg of an aqueous solution of Sucrose is cooled and maintained at –4°C. How much ice will be separated out if the molality of the solution is 0.75? K_f (H_2O) = 1.86 Kg $mol^{-1}K$.

Sol. Molar mass of sucrose ($C_{12}H_{22}O_{11}$) = M = 342 gm mol^{-1}

Molality of the solution = 0.75 m

= 0.75 mol kg^{-1} solvent

= 0.75 × 342 gm Sucrose per kg solvent

= 256.5 gm Sucrose per kg solvent

hence, weight of 1 molal solution = 1000 + 256.5 = 1256.5 gm

Sucrose present in 1 kg solution $= \dfrac{256.5}{1256.5} \times 1000$ = 204.14 gm

Weight of solvent (H_2O) present in 1 kg solution = 1000 – 204.14 = 795.86 gm

Since depression in freezing point

$$\Delta T_f = K_f \times \frac{w}{M} \times \frac{1000}{W},$$

Where W = weight of solvent

w = weight of the solute

$$4 = 1.86 \times \frac{204.14}{342} \times \frac{1000}{W}$$

$\therefore$ W = 277.55 gm

i.e., weight of solvent required to maintain this solution at – 4°C is

W = 277.55

Hence rest weight of H_2O will convert into ice.

Hence amount of ice formed = 795.86 – 277.55 = 518.31 gm

Example 13: What is the percent by mass of iodine needed to reduce the freezing point of benzene to 3.5°C? The freezing point and cryoscopic constant of pure benzene are 5.5°C and 5.12 K/m respectively.

Sol. $\Delta T_f = T_f^0 - T_f = K_f.m$

5.5°C – 3.5°C = 5.12 K/m × m

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

$\therefore$ Mass of iodine needed for 1000g of benzene

= m × molar mass of iodine I_2

= 0.39 mol/kg × 254 g/mol = 99.06 g/kg

$\therefore$ 1000g + 99.06g solution contains 99.06g I_2

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

Example 14: Calculate the freezing point of a solution of a non-volatile solute in an unknown solvent of molar mass 30 g/mol having mole fraction of solvent equal to 0.8. Given that latent heat of fusion of solid solvent = 2.7 kcal mol^{-1}, freezing point of solvent = 27°C and R = 2cal mol^{-1} K^{-1}.

Sol. $\because\ K_f = \dfrac{MRT_f^2}{1000\,\Delta H_f} = \dfrac{30 \times 2 \times 300 \times 300}{1000 \times 2700}$

$= 2.00 \text{ K kg mol}^{-1}$

mole fraction of water = 0.8

$\therefore$ mole fraction of solute = 0.2

or $0.2 = \dfrac{n}{n+N}$ and $0.8 = \dfrac{N}{n+N}$

$$\therefore\ \frac{n}{N} = \frac{0.2}{0.8} = \frac{1}{4} = \frac{wM}{mW}$$

$$\text{or}\ \frac{1}{4} = \frac{w \times 30}{mW} \qquad \therefore\ \frac{w}{mW} = \frac{1}{4 \times 30}$$

$$\therefore\ \Delta T_f = \frac{1000 \times w \times K_f}{m \times W} = \frac{1000 \times 2.0}{4 \times 30} = 16.67$$

F.P of solution = 27 – 16.67 = 10.33°C

Concept Application

12. What weight of glycerol would have to be added in 1000 g of water in order to lower its freezing point by 10°C? K_f for water is 1.86 K mol^{-1} kg.

13. How much ethyl alcohol must be added to 1.00 litre of water so that the solution will freeze at 14°F? (K_f for water = 1.86°C/mol)

4. Osmosis

The spontaneous flow of the solvent through semipermeable membrane from pure solvent to solution (or) from a dilute solution to concentrated solution is known as **osmosis**.

The membrane which allow to pass only solvent molecules through it but not solute molecules is called semipermeable membrane.

3D Model

Scan this QR code to understand Osmotic Pressure through 3D model. To learn more download the Physics Wallah App.

Osmotic pressure (π)

The minimum pressure required to be applied on the solution to prevent the inflow of solvent into the solution, when the solution is separated from the pure solvent by a semipermeable membrane.

Van't Hoff's theory of dilute solutions

According to van't Hoff's, dilute solutions behave as ideal gases. Hence the laws that are applicable to ideal gases are also applicable to dilute solutions.

Van't Hoff's Boyle's law

At constant temperature, the osmotic pressure (π) of a dilute solution is directly proportional to its concentration (C).

$$\pi \propto C \quad (C = \text{mole / litre})$$

$$\pi \propto \frac{1}{V} \quad \left(\because C \propto \frac{1}{V}\right)$$

$$\pi V = K \ \ (\text{constant}) \qquad ...(i)$$

Van't Hoff's Charle's law

The osmotic pressure (π) of a solution of constant concentration (C) is directly proportional to the temperature in Kelvin Scale (T)

$$\pi \propto T$$

$$\pi = KT \qquad ...(ii)$$

from (*i*) and (*ii*) $\pi \propto \frac{T}{V}$

$$\pi = S\frac{T}{V}$$

$$\therefore \pi = CST \qquad \left[\because \frac{1}{V} = C\right]$$

here S = solution constant

The value of 'S' is nearly equal to the value of 'R' (gas constant)

Hence, $\pi V = RT$ for 1 mole

for 'n' mole $\boxed{\pi V = nRT}$

If 'w' is weight of the solute and 'M' is its molecular weight then

$$n = \frac{w}{M}$$

for 'n' moles $\pi V = \frac{w}{M} RT$

$$\boxed{(a)\ M = \frac{wRT}{\pi V} \qquad (b)\ M = \frac{wRTC}{\pi}}$$

Biological significance of osmotic pressure

Osmotic pressure can be utilized to determine molar masses of solutes. This method has advantages over other methods because pressure measurement is around the room temperature and molarity is used instead of molality. Compared to other colligative properties, its magnitude is large even for very dilute solutions. This method of determining molar mass of solutes is especially useful for biomolecules because biomolecules are not stable at higher temperatures and polymers have poor solubility.

Isotonic Solutions

At a given temperature, solutions of same osmotic pressure are called isotonic solutions.

eg: Blood is isotonic with saline (0.9% w/v NaCl solution)

Consider two solutions I and II having n_1 and n_2 moles of the solute in V_1 and V_2 litres of the solution respectively. Let P_1 and P_2 be their osmotic pressures at the same temperature (T)

If $P_1 = P_2$ i.e., isotonic solutions

then $\frac{n_1}{V_1} = \frac{n_2}{V_2}$

$$\boxed{\frac{W_1}{M_1V_1} = \frac{W_2}{M_2V_2}}$$

Hypotonic solutions:

Solutions having lower osmotic pressure

Hypertonic Solutions:

Solutions having higher osmotic pressure

Plasmolysis:

The flow of the liquid from the plant cell when placed in a hypertonic solution is called **plasmolysis**. The plant cell undergoes shrinkage. It is an example to **exo-osmosis.**

Haemolysis:

When a plant cell is placed in hypotonic solution then the solvent flows into plant cell. This is known as **Haemolysis**. The plant cell finally bursts. It is an example to **endo-osmosis**.

Reverse Osmosis and Water Purification

When a pressure greater than that of osmotic pressure is applied on solution side, then the solvent from the solution flows into pure solvent and this process is called **reverse osmosis**.

3D Model

Scan this QR code to understand Reverse Osmosis through 3D model. To learn more download the Physics Wallah App.

It is used in desalination or purification of sea water.

One of the most significant water purification technologies is RO. By pumping water under pressure across a semipermeable membrane, pollutants that are present in the water are removed. So pure water that is safe for drinking is squeezed out. Seawater desalination involves the use of RO. A reliable source of potable water is RO.

Train Your Brain

Example 15: The relationship between osmotic pressure at 273 K when 10 g glucose (P_1) 10 g urea (P_2) and 10 g sucrose (P_3) are dissolved in 250 mL of water is:

(1) $P_1 > P_2 > P_3$

(2) $P_3 > P_1 > P_2$

(3) $P_2 > P_1 > P_3$

(4) $P_2 > P_3 > P_1$

Sol. $\pi = CRT = \frac{m \times RT}{M.Wt \times V}$

Osmotic pressure is directly proportional to concentration and inversely proportional to molecular weight.

Example 16: At 27°C, 36 g of glucose per litre has an osmotic pressure of 4.92 atm. If the osmotic pressure of solution is 1.5 atm at the same temperature, what should be its concentration?

Sol. Given that, $\pi_1 = 4.92$ atm, $\pi_2 = 1.5$ atm

$$C_1 = \frac{36}{180 \times 1}\ \text{g / L} \qquad \left(\because C = \frac{w}{M \times V}\right),\ C_2 = ?$$

$$\pi_1 V_1 = n_1 S T_1$$

$$\pi_2 V_2 = n_2 S T_2$$

At same temperature,

$$\frac{\pi_1}{\pi_2} = \frac{n_1}{V_1} \times \frac{V_2}{n_2} = \frac{C_1}{C_2}$$

$$\therefore\ \frac{4.92}{1.5} = \frac{36}{180 \times C_2}$$

$$\therefore\ C_2 = 0.061\ \text{mol/L} = 0.061\ \text{M}$$

Example 17: At 25°C, a solution containing 0.2 g of polyisobutylene in 100 mL of benzene developed a rise of 2.4 mm at osmotic equilibrium. Calculate the molecular weight of polyisobutylene if the density of solution is 0.88 g/mL.

Sol. Height developed = 2.4mm

$$\text{Osmotic pressure} = \text{h.d.g} = \frac{2.4}{10} \times 0.88 \times 981$$

$$= 207.187\ \text{dyne cm}^{-2}$$

Now $\pi V = nST$

$$207.187 \times 100 = \frac{0.2}{M} \times 8.314 \times 10^7 \times 298$$

(R in erg; V in mL, using CGS system)

$M = 2.39 \times 10^5$ g/mol

Concept Application

14. At 300 K, two solution of glucose in water of concentration 0.01M and 0.001 M are separated by semipermeable membrane with respect to water. On which solution, the pressure needs to be applied to prevent osmosis? Calculate the magnitude of this applied pressure.

15. A 5% solution (wt./vol.) of cane-sugar is isotonic with 0.877% (wt./vol.) of urea solution. Find M. Wt. of urea, if M. Wt. of sugar is 342.

ABNORMAL MOLAR MASS

Colligative properties are shown by dilute solutions.

Electrolytes undergo ionisation in aqueous solutions, and as a result, the number of particles in the solution increases, thus the magnitude of colligative properties increases.

Colligative property and molar mass of solute are inversely proportional to each other. So the molar mass of electrolytic solutes determined experimentally is less than the true value.

Association and Dissociation of Solute Particles

Association of Solute Particles

Some solute molecules start to associate inside the solution. This means now there are less number of solute particles in the solution. As colligative properties vary with solute particles in the solution, they will decrease along with the solute particles. As colligative properties are inversely proportional to the molecular mass of solute, we get a higher molar mass of the solute. For Example, ethanoic acid or acetic acid (CH_3COOH) associate in solution to form a dimer due to hydrogen bonding.

3D Model

Scan this QR code to understand Association and Dissociation of solute particles through 3D model. To learn more download the Physics Wallah App.

Dissociation of Solute Particles

Some solute molecules, generally electrolytes dissociate into two or more ions/particles when dissolved in a solution. This leads to increase in solute particles in the solution, thereby increase in colligative properties of solutions. As colligative properties and molecular mass of solute varies inversely, we get a lower molar mass of the solute.

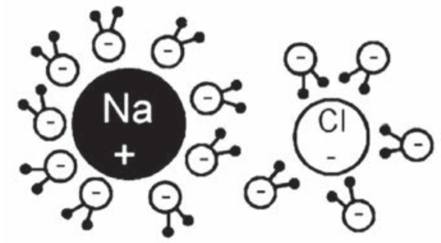


Fig. 1: NaCl dissociate into two ions when dissolved in water

Such a molar mass, whose value is higher or lower than its expected value is known as Abnormal Molar Mass. For Example, weak electrolytes dissociate in water to form ions, example Hydrofluoric Acid (HF), dissociate into hydrogen cation and fluorine anion.

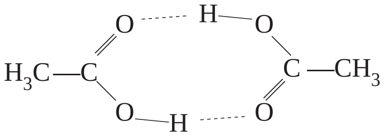


Fig. 2: Ethanoic Acid dimerise due to hydrogen bonding

Van't Hoff Factor (i)

Van't Hoff introduced a factor '*i*' in the equations to equalise the experimental value and calculated value.

$$i = \frac{\text{Experimental value of colligative property}}{\text{Calculated value of colligative property}}$$

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

Van't Hoff factor and degree of dissociation

For solutes which undergo dissociation: Let a solute on ionisation gives 'n' ions (particles) and 'α' is degree of ionisation at the given concentration, we will have $[1 + (n - 1)\alpha]$ particles (ions) after ionisation.

$$\begin{array}{lll} A_n & \leftrightarrow & nA \\ 1 & & 0 \\ 1-\alpha & & n\alpha \end{array}$$

$$i = \frac{\text{no.of particles after dissociation}}{\text{no.of particles before dissociation}}$$

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

'α is degree of dissociation or ionisation.

Salt	Van't Hoff Factor i for complete dissociation of solute
NaCl	2.0
KCl	2.0
$MgSO_4$	2.0
K_2SO_4	3.0

Van't Hoff factor & degree of association

For solutes which undergo association

If 'n' molecules of 'A' combine to give A_n, we have

$$\begin{array}{ll} nA \rightleftharpoons & A_n \\ 1 & O \\ 1-\alpha & \dfrac{\alpha}{n} \end{array}$$

(α = degree of association at the given concentration)

$\therefore$ Total particle after association $= 1-\alpha+\dfrac{\alpha}{n}$

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

$$\boxed{\alpha_{\text{association}} = \frac{i-1}{\frac{1}{n}-1}} \quad \text{or} \quad \boxed{\alpha_{\text{association}} = \frac{1-i}{1-\frac{1}{n}}}$$

Significance of van't Hoff factor

The Van't Hoff factor is indicated by the alphabet i. The parameter i measures the solute's effect on the various properties of a solution, primarily the colligative properties. Here, the colligative properties—such as osmotic pressure, depression in freezing point, elevation in boiling point, and lowering in vapor pressure—and their relationships with solute particles are measured.

The following equations can be used to calculate the Van't Hoff factor i:

1. $i = \dfrac{\text{Normal molar mass}}{\text{abnormal molar molarmass}}$
2. $i = \dfrac{\text{observed colligative property}}{\text{calculated colligative property}}$
3. $\dfrac{\text{total number of moles of particles after association or dissociation}}{\text{number of moles of particles before association or dissociation}}$

For association, the value of i is less than 1.

For dissociation, the value of i is more significant than 1.

If there is no association or dissociation value of i =1.

Van't Hoff factor i can therefore calculate the solute's molar mass, the values of colligative properties, and the association or dissociation of particles

Key Note

- ❍ Boiling point of solution ∝ no. of ions present in solute
- ❍ Freezing point of solution $\propto \dfrac{1}{\text{No. of ions present in a solute}}$

Train Your Brain

Example 18: When 11.7g of NaCl are dissolved in 200g of water the depression in freezing point is doubled than the depression caused by 342g of cane sugar in 1000g of water. From this information find degree of dissociation of NaCl in solution?

Sol. In case of NaCl

Given, $2\Delta T = \dfrac{1000\times K_f \times 11.7}{200\times M}\times i$ ...(i)

(Let depression in freezing point for sugar = ΔT)

In case of sugar

$\Delta T = \dfrac{1000\times K_f \times 342}{1000\times 342}$ ...(ii)

Divide (i) by (ii)

i = 2

$i = \dfrac{1+\alpha}{1}$

α = 1

Example 19: A 0.01 m aqueous solution of $K_3[Fe(CN)_6]$ freezes at –0.062°C. What is the apparent percentage of dissociation? (K_f of water = 1.86)

(1) 22% (2) 78 %

(3) 75 % (4) 50 %

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

[0 – (–0.062)] = i × 1.86 × 0.01

⇒ i = 3.33

$\alpha = \dfrac{i-1}{n-1} = \dfrac{3.33-1}{4-1} = 0.777$

$\alpha = 77.7\% \simeq 78\%$

Example 20: A solution is prepared by dissolving 26.3g of $CdSO_4$ in 1000g water. The depression in freezing point of solution was found to be 0.284K. Calculate the Van't Hoff factor. The cryoscopic constant of water is 1.86K kg mol^{-1}.

Sol. Molar mass of $CdSO_4 = 112.4 + 32 + 4 \times 16$
$= 208.4$ g/mol

$$\text{Molality} = \frac{\text{Mass of } CdSO_4}{\text{Molar mass of } CdSO_4 \times \text{Mass of solvent in kg}}$$

$$= \frac{26.3\text{g}}{(208.4\text{g / mol}) \times \left(\frac{1000}{1000}\text{kg}\right)} = 0.126 \text{ m}$$

$$\Delta T_f = iK_f m \text{ or } i = \frac{\Delta T_f}{K_f m} = \frac{0.284\text{K}}{1.86\text{K / m} \times 0.126\text{m}}$$

$$= 1.21$$

Concept Application

16. The ratio of value of colligative property for equimolar Hg_2Cl_2 solution to that for sugar solution is nearly:

(1) 4	(2) 1
(3) 8	(4) 3

17. Calculate the boiling point of a solution containing 0.61 g of benzoic acid in 50 g of carbon disulphide assuming 84% dimerization of the acid. The boiling point and K_b of CS_2 are 46.2°C and 2.3 K kg mol^{-1}

SHORT NOTES

Vapour Pressure

Pressure exerted by vapours over the liquid surface at equilibrium.

T↑ ⇒ V.P.↑

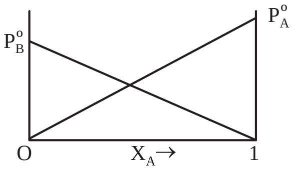
Attractive Forces↑ ⇒ V.P. ↓

Raoult's Law

(1) Volatile binary liquid mix:

Volatile liq.	A	B
Mole fraction	X_A / Y_A	X_B / Y_B ⇒ liq/vapour
V.P. of pure liq.	P_A^o	P_B^o

Binary liquid solution:



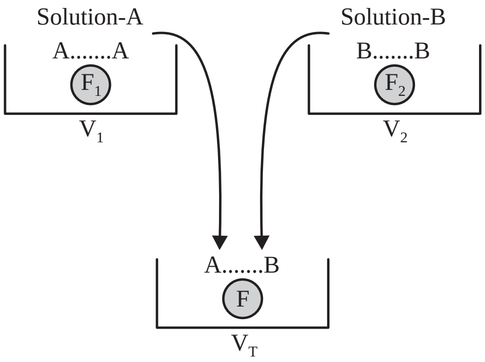
By Raoult's law ⇒ $P_T = P_A^0 X_A + P_B^0 X_B = P_A + P_B$ ...(*i*)

By Dalton's law ⇒ $P_A = Y_A P_T$ ...(*ii*)

$P_B = Y_B P_T$ ...(*iii*)

Ideal and Non-Ideal Solutions

Ideal Solutions



$$\text{Ideal solution} : \begin{array}{l} F_1 \simeq F_2 \simeq F \\ V_T = V_1 + V_2 \end{array} \Rightarrow \Delta H_{solution} = 0$$

Non-Ideal Solutions

(1) Solution showing +ve deviation :

$F < F_1$ or F_2

$V_T > V_1 + V_2$

$\because$ $\Delta H_{solution} > 0$

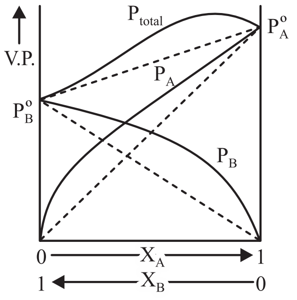


Fig.: A solution that shows +ve deviation from Raoult's law

(2) Solution showing -ve deviation:

⇒ $F > F_1$ and F_2

⇒ $V_T < (V_1 + V_2)$

⇒ $\Delta H_{solution} < 0$

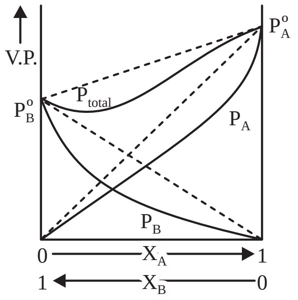


Fig.: A solution that shows -ve deviation from Raoult's law

Table: Deviation from Raoult's Law

	Positive deviation (ΔH = +ve)	Negative deviation (ΔH = – ve)	Zero deviation (ΔH = 0)
(*i*)	ethanol + cyclohexane	acetone + chloroform	benzene + toluene
(*ii*)	acetone + carbon disulphide	benzene + chloroform	*n*-hexane + *n*-heptane
(*iii*)	acetone + benzene	nitric acid + chloroform	ehyl bromide + ethyl iodide
(*iv*)	ethanol + acetone	acetone + aniline	chlorobenzene + bromo benzene
(*v*)	ethanol + water	water + nitric acid	
(*vi*)	carbon tetrachloride + chloroform	diethyl ether + chloroform	

Azeotropic mixtures: Some liquids on mixing in a particular composition form azeotropes which are binary mixture having same composition in liquid and vapour phase and boil at a constant temperature. Azeotropic mixture cannot be separated by fractional distillation.

Types of Azeotropic Mixtures

(*i*) **Maximum boiling Azeotropic mixtures:** The mixture of two liquids whose boiling point are more than either of the two pure components. They are formed by non-ideal solutions showing negative deviation. For example, HNO_3 (68%) + water (32%) mixture boils at 393.5 K.

(*ii*) **Minimum boiling Azeotropic mixtures:** The mixture of two liquids whose boiling point is less than either of the two pure components. They are formed by non-ideal soluton showing positive deviation. For example, ethanol (95.5%) + water (4.5%) water boils at 351.15 K.

Colligative Properties

Properties depends on relative no. of particles of non volatile solute in solution.

No. of particle of Non volatile solute ↑ ⇒ Colligative Properties ↑

(1) Relative lowering of V.P. :

$$\frac{P_A^0 - P_A}{P_A^{\circ}} = i\frac{n_B}{n_A + n_B} \simeq i\frac{n_B}{n_A} \quad \text{[For dilute solution]}$$

where n_B = mole of Non-volatile solute.

i = Van't Hoff's factor.

(2) Elevation in B.P. :

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

where $K_b = \dfrac{RT_b^2}{1000 \times l_v}$

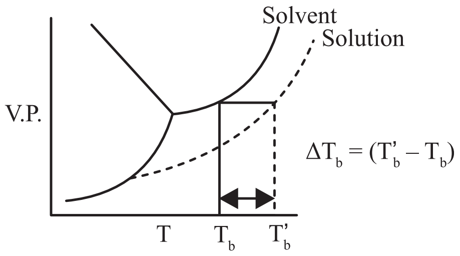
where T_b = B.P. of pure solvent.

l = Latent heat of vapourization (per gm)

K_b = molal elevation constant

M = Molar mass

where $l_v = \left(\dfrac{\Delta H_{vap}}{M}\right)$



(3) Depression in FP:

$\Delta T_f = T_f - T_f' = i\ K_f \times m$

where $K_f = \dfrac{RT_f^2}{1000 \times \ell_f}$

T_f = F.P. of pure solvent

K_f = molal depression constant

l_f = latent heat of fusion per gm.

(4) Osmotic pressure:

$\pi \propto (P_A^0 - P_A)$

π = iC. R.T.

where π = osmotic pressure

C = molarity (mole/lit)

Sol. (1) and Sol (2)

If $\pi_1 = \pi_2$ Isotonic

If $\pi_1 > \pi_2$ sol^n (1) hypertonic, sol^n (2) hypotonic

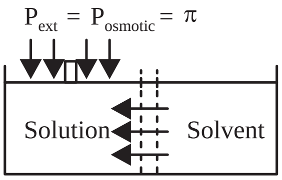


Table: Van't Hoff factor for different cases of solutes undergoing Ionisation and Association

Solute	Example	Ionisation/association (x degree)	y*	Van't Hoff factor	Abnormal mol. wt. (m_1')
Non-electrolyte	urea, glucose, sucrose etc.	none	1	1	normal mol.wt.
Ternary electrolyte	K_2SO_4, $BaCl_2$	$\underset{1-x}{A_2B} \rightleftharpoons \underset{2x}{2A^+} + \underset{x}{B^{2-}}$	3	(1 + 2x)	$\dfrac{m_1}{(1+2x)}$
Electrolyte	$K_3[Fe(CN)_6]$,	$\underset{1-x}{A_3B} \rightleftharpoons \underset{x}{A^{3+}} + \underset{3x}{3B^-}$	4	(1 + 3x)	$\dfrac{m_1}{(1+3x)}$
Associated Solute	benzoic acid in benzene	$\underset{1-x}{2A} \rightleftharpoons \underset{x/2}{A_2}$	$\frac{1}{2}$	$\left(1-\frac{x}{2}\right)=\left(\frac{2-x}{2}\right)$	$\dfrac{2m_1}{(2-x)}$
	forming dimer	$\underset{(1-x)}{A} \rightleftharpoons \frac{1}{2}\underset{x/2}{A_2}$	$\frac{1}{2}$	$\left(1-\frac{x}{2}\right) = \left(\frac{2-x}{2}\right)$	$\dfrac{2m_1}{(2-x)}$
	any solute	$\underset{1-x}{nA} \rightleftharpoons \underset{x/n}{A_n}$	$\frac{1}{n}$	$\left[1+\left(\frac{1}{n}-1\right)x\right]$	$\left[\dfrac{m_1}{1+\left(\frac{1}{n}-1\right)x}\right]$
	forming polymer A_n	$\underset{(1-x)}{A} \rightleftharpoons \frac{1}{n}\underset{x/n}{A_n}$	$\frac{1}{n}$	$1-x+\frac{x}{n}$	$\dfrac{m_1}{1-x+\frac{x}{n}}$
General	one mole of solute giving y mol of products	$\underset{1-x}{A} \rightleftharpoons \underset{xy}{yB}$	y	[1 + (y −1)x]	$\dfrac{m_1}{[1+(y-1)x]}$

*** number of products from one mole of solute**

AARAMBH (SOLVED EXAMPLES)

1. Heptane and octane form ideal solution. At 373K, the vapour pressures of the two liquids are 105.2 kPa and 46.8 kPa respectively. What will be the vapour pressure, in bar, of a mixture of 25g of heptane and 35g of octane?

Sol. (A) Heptane C_7H_{16} mA = 100

(B) Octane C_8H_{18} $m_B = 114$

$$n_A = \frac{w_A}{m_A} = \frac{25}{100} = 0.25;\ n_B = \frac{35}{114} = 0.3$$

$$x_A = \frac{0.25}{0.25+0.30} = 0.45;\ x_B = \frac{0.3}{0.25+0.30} = 0.55$$

$$P = p_A^0 x_A + p_B^0 x_B$$

$= 105.2 \times 0.45 + 46.8 \times 0.55$

$= 47.34 + 25.74 = 73.08$ kPa $= 0.7308$ bar

2. The vapour pressure of pure benzene at 50°C is 268 mm of Hg. How many moles of non-volatile solute per mole of benzene are required to prepare a solution of benzene having a vapour pressure 167.0mm of Hg at 50°C?

Sol. Applying Raoult's law in the following form

$$\frac{p_0 - p_s}{p_s} = \frac{wM}{Wm} = \frac{w/m}{W/M}$$

= No. of moles of solute per mole of benzene

$$\text{or } \frac{n}{N} = \frac{(268-167)}{167} = 0.6047 = 0.605$$

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

Sol. $\Delta T = 6°C$, W = 4 kg = 4000g, m = 62, $K_f = 1.85$

$$w = \frac{m \times W \times \Delta T}{1000 \times K_f}$$

$$= \frac{62 \times 4000 \times 6}{1000 \times 1.85} = 804.32g$$

4. 1.4 g of acetone dissolved in 100g of benzene gave a solution which freezes at 277.12K. Pure benzene freezes at 278.4K. 2.8g of solid (A) dissolved in 100g of benzene gave a solution which froze at 277.76K. Calculate the molecular mass of (A)

Sol. We know that

$$\Delta T = K_f \times \frac{w \times 1000}{m \times W}$$

Where, ΔT = Depression in freezing point

K_f = Molal depression constant of benzene

w = Mass of solute

m = Molar mass of solute

W = Mass of solvent

$$\text{Case-I: } (278.4 - 277.12) = K_f \times \frac{1.4 \times 1000}{58 \times 100}$$

$$1.28 = K_f \times \frac{14}{58} \quad \dots (i)$$

$$\text{Case-II: } (278.4 - 277.76) = K_f \times \frac{2.8 \times 1000}{m_{(A)} \times 100}$$

$$0.64 = K_f \frac{28}{m_{(A)}} \quad \dots (ii)$$

Dividing equation (*i*) by (*ii*), we get

$m_{(A)} = 232$ g/mol

5. At 27°C, 36 g of glucose per litre has an osmotic pressure of 4.92 atm. If the osmotic pressure of solution is 1.5 atm at the same temperature, what should be its concentration?

Sol. Given that, $\pi_1 = 4.92$ atm, $\pi_2 = 1.5$ atm

$$C_1 = \frac{36}{180 \times 1} \quad \left(\because C = \frac{w}{M \times V}\right), C_2 = ?$$

$\pi_1 V_1 = n_1 S T_1$

$\pi_2 V_2 = n_2 S T_2$

At same temperature,

$$\frac{\pi_1}{\pi_2} = \frac{n_1}{V_1} \times \frac{V_2}{n_2} = \frac{C_1}{C_2}$$

$$\therefore \frac{4.92}{1.5} = \frac{36}{180 \times C_2}$$

$\therefore C_2 = 0.061$ mol/litre

6. The molal freezing point constant of C_6H_6 is 4.90 and its melting point is 5.51°C. A solution of 0.816 g of a compound A dissolved in 7.5 g of benzene freezes at 1.59°C. Calculate molar mass of compound A.

Sol. Given,

$\Delta T = 5.51 - 1.59 = 3.92$

$K_f' = 4.9$ K mol^{-1} kg

w = 0.816 g, W = 7.5 g

$$\because \Delta T = \frac{1000 \times K_f' \times w}{M \times W}$$

$$3.92 = \frac{1000 \times 4.9 \times 0.816}{M \times 7.5}$$

$\therefore M = 136$ g/mol

7. What will be the boiling point of bromine when 174.5 mg of octa atomic sulphur is added to 78 g of bromine? K_b' for Br_2 is 5.2 K mol^{-1} kg and b. pt. of Br_2 is 332.15 K.

Sol. Given, $w = 174.5 \times 10^{-3}$ g, $W = 78$ g

$m = 8 \times 32 = 256$ ($\because$ Octa atomic), $K_b' = 5.2$

$$\because \Delta T = \frac{1000K_b'w}{WM} = \frac{1000 \times 5.2 \times 174.5 \times 10^{-3}}{78 \times 256}$$

$= 0.045$

$\therefore$ Boiling pt. of Br_2 solution $= 332.15 + \Delta T$

$= 332.15 + 0.045 = 332.195$ K

8. The boiling point of $CHCI_3$ was raised by 0.323°C when 0.5143 g of anthracene was dissolved in 35 g $CHCI_3$. Calculate the molar mass of anthracene. K_b' for $CHCI_3$ = 3.9 K mol^{-1} kg.

Sol. Given that, $w = 0.5143$ g, $W = 35$ g

$K_b' = 3.9$ K mol^{-1} kg, $\Delta T_b = 0.323°C$

$$\because \quad \Delta T_b = \frac{1000K_b'w}{MW}$$

$$\therefore \quad 0.323 = \frac{1000 \times 3.9 \times 0.5143}{M \times 35}$$

M = 177.42 g/mol

9. What weight of non-volatile solute, urea (NH_2CONH_2) needs to be dissolved in 100g of water, in order to decrease the vapour pressure of water by 25%. What will be the molality of solution?

Sol. According to Raoult's law:

$$\frac{P° - P_S}{P_S} = \frac{w}{m} \times \frac{M}{W}$$

Given if P° = 100, then P_S = 75mm, m = 60,

W = 100g, M = 18

$$\frac{100 - 75}{75} = \frac{w \times 18}{60 \times 100}$$

$\therefore$ w = 111.11g

Also molality of solution,

$$= \frac{\text{weight of solute}}{\text{mol. wt of solute} \times \text{weight of solvent (in kg)}}$$

$$= \frac{111.11}{60 \times \frac{100}{1000}}$$

= 13.88 m

10. How much copper sulphate will be required to saturate 100g of a dilute aqueous solution of $CuSO_4$ at 25°C if 10g of the dilute solution leave on evaporation and drying 1.2g of anhydrous $CuSO_4$? The solubility of $CuSO_4$ in water at 25°C is 25.

Sol. 100g of dilute solution of $CuSO_4$ contains = 1.2 × 10 = 12.0g $CuSO_4$

Mass of water present in dilute solution = (100 – 12) = 88g

To saturate 100g of water, $CuSO_4$ required = 25g

So, to saturate 88g of water $CuSO_4$ required $= \frac{25 \times 88}{100} = 22$ g

Thus, the mass of $CuSO_4$ to be added to 100 g of dilute solution to saturate it = (22 – 12) = 10g.

11. For a binar y ideal liquid solution, the total pressure of the solution is given as:

(1) $P_{total} = P_A^0 + (P_A^0 + P_B^0)\, X_B$

(2) $P_{total} = P_B^0 + (P_A^0 - P_B^0)\, X_A$

(3) $P_{total} = P_B^0 + (P_B^0 - P_A^0)\, X_A$

(4) $P_{total} = P_B^0 + (P_B^0 - P_A^0)\, X_B$

Sol. For binary ideal solution

For a binary ideal liquid solution

$$P_{total} = X_A P_A + X_B P_B^0 \qquad ...(i)$$

and $X_A + X_B = 1$

$X_B = (1 - X_A)$

Putting the value of X_B in equation (*i*)

$$P_{Total} = X_A P_A^0 + (1 - X_A)\, P_B^0 = X_A P_A^0 + P_B^0 - X_A P_B^0$$

$$\therefore P_{Total} = P_B^0 + X_A(P_A^0 - P_B^0)$$

12. 36 g water and 828 g ethyl alcohol form an ideal solution. The mole fraction of water in it is:

(1) 1.0 (2) 0.7 (3) 0.4 (4) 0.1

Sol. Number of moles $C_2H_5OH = \frac{828}{46} = 18$

Number of moles of $H_2O(n) = \frac{36}{18} = 2$

$$\therefore H_2O = \frac{n}{n + N} = \frac{2}{2 + 18} = 0.1$$

13. The molarity of pure water is:

(1) 55.6 (2) 5.56

(3) 100 (4) 18

Sol. $\text{Molarity} = \frac{\text{No. of moles of solute}}{\text{Volume of solution in L}}$

Let water = 1L = 1000 mL

1D = 1 g/mL

$\therefore$ Mass of water = 1000 g

$n_{H_2O} = d = 55.55$ moles

This, molarity $= \frac{55.55 \text{ mol}}{1L}$

14. Dissolving 120 g of urea (mol. wt. 60) in 1000 g of water gave a solution of density 1.15 g/mL. The molarity of the solution is:

(1) 1.78 M (2) 2.00 M

(3) 2.05 M (4) 2.22 M

Sol. Total mass of solution = 1000 + 120 = 1120 g

Total volume of solution in (L) = $\dfrac{1120}{1.15\times10^3}$

$$M = \frac{W}{M}\times\frac{1}{V(\text{in L})}$$

$$= \frac{120}{60}\times\frac{1.15\times10^3}{1120}$$

= 2.05 M

15. The aqueous solution of 0.004 M Na_2SO_4 and 0.01 M glucose are isotonic. Degree of dissociation of Na_2SO_4 is:

(1) 75% (2) 50%

(3) 25% (4) 85%

Sol. For two solution to be isotonic

$\pi_{Na_2SO_4} = \pi_{\text{glucose}}$

π = iCRT

$iCNa_2SO_4$ = Cglucose

i × 0.004 = 1 × 0.01

i = 2.5

$Na_2SO_4 \rightarrow 2Na + SO_4^{2-}$

The number of ions are 3.

∴ The degree of dissociation

$$d = \frac{i-1}{n-1}$$

$$d = \frac{2.5-1}{3-1} = 0.75 \text{ or } 75\%.$$

BOARD LEVEL PROBLEMS

MULTIPLE CHOICE QUESTIONS

1. Which of the following units is useful in relating concentration of solution with its vapour pressure?

(1) Mole fraction (2) Parts per million

(3) Mass percentage (4) Molality

2. The Van't Hoff factor for 0.01 M Na_2SO_4 solution is 1.32. The degree of dissociation is:

(1) 13% (2) 16%

(3) 20% (4) 18%

3. Which of the following solutions would have the highest osmotic pressure:

(1) $\frac{M}{10}$ NaCl (2) $\frac{M}{10}$ Urea

(3) $\frac{M}{10}$ $BaCl_2$ (4) $\frac{M}{10}$ Glucose

4. The freezing point of 11% aqueous solution of calcium nitrate will be:

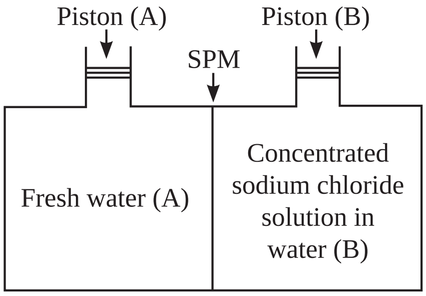
(1) 0°C (2) above 0°C

(3) 1°C (4) below 0°C

5. Henry's law constant K of CO_2 in water at 25°C is 3×10^{-2} mol/L atm^{-1}. Calculation the mass of CO_2 present in 100 L of soft drink bottled with a partial pressure of CO_2 of 4 atm at the same temperatrue.

(1) 5.28 g (2) 12.0 g (3) 428 g (4) 528 g

6. Consider the following figure and mark the correct option.



(1) Water will move from side (A) to side (B) if a pressure lower than osmotic pressure is applied on piston (B).

(2) Water will move from side (B) to side (A) if a pressure greater than osmotic pressure is applied on piston (B).

(3) Water will move from side (B) to side (A) if a pressure equal to osmotic pressure is applied on piston (B).

(4) Water will move from side (A) to side (B) if pressure equal to osmotic pressure is applied on piston (A).

7. If two liquids A and B form minimum boiling azeotrope at some specific composition then _______________.

(1) A–B interactions are stronger than those between A–A or B–B.

(2) Vapour pressure of solution increases because more number of molecules of liquids A and B can escape from the solution.

(3) Vapour pressure of solution decreases because less number of molecules of only one of the liquids escape from the solution.

(4) A–B interactions are weaker than those between A–A or B–B.

8. We have three aqueous solutions of NaCl labelled as 'A', 'B' and 'C' with concentrations 0.1M, 0.01M and 0.001M, respectively. The value of van't Hoff factor for these solutions will be in the order______.

(1) i A < i B < i C (2) i A > iB > iC

(3) i A = i B = i C (4) i A < i B > i C

9. 0.2 molal acid HX is 20 %. Ionised in solution. $K_f = 1.86$ K m^{-1}. The freezing point of the solution is

(1) – 0.45°C (2) – 0.90°C

(3) – 0.31°C (4) – 0.53°C

10. Which of the following statements is false?

(1) Two different solutions of sucrose of same molality prepared in different solvents will have the same depression in freezing point.

(2) The osmotic pressure of a solution is given by the equation $\Pi = CRT$ (where C is the molarity of the solution).

(3) Decreasing order of osmotic pressure for 0.01 M aqueous solutions of barium chloride, potassium chloride, acetic acid and sucrose is $BaCl_2 > KCl > CH_3COOH >$ sucrose.

(4) According to Raoult's law, the vapour pressure exerted by a volatile component of a solution is directly proportional to its mole fraction in the solution.

ASSERTION AND REASON QUESTIONS

1. **Assertion:** When methyl alcohol is added to water, boiling point of water increases.

Reason: When a non-volatile solute is added to a volatile solvent elevation in boiling point is observed.

(1) Assertion and reason both are true and reason is correct explanation for assertion.

(2) Assertion and reason both are true but reason is not correct explanation for assertion.

(3) Assertion is true but reason is false.

(4) Assertion is false but reason is true.

2. **Assertion:** When NaCl is added to water a depression in freezing point is observed.

Reason: The lowering of vapour pressure of a solution causes depression in the freezing point.

(1) Assertion and reason both are true and reason is correct explanation for assertion.

(2) Assertion and reason both are true but reason is not correct explanation for assertion.

(3) Assertion is true but reason is false.

(4) Assertion is false but reason is true.

MATCH THE COLUMN TYPE QUESTIONS

1. Match the column and choose correct option

Vant'Hoff factor		Behaviour of compound	
A.	$i = 1$	P.	Impossible
B.	$i > 1$	Q.	Association is the solution
C.	$i < 1$	R.	Dissociation in the solution
D.	$i = 0$	S.	No dissociation or association

(1) A-(S); B-(R); C-(P); D-(Q)

(2) A-(R); B-(S); C-(Q); D-(P)

(3) A-(S); B-(P); C-(R); D-(Q)

(4) A-(S); B-(R); C-(Q); D-(P)

2. Match the law given in column-I with expressions given in column-II.

	Column-I		Column-II
A.	*Raoult's law*	P.	$\Delta T_f = K_f m$
B.	*Henry's law*	Q.	$\Pi = CRT$
C.	*Elevation of boiling point*	R.	$p = x_1 p_1^o + x_2 p_2^o$
D.	*Depression in freezing point*	S.	$\Delta T_b = K_b m$
E.	*Osmotic pressure*	T.	$p = K_H x$

(1) A-(R); B-(T); C-(S); D-(P); E-(Q)

(2) A-(T); B-(R); C-(P); D-(P); E-(S)

(3) A-(S); B-(P); C-(R); D-(T); E-(Q)

(4) A-(Q); B-(S); C-(T); D-(P); E-(R)

VERY SHORT ANSWER QUESTIONS

1. The vapour pressure of water is 12.3 Kpa at 300K. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it.

2. How many grams of KCl should be added to 1 kg of water to lower its freezing point to – 8.0ºC? (K_f = 1.86 K kg/mol)

3. An aqueous solution of 2% non-volatile solute exerts a pressure of 1.004 Bar at the normal boiling point of the solvent. What is the molar mass of the solute?

LONG ANSWER QUESTIONS

1. Equal moles of liquid P and Q are mixed. What is the ratio of their moles in the vapour phase ? Given that $P_P^\circ = 2P_Q^\circ$.

2. Two liquids A and B boil at 145ºC and 190ºC respectively. Which of them has higher vapour pressure at 80ºC?

3. (1) What is the value of ''i'' for $Al_2(SO_4)_3$ when it is completely dissociated? (2) Calculate the boiling point of a solution prepared by adding 15.00g of NaCl to 250g of water. (K_b = 0.512 K kg mol^{-1} and molar mass of NaCl = 58.44g mol^{-1})

4. (1) What is the value of ''i'' when solute is associated and dissociated?

(2) Calculate the freezing point of an aqueous solution containing 10.50 g of $MgBr_2$ in 200 g of water. (Molar mass of $MgBr_2$ = 184, K_f = 1.86 K kg mol^{-1})

5. (1) Outer shells of two eggs are removed. One of the egg is placed in pure water and the other is placed in saturated solution of NaCl. What will be observed and why?

(2) A solution prepared by dissolving 8.95 mg of a gene fragment in 35.0 ml of water has an osmotic pressure of 0.335 ton at 25ºC. Assuming the gene fragment is a non-electrolyte, determine the molar mass?

6. Explain the terms ideal and non-ideal solutions in the light of forces of interactions operating between molecules in liquid solutions?

7. Explain why on addition 1 mol of NaCl to 1 litre of water, the boiling point of water increases, while addition of 1 mol of methyl alcohol to one litre of water decreases its boiling point?

CASE BASED STUDY TYPE

Read the passage given below and answer the following questions:

Boiling point or freezing point of liquid solution would be affected by the dissolved solids in the liquid phase. A soluble solid in solution has the effect of raising its boiling point and depressing its freezing point. The addition of non-volatile substances to a solvent decreases the vapor pressure and the added solute particles affect the formation of pure solvent crystals. According to many researches the decrease in freezing point directly correlated to the concentration of solutes dissolved in the solvent. This phenomenon is expressed as freezing point depression and it is useful for several applications such as freeze concentration of liquid food and to find the molar mass of an unknown solute in the solution. Freeze concentration is a high quality liquid food concentration method where water is removed by forming ice crystals. This is done by cooling the liquid food below the freezing point of the solution. The freezing point depression is referred as a colligative property and it is proportional to the molar concentration of the solution (m), along with vapour pressure lowering, boiling point elevation, and osmotic pressure. These are physical characteristics of solutions that depend only on the identity of the solvent and the concentration of the solute. The characters are not depending on the solute's identity. (Jayawardena, J. A. E. C., Vanniarachchi, M. P. G., & Wansapala, M. A. J. (2017). Freezing point depression of different Sucrose solutions and coconut water.)

1. When a non volatile solid is added to pure water it will:

(1) Boil above 100°C and freeze above 0°C

(2) Boil below 100°C and freeze above 0°C

(3) Boil below 100°C and freeze below 0°C

(4) Boil above 100°C and freeze below 0°C

2. Colligative properties are:

(1) Dependent only on the concentration of the solute and independent of the solvent's and solute's identity.

(2) Dependent only on the identity of the solute and the concentration of the solute and independent of the solvent's identity.

(3) Dependent on the identity of the solvent and solute and thus on the concentration of the solute.

(4) Dependent only on the identity of the solvent and the concentration of the solute and independent of the solute's identity.

3. Assume three samples of juices A, B and C have glucose as the only sugar present in them. The concentration of sample A, B and C are 0.1M, .5M and 0.2 M respectively. Freezing point will be highest for the fruit juice:

(1) A

(2) B

(3) C

(4) All have same freezing point

4. Identify which of the following is a colligative property:

(1) Freezing point (2) Boiling point

(3) Osmotic pressure (4) All of the above

PRARAMBH EXERCISE-1 (TOPICWISE)

EXPRESSING CONCENTRATION OF SOLUTIONS

1. The density of a solution prepared by dissolving 120 g of urea (molar mass = 60 g) in 1000 g of water is 1.15 g/ml. The molarity of this solution is:

(1) 1.78 M (2) 1.02 M

(3) 2.05 M (4) 0.50

2. When the volume of the solution is doubled, the following becomes exactly half

(1) Molality (2) Mole-fraction

(3) Molarity (4) Weight percent

3. A semi molar solution is the one, which contains:

(1) One mole solute in 2 litres

(2) 2 moles solute in 2 litres

(3) 0.1 mole solute in 1 litre

(4) 0.2 moles solute in 2 litres

4. 1 kg of NaOH is added to 10 ml of 0.1N HCl, the resulting solution will:

(1) Turn blue litmus red

(2) Turn phenolphthalein solution pink

(3) Turn methyl orange red

(4) Will have no effect on red or blue litmus paper

5. What is the mole fraction of glucose in 10% w/w glucose solution?

(1) 0.01 (2) 0.02 (3) 0.03 (4) 0.04

6. Normality of 0.1M H_3PO_3 is:

(1) 0.2N (2) 0.30N

(3) 0.033N (4) 0.05N

7. In a normal solution of $BaCl_2$, normalities of Ba^{2+} and Cl^- are in the ratio:

(1) 2:1 (2) 1:2 (3) 1:1 (4) 2:3

8. Molarity of 0.1N oxalic acid is:

(1) 0.05 M (2) 0.1 M

(3) 0.2 M (4) 0.3M

9. 138 g ethyl alcohol is mixed with 72 g of water. The ratio of mole fraction of alcohol to water is:

(1) 3 : 4 (2) 1 : 2 (3) 1 : 4 (4) 1 : 1

10. How much the amount of benzoic acid (C_6H_5COOH) required for preparing 250 mL of 0.15 M solution in methanol?

(1) 45.75 g (2) 4.575 g

(3) 0.2 M (4) 9.15 g

11. The equivalent weight of Mohr's salt during redox reaction is equal to its:

(1) Molecular weight/2 (2) Atomic weight/2

(3) Molecular weight/3 (4) Molecular weight

12. The equivalent weight of $MnSO_4$ is half its molecular weight, when it is converted to:

(1) Mn_2O_3 (2) MnO_2

(3) MnO_4 (4) MnO_4^{-2}

13. 2.5 cm^3 of 0.2 M H_2SO_4 solution is diluted to 0.5 dm^3. Find normality of the diluted solution.

(1) 0.2 N (2) 0.02 N

(3) 0.002 N (4) 0.04 N

14. Number of moles of solute dissolved in 1000g of the solvent is called:

(1) Molarity (2) Molality

(3) Formality (4) Normality

15. Which of the following has no units?

(1) Molarity (2) Normality

(3) Molality (4) Mole fraction

16. Molarity of 4% (w/v) solution of NaOH is:

(1) 0.1 (2) 0.5

(3) 0.001 (4) 1.0

17. The number of moles of solute present in 2.0 litres of 0.5M NaOH solution is:

(1) 2 (2) 1 (3) 4 (4) 0.1

18. What is the molarity of 0.2 N Na_2CO_3 solution?

(1) 0.1 M
(2) 0 M
(3) 0.4 M
(4) 0.2 M

19. 10 millimoles of solute is present in the following volume of 0.08M solution:

(1) 125ml
(2) 625ml
(3) 500 ml
(4) 1000ml

20. The concentration of a 100 ml solution containing X grams of Na_2CO_3 (Mol. wt. = 106) is Y M. The values of X and Y are respectively:

(1) 2.12, 0.05
(2) 1.06, 0.2
(3) 1.06, 0.1
(4) 2.12, 0.1

21. How many milli litres of 1M H_2SO_4 will be neutralised by 10ml of 1M NaOH solution?

(1) 10
(2) 20
(3) 2.5
(4) 5

22. The normality of orthophosphoric acid having purity of 70% by weight and specific gravity 1.54 gm/ml is:

(1) 11 N
(2) 22 N
(3) 33 N
(4) 44 N

23. The volume of water that must be added to a mixture of 250ml of 6M HCl and 650ml of 3M HCl to obtain 3M solution is:

(1) 75ml
(2) 150ml
(3) 300ml
(4) 250ml

24. If 36.0 g of glucose is present in 400 ml of solution, molarity of the solution is:

(1) 0.05M
(2) 11.0 M
(3) 0.5M
(4) 2.0 M

25. What volume of 0.8M solution contains 0.1 mole of the solute?

(1) 100 ml
(2) 125 ml
(3) 500 ml
(4) 62.5 ml

26. If 0.01 mole of solute is present in 500 ml of solution, its molarity is:

(1) 0.01 M
(2) 0.005M
(3) 0.02 M
(4) 0.1M

27. 0.126 g of an acid is titrated with 0.1 N 20 ml of a base. The equivalent weight of the acid is:

(1) 63
(2) 50
(3) 53
(4) 23

28. The density of 2 M solution of acetic acid (Mol. wt. 60) is 1.02 g mL^{-1}. The molality of the solution 'X' is:

(1) 1.0
(2) 2.0
(3) 2.22
(4) 2.25

29. The weight of $H_2C_2O_4.2H_2O$ required to prepare 500ml of 0.2N solution is:

(1) 1.26g
(2) 6.3g
(3) 1.575g
(4) 3.15g

30. 3.42 g of a substance of molar weight 342 g is present in 250g of water. Molality of this solution is:

(1) 0.4m
(2) 0.04 m
(3) 0.8 m
(4) 4m

31. 3g of a salt [Mol. wt. 30 g/mol] is dissolved in 250 g of water the molality of the solution is:

(1) 0.4
(2) 0.2
(3) 0.6
(4) 0.8

32. Mole fraction of a solute in benzene is 0.2, then find molality of solution:

(1) 3.2
(2) 2
(3) 4
(4) 3.6

33. How much volume of 1 M H_2SO_4 is required to neutralise 20 ml of 1 M NaOH?

(1) 10 ml
(2) 20 ml
(3) 5 ml
(4) 15 ml

SOLUBILITY

34. How many grams of CO_2 gas is dissolved in a 1 L bottle of carbonated water if the manufacturer uses a pressure of 2.4 atmosphere in the bottling process at 25°C? Given: K_H of CO_2 water = 29.76 atm/mol./L at 25°C

(1) 3.52
(2) 4.2
(3) 3.1
(4) 2.5

35. H_2S is a toxic gas used in qualitative analysis. If solubility of H_2S in water at STP is 0.195 m, what is the value of K_H?

(1) 0.0263 bar
(2) 69.16 bar
(3) 192 bar
(4) 282 bar

36. The law which indicates the relationship between solubility of a gas in liquid and pressure is:

(1) Raoult's law
(2) Henry's law
(3) Lowering of Vapour pressure
(4) Van't Hoff's law

37. Four gases like H_2, He, CH_4 and CO_2 have Henry's constant values (K_H) as 69.16, 144.97, 0.413 and 1.67. The gas which is more soluble in liquid is:

(1) He
(2) CH_4
(3) H_2
(4) CO_2

38. Correct statement(s) is/are:

A. The solubility of gases in liquid increases with increase of temperature.
B. Aquatic species are more comfortable in warm waters rather than in cold waters.
C. At high altitudes the partial pressure of oxygen is less than that at the ground level.
D. There is low concentration of O_2 in the blood and tissue of the people living at high altitude.

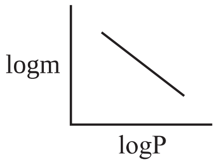
(1) A and B
(2) B, C and D
(3) C and D
(4) Only A

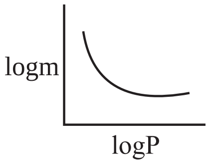
39. Henry's law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. The quantity of CO_2 in 500 mL of soda water when packed under 2.5 atm CO_2 pressure at 298 K is:

(1) 0.0084 grams (2) 0.00084 grams

(3) 1.848 grams (4) 8.4 grams

40. Which of these curves represents Henry's Law?

(1)


(2)


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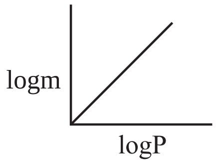
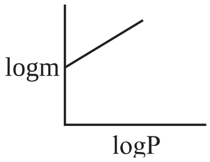


(4)


41. Which of the following equations represents Henry's law?

(1) $p = K_H\, x$ (2) $P_{total} = p_1 + p_2$

(3) $p = K_H + p_1$ (4) $p = K_H \div p_2$

42. Which one of the following gases has the lowest value of Henry's law constant?

(1) N_2 (2) He (3) CO_2 (4) O_2

43. Which of the following statement (s) are correct?

A. Polar solutes dissolve in polar solvents.

B. Sodium chloride and sugar dissolve readily in benzene.

C. Non polar solutes dissolve in non-polar solvents.

D. Naphthalene and anthracene dissolve readily in water.

(1) A, B and C (2) A and C

(3) A, C and D (4) B, C and D

44. Henry's law constant of oxygen is 1.4×10^{-3} mol l^{-1} atm^{-1} at 298 K. How much of oxygen is dissolved in 100 ml at 298 K when the partial pressure of oxygen is 0.5 atm?

(1) 1.4 g (2) 3.2 g

(3) 2.24 mg (4) 5.2 g

45. Solubility of gases in liquids:

(1) Increases with decrease in temperature

(2) Increases with rise in temperature

(3) Remain unaffected with rise in temperature

(4) None of these

VAPOUR PRESSURE OF LIQUID SOLUTIONS

46. A mixture of ethyl alcohol and propyl alcohol has a vapour pressure of 290 mm at 27°C. If mole fraction of ethyl alcohol is 0.65, calculate the vapour pressure of pure ethyl alcohol, if vapour pressure of pure propyl alcohol is 210 mm.

(1) 333.1 mm (2) 133.1 mm

(3) 373.2 mm (4) 433.1 mm

47. The boiling point of C_6H_6,CH_3OH, $C_6H_5NH_2$ and $C_6H_5NO_2$ are 80°C, 65°C, 184°C and 212°C respectively. Which will show highest vapour pressure at room temperature?

(1) C_4H_6 (2) CH_3OH

(3) $C_6H_5NH_2$ (4) $C_6H_5NO_2$

48. At 300 K, the vapour pressure of an ideal solution containing one mole of A and 3 mole of B is 550 mm of Hg. At the same temperature, if one mole of B is added to this solution, the vapour pressure of solution increases by 10 mm of Hg. Calculate the vapour pressure of A and B (in mm Hg) respectively in their pure state.

(1) 400, 600 (2) 100, 200

(3) 300, 400 (4) 800, 400

49. Partial pressure of a solution component is directly proportional to its mole fraction. This is known as:

(1) Henry's law (2) Raoult's law

(3) Distribution law (4) Ostwald's dilution law

50. The vapour pressure of water depends upon

(1) Surface area of container

(2) Volume of container

(3) Temperature

(4) All of the above

51. 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?

(1) 0.11 torr (2) 35.5 torr

(3) 27.78 torr (4) 46.9 torr

52. An aqueous solution containing liquid A (M = 128) 64% by weight has a vapour pressure of 145mm Hg. Find the vapour pressure of pure A, if that of water is 155mm Hg at the same temperature.

(1) 105 mm Hg (2) 208 mm Hg

(3) 1.05 mm Hg (4) 2.08 mm Hg

53. A mixture of two immiscible liquids nitrobenzene and water boiling at 99°C has a partial vapour pressure of water 733 mm and that of nitrobenzene 27 mm. Calculate the ratio of the weights of nitrobenzene to the water in distillate.

(1) 1 : 4 (2) 4 : 1 (3) 1 : 3 (4) 3 : 1

54. Vapour pressure is the pressure exerted by vapours:

(1) In equilibrium with liquid

(2) In any condition

(3) In an open system

(4) In atmospheric conditions

55. Two liquids X and Y form an ideal solution. The mixture has a vapour pressure of 400 mm at 300 K when mixed in the molar ratio of 1 : 1 and a vapour pressure of 350 mm when mixed in the molar ratio of 1 : 2 at the same temperature. The vapour pressures of the two pure liquids X and Y respectively are:

(1) 250 mm, 550 mm (2) 350 mm, 450 mm

(3) 350 mm, 700 mm (4) 550 mm, 250 mm

IDEAL AND NON-IDEAL SOLUTIONS

56. The system that forms maximum boiling azeotrope is:

(1) Carbon disulphide - acetone

(2) Benzene - toluene

(3) Acetone - chloroform

(4) n - hexane - n heptane

57. A non-ideal solution was prepared by mixing 30 ml chloroform and 50 ml acetone. The volume of mixture will be:

(1) > 80 ml (2) < 80 ml
(3) = 80 ml (4) ≥ 80 ml

58. A solution of acetone in ethanol:

(1) Shows a negative deviation from Raoult's law
(2) Shows a positive deviation from Raoult's law
(3) Behaves like a near ideal solution
(4) Obey Raoult's law

59. Which of the following will show a negative deviation from Raoult's law?

(1) Acetone - benzene (2) Acetone - ethanol
(3) Benzene - methanol (4) Acetone - chloroform

60. A solution containing components A and B follows Raoult's law:

(1) A – B attraction is greater than A – A and B – B
(2) A – B attraction forces is less than A – A and B – B
(3) A – B attraction forces remains same as A – A and B – B
(4) Volume of solution is different from sum of volumes of solute and solvent

61. What are the conditions for an ideal solution which obeys Raoult's law over the entire range of concentration?

(1) $\Delta H_{mix} = 0, \Delta V_{mix} = 0,\ P_{total} = P_A^0 x_A + P_B^0 x_B$
(2) $\Delta H_{mix} = +ve, \Delta V_{mix} = 0,\ P_{total} = P_A^0 x_A + P_B^0 x_B$
(3) $\Delta H_{mix} = 0, \Delta V_{mix} = +ve,\ P_{total} = P_A^0 x_A + P_B^0 x_B$
(4) $\Delta H_{mix} = 0, \Delta V_{mix} = 0,\ P_{total} = P_B^0 x_B$

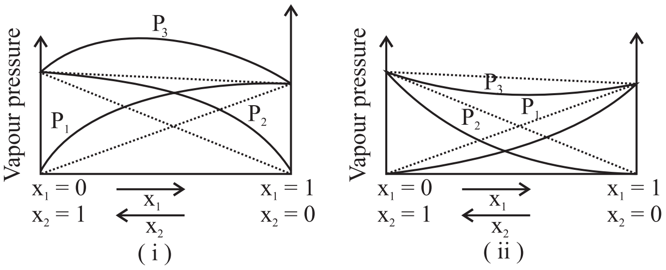
62. Which of the following liquid pairs will exhibit a positive deviation from Raoult's law?

(1) Water – Hydrochloric acid
(2) Cyclohexane – Ethanol
(3) Acetone – Chloroform
(4) Water – Nitric acid

63. Which of the following azeotropes is not correctly matched?

(1) HNO_3 (68%) + H_2O (32%): Maximum boiling azeotrope, B.P = 393.5 K
(2) H_2O (43%) + HI (56.7%): Minimum boiling azeotrope, B.P = 290 K
(3) C_2H_5OH (95.5%) + H_2O(4.5%): Minimum boiling azeotrope, B.P. = 351.15 K
(4) Chloroform (93.2%) + C_2H_5OH (6.8%): Minimum boiling azeotrope, B.P. = 332.3 K

64. Study the figures given below and mark the correct statement:



(i) (ii)

(1) (i) Nitric acid + water (ii) Acetone + ethyl alcohol
(2) (i) Water + ethyl alcohol (ii) Acetone + Benzene
(3) (i) Acetone + ethyl alcohol (ii) Acetone + chloroform
(4) (i) Benzene + toluene (ii) Acetone + chloroform

65. Which of the following gas mixture is used by the divers inside the sea?

(1) O_2 + He (2) O_2 + Xe
(3) O_2 + Ar (4) $O_2 + N_2$

66. The vapour pressure of pure solvent is 0.8 mm of Hg at a particular temperature. On addition of a non - volatile solute 'A' the vapour pressure of solution becomes 0.6 mm of Hg. The mole fraction of component 'A' is:

(1) 0.25 (2) 0.75
(3) 0.5 (4) 0.35

67. Lowering of vapour pressure of an aqueous solution of a non-volatile, non-electrolyte 1 M aqueous solution at 100^0C is:

(1) 14.12 torr (2) 312 torr
(3) 13.45 torr (4) 352 torr

68. A solution of two liquids boils at a temperature more than the boiling point of either of them. Hence, the binary solution shows:

(1) Negative deviation from Raoult's law
(2) Positive deviation from Raoult's law
(3) No deviation from Raoult's law
(4) Positive or negative deviation from Raoult's law depending upon the composition.

COLLIGATIVE PROPERTIES, DETERMINATION OF (MOLAR) MASS & ABNORMAL MOLAR MASS

69. Camphor is used as solvent to determine the molecular mass of non volatile solute by Rast method because for Camphor

(1) Molal depression constant is high
(2) Melting point is high
(3) Being cheap
(4) All the above

70. If the elevation in boiling point of a solution of 10gm of solute (mol. wt.=100) in 100 gm of water is ΔT_b, the ebullioscopic constant of water is:

(1) 10 (2) $10\Delta T_b$ (3) ΔT_b (4) $\frac{\Delta T_b}{10}$

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

(1) –0.360°C (2) –0.260°C
(3) +0.480°C (4) –0.480°C

72. A solution containing 12.5g of non-electrolyte substance in 185g of water shows boiling point elevation of 0.80 K. Calculate the molar mass of a substance. (K_b = 0.52 K kg mol^{-1})

(1) 53.06 g mol^{-1} (2) 25.3 g mol^{-1}
(3) 16.08 g mol^{-1} (4) 43.92 g mol^{-1}

73. 10% solution of urea is isotonic with 6% solution of a non-volatile solute X, what is the molecular mass of solute X?

(1) 6 g mol^{-1} (2) 60 g mol^{-1}

(3) 36 g mol^{-1} (4) 32 g mol^{-1}

74. Choose the correct statement.

(1) The boiling point of the solution falls on increasing the amount of the solute.

(2) The freezing point of the solution is lowered on adding more of solvent.

(3) The freezing point of the solution is raised on adding more of solute.

(4) The freezing point of the solution decreases on increasing the amount of the solute.

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

(1) 6239.3 g mol^{-1} (2) 12315.5 g mol^{-1}

(3) 3692.1 g mol^{-1} (4) 7368.4 g mol^{-1}

76. A solution is made by dissolving 20 g of a substance in 500ml of water. Its osmotic pressure was found to be 600 mm of Hg at 15°C. Find the molar mass of the substance.

(1) 1198 g mol^{-1} (2) 500 g mol^{-1}

(3) 1200 g mol^{-1} (4) 1000 g mol^{-1}

77. An aqueous solution of 2% non-volatile solute exerts a pressure of 1.004 bar at a normal boiling point of the solvent. What is the molar mass of the solute?

(1) 23.4 g mol^{-1} (2) 41.35 g mol^{-1}

(3) 10 g mol^{-1} (4) 20.8 g mol^{-1}

78. Which of the following statement is correct?

(1) A saturated solution will remain saturated at all temperatures.

(2) A plant cell swells when placed in hypertonic solution.

(3) The depression in freezing point is directly proportional to molality of the solution.

(4) Lowering in vapour pressure is a colligative property.

79. A solution containing 10.2 g glycerine per litre is isotonic with a 2% (w/v)solution of glucose. What is the molar mass of glycerine?

(1) 91.8 g/mol (2) 1198 g/mol

(3) 83.9 g/mol (4) 890.3 g/mol

80. Which among the following will show maximum osmotic pressure?

(1) 1M NaCl (2) 1M $MgCl_2$

(3) 1M $(NH_4)_3PO_4$ (4) 1M Na_2SO_4

81. What weight of glycerol should be added to 600 g of water in order to lower its freezing point by 10°C? (K_f = 1.86 K kg mol^{-1})

(1) 496 g (2) 297 g

(3) 310 g (4) 426 g

82. If 1 g of solute (molar mass = 50 g mol^{-1}) is dissolved in 50 g of solvent and the elevation in boiling point is 1 K. The molal elevation constant of the solvent is:

(1) 2 (2) 3 (3) 2.5 (4) 5

83. The colligative property is not represented by:

(1) Elevation in boiling point

(2) Osmotic pressure

(3) Optical activity

(4) Relative lowering of vapour pressure

84. Isotonic solutions have:

(1) Same boiling point (2) Same vapour pressure

(3) Same melting point (4) Same osmotic pressure

85. The boiling point of benzene is 353.23 K. When 1.80g of a non-volatile solute was dissolved in 90g of benzene,the boiling point is raised to 354.11 K. The molar mass of the solute is: (K_b for benzene is 2.53 K kg mol^{-1})

(1) 58 g mol^{-1} (2) 106 g mol^{-1}

(3) 174 g mol^{-1} (4) 232 g mol^{-1}

86. If the elevation in boiling point of a solution of 1 g of solute (molecular weight = 100) in 100 g of water is ΔT_b, the ebullioscopic constant of water is:

(1) 10 (2) 100 T_b (3) 10 ΔT_b (4) $\Delta T_b/10$

87. The osmotic pressure is expressed in the unit of:

(1) MeV (2) Calorie

(3) cm/sec (4) atm

88. Which of the following will have highest boiling point at 1 atm pressure?

(1) 0.1M NaCl (2) 0.1 M Sucrose

(3) 0.1M $BaCl_2$ (4) 01. M Glucose

89. The freezing point of one molal NaCl, assuming NaCl to be 100% dissociated in water is: (molar depression constant is 1.86)

(1) – 2.72°C (2) – 3.72°C

(3) 2.72°C (4) 3.72°C

90. What happens to freezing point of benzene when naphthalene is added?

(1) Increases

(2) Decreases

(3) Remain unchanged

(4) First decreases and then increases

91. The order of boiling point of four equimolar aqueous solutions is $C< B < A < D$. The correct order of their freezing point is:

(1) $D < C < B < A$ (2) $D > C < B < A$

(3) $D < A < B < C$ (4) $D > A > B > C$

92. The boiling point of a solution of 0.01g of a substance in 15 g of ether was found to be 0.1°C higher than that of pure ether. The molecular weight of the substance will be: (K_b = 2.16 K kg mol^{-1}).

(1) 13.6 (2) 14.4 (3) 15.8 (4) 16.6

93. Dissolution of 1.5 g of a non-volatile solute (molecular weight = 60) in 250 g of a solvent reduces its freezing point by 0.01°C. Find the molal depression constant of the solvent.

(1) 0.01 (2) 0.001 (3) 0.0001 (4) 0.1

94. A solution has higher osmotic pressure than its standard solution. Which of the following term will be used for this solution?

(1) Isotonic (2) Hypertonic
(3) Dilute (4) Hypotonic

95. The boiling point of 0.1molal $K_4[Fe(CN)_6]$ solution will be (Given K_b for water = 0.52 K kg mol^{-1}.

(1) 100.52°C (2) 100.104°C
(3) 100.26°C (4) 102.6°C

96. 2 g of an non-volatile solute is added to 500 g of solvent, freezing point of pure solvent = 5.48°C and that of solution is 4.47°C, K_f = 1.93 K kg mol^{-1} molecular mass of solute is:

(1) 7.72 (2) 7.64 (3) 7.32 (4) 7.06

97. Which has the least freezing point?

(1) 1% sucrose (2) 1% NaCl
(3) 1% $CaCl_2$ (4) 1% glucose

98. Which of the following solutions will have the highest boiling point?

(1) 0.1M $Al_2(SO_4)_3$ (2) 0.1M $FeCl_3$
(3) 0.1M NaCl (4) 0.1 M Urea

99. Two elements A and B form compounds of formula AB_2 and AB_4. When dissolved in 20.0g of benzene 1.0g of AB_2 lowers F.pt. by 2.3 K whereas 1.0g of AB_4 lowers F.pt. by 1.3 K. The K_f for benzene is 5.4. The atomic masses of A and B are respectively:

(1) 27, 45 (2) 42, 25 (3) 52, 48 (4) 48, 52

100. A compound MX_2 has observed and normal molar masses 65.6 and 164 respectively. Calculate the apparent degree of ionization of MX_2.

(1) 75% (2) 85% (3) 65% (4) 25%

101. Molal elevation constant and molal depression constant of water respectively (in Km^{-1}) are:

(1) 0.52, 1.86 (2) 1.86, 0.52
(3) 1.52, 0.86 (4) 0.86, 1.52

102. What is the normal b.p of an aqueous solution whose freezing point is –2.48°C?

(K_f = 1.86°C.kg/mol, K_b = 0.512°C.kg/mol)

(1) 100.7°C (2) 102.5°C
(3) 109.0°C (4) 99.3°C

103. The mass of glucose that should be dissolved in 100 g of water in order to produce same lowering of vapour pressure as is produced by dissolving 1 g of urea (mol. Mass = 60) in 50 g of water is: (Assume dilute solution in both cases)

(1) 1 g (2) 2 g (3) 6 g (4) 12 g

104. The osmotic pressure of a decimolar solution of urea at 27°C is

(1) 2.49 bar (2) 5 bar (3) 3.4 bar (4) 1.25 bar

105. What is the volume of solution containing 1 mole of sugar that will give rise to an osmotic pressure of 1 atm at 0°C?

(1) 11.2 lit (2) 112 lit
(3) 224 lit (4) 22.4 lit

106. Which of following representations of i (van't hoff factor) is not correct?

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

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

(3) $i = \dfrac{\text{No. of molecules actually present}}{\text{Molecules expected to be present}}$

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

107. Which of the following will have same value of Van't Hoff factor as that of $K_4\,[Fe(CN)_6]$?

(1) $Al_2\,(SO_4)_3$ (2) $AlCl_3$
(3) $Al\,(NO_3)_3$ (4) $Al(OH)_3$

108. What will be the degree of dissociation of 0.1 M $Mg(NO_3)_2$ solution if Van't Hoff factor is 2.74?

(1) 75% (2) 87%
(3) 100% (4) 92%

109. Which of the following has the highest freezing point?

(1) 1m NaCl solution (2) 1m KCl solution
(3) 1m $AlCl_3$ solution (4) 1m $C_6H_{12}O_6$ solution

110. If α is the degree of dissociation of Na_2SO_4, the van't Hoff's factor (*i*) used for calculating the molecular mass is:

(1) 1 + α (2) 1 – α (3) 1+ 2 α (4) 1 – 2α

111. The Van't Hoff factor of 0.005 M aqueous solution of KCl is 1.95. The degree of ionisation of KCl is:

(1) 0.95 (2) 0.97 (3) 0.94 (4) 0.96

112. 0.2 molal aq. HA acid ionises to the extent of 20%. K_f for acid is 1.86, then calculate the freezing point of the solution.

(1) –0.45°C (2) –0.50°C
(3) –0.31°C (4) –0.53°C

113. Van't Hoff factor more than unity indicates that the solute in solution is:

(1) Dissociated (2) Associated
(3) Both (1) and (2) (4) Cannot say anything

114. KBr is 80% dissociated in aqueous solution of 0.5 m concentration (given, K_f for water = 1.86 K Kg mol^{-1}). The solution freezes at:

(1) 271.326 K (2) 272 K
(3) 270.5 K (4) 268.5 K

115. Van't Hoff factor of $Ca(NO_3)_2$ is:

(1) One (2) Two (3) Three (4) Four

PRABAL EXERCISE-2 (LEARNING PLUS)

1. Which of the following units is useful in relating concentration of solution with its vapour pressure?

(1) Mole fraction (2) Parts per million
(3) Mass percentage (4) Molality

2. On dissolving sugar in water at room temperature solution feels cool to touch. Under which of the following cases dissolution of sugar will be most rapid?

(1) Sugar crystals in cold water
(2) Powdered sugar in cold water
(3) Sugar crystals in hot water
(4) Powdered sugar in hot water

3. At equilibrium, the rate of dissolution of a solid solute in a volatile liquid solvent is:

(1) Less than the rate of crystallisation
(2) Greater than the rate of crystallisation
(3) Equal to the rate of crystallisation
(4) Zero

4. A beaker contains a solution of substance A. Precipitation of substance A takes place when small amount of A is added to the solution. The solution is:

(1) Saturated (2) Supersaturated
(3) Unsaturated (4) Concentrated

5. Maximum amount of a solid solute that can be dissolved in amount of a given liquid solvent does not depend upon:

(1) Temperature (2) Nature of solute
(3) Pressure (4) Nature of solvent

6. Low concentration of oxygen in the blood and tissues of people living at high altitude is due to:

(1) Low temperature
(2) Low atmospheric pressure
(3) High atmospheric pressure
(4) Both low temperature and high atmospheric pressure

7. Considering the formation, breaking and strength of hydrogen bond, predict which of the following mixtures will show a positive deviation from Raoult's law?

(1) Methanol and acetone
(2) Chloroform and acetone
(3) Nitric acid and water
(4) Phenol and aniline

8. Colligative properties depend on:

(1) The nature of the solute particles dissolved in solution
(2) The number of solute particles in solution
(3) The physical properties of the solute particles dissolved in solution
(4) The nature of solvent particles

9. Which of the following aqueous solutions should have the highest boiling point?

(1) 1.0 M NaOH (2) 1.0 MNa_2SO_4
(3) 1.0 M NH_4NO_3 (4) 1.0 MKNO_3

10. The unit of ebullioscopic constant is:

(1) K kg mol^{-1} or K (molality)$^{-1}$
(2) mol kg K^{-1} or K^{-1} (molality)
(3) kg mol^{-1} K^{-1} or K^{-1} (molality)$^{-1}$
(4) K mol kg^{-1} or K (molality)

11. In comparison to a 0.01 M solution of glucose, the depression in freezing point of a 0.01 M $MgCl_2$ solution is:

(1) The same (2) About twice
(3) About three times (4) About six times

12. An unripe mango placed in a concentrated salt solution to prepare pickle shrivels because:

(1) It gains water due to osmosis.
(2) It loses water due to reverse osmosis.
(3) It gains water due to reverse osmosis.
(4) It loses water due to osmosis.

13. At a given temperature, osmotic pressure of a concentrated solution of a substance:

(1) Is higher than that of a dilute solution.
(2) Is lower than that of a dilute solution.
(3) Is same as that of a dilute solution.
(4) Cannot be compared with osmotic pressure of dilute solution.

14. Which of the following statements is false?

(1) Two different solutions of sucrose of same molality prepared in different solvents will have the same depression in freezing point.
(2) The osmotic pressure of a solution is given by the equation $\pi = CRT$ (where, C is the molarity of the solution.
(3) Decreasing order of osmotic pressure for 0.01 M aqueous solutions of barium chloride, potassium chloride, acetic acid and sucrose is $BaCl_2 > KCl > CH_3COOH >$ sucrose.
(4) According to Raoult's law, the vapor pressure exerted by a volatile component of a solution is directly proportional to its mole fraction in the solution.

15. The values of van't Hoff factors for KCl, NaCl and K_2SO_4 respectively are:

(1) 2, 2 and 2 (2) 2, 2 and 3
(3) 1, 1 and 2 (4) 1, 1 and 1

16. Which of the following statements is false?

(1) Units of atmospheric pressure and osmotic pressure are the same.

(2) In reverse osmosis, solvent molecules move through a semipermeable membrane from a region of lower concentration of solute to a region of higher concentration.

(3) The value of molal depression constant depends on nature of solvent.

(4) Relative lowering of vapour pressure, is a dimensionless quantity.

17. Value of Henry's constant K_H:

(1) Increases with increase in temperature represents the decrease in solubility.

(2) Decreases with increase in temperature the decrease in solubility.

(3) Remains constant

(4) First increases then decreases

18. The value of Henry's constant, K_H is:

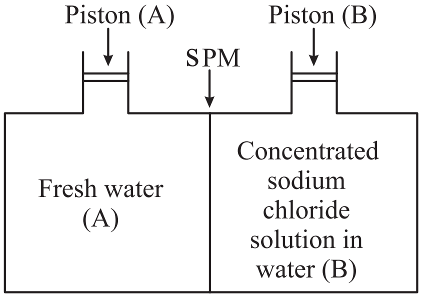
(1) Greater for gases with higher solubility

(2) Greater for gases with lower solubility

(3) Constant for all gases

(4) Not related to the solubility of gases

19. Consider the figure and mark the correct option:



(1) Water will move from side (A) to side (B) if a pressure lower than osmotic pressure is applied on piston (B).

(2) Water will move from side (B) to side (A) if a pressure greater than osmotic pressure is applied on piston (B).

(3) Water will move from side (B) to side (A) if a pressure equal to osmotic pressure is applied on piston (B).

(4) Water will move from side (A) to side (B) if pressure equal to osmotic pressure is applied on piston (B).

20. We have three aqueous solutions of NaCl labelled as 'A', 'B' and 'C with concentrations 0.1 M, 0.01 M and 0.001 M, respectively. The value of van't Hoff factor for these solutions will be in the order:

(1) iA < iB < iC (2) iA > iB > iC

(3) iA = iB = iC (4) iA < iB > iC

21. On the basis of information given below mark the correct option: Information

(*i*) In bromoethane and chloroethane mixture intermolecular interactions of A—A and B—B type are nearly same as A—B type interactions.

(*ii*) In ethanol and acetone mixture A—A or B—B type intermolecular interactions are stronger than A—B type interactions.

(*iii*) In chloroform and acetone mixture A—A or B—B type intermolecular interactions are weaker than A—B type interactions.

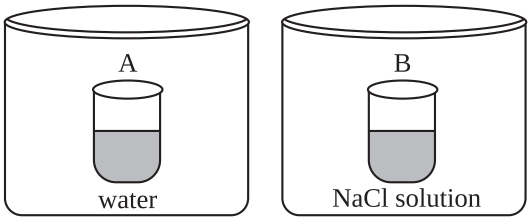
(1) Solution (*i*) will not follow Raoult's law

(2) Solution (*ii*) will show positive deviation from Raoult's law

(3) Solution (*i*) will show negative deviation from Raoult's law

(4) Solution (*iii*) will show positive deviation from Raoult's law

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



At a given temperature, which of the following statement is correct about the vapour pressure of pure water and that of NaCl solution?

(1) Vapour pressure in container (A) is more than that in container (B).

(2) Vapour pressure in container (A) is less than that in container (B).

(3) Vapour pressure is equal in both the containers.

(4) Vapour pressure in container (B) is twice the vapour pressure in container (A).

23. In isotonic solutions:

(1) Solute and solvent both are always different.

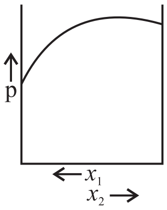
(2) Osmotic pressure is same.

(3) Solute and solvent are always same.

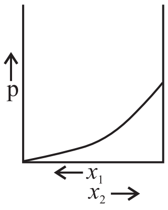
(4) Vapour pressure is always same.

24. For a binary ideal liquid solution, the variation in total vapour pressure versus composition of solution is given by which of the curves?

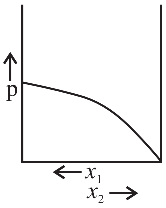
(1)



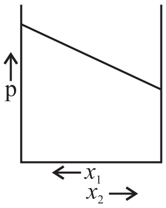
(2)



(3)



(4)



25. On the basis of information given below mark the correct option.

Information: On adding acetone to methanol some of the hydrogen bonds between methanol molecules break:

(1) At specific composition methanol-acetone mixture will form minimum boiling azeotrope and will show positive deviation from Raoult's law

(2) At specific composition methanol-acetone mixture will form maximum boiling azeotrope and will show positive deviation from Raoult's law

(3) At specific composition methanol-acetone mixture will form minimum boiling azeotrope and will show negative deviation from Raoult's law

(4) At specific composition methanol-acetone mixture will form maximum boiling azeotrope and will show negative deviation from Raoult's law

26. K_H value for Ar(g), CO_2 (g), HCHO (g) and CH_4 (g) are 40.39, 1.67, 1.83×10^{-5} and 0.413 respectively. Arrange these gases in the order of their increasing solubility:

(1) $HCHO < CH_4 < CO_2 < Ar$

(2) $HCHO < CO_2 < CH_4 < Ar$

(3) $Ar < CO_2 < CH_4 < HCHO$

(4) $Ar < CH_4 < CO_2 < HCHO$

27. Which of the following factor(s) affect the solubility of a gaseous solute in the fixed volume of liquid solvent?

(*i*) Nature of solute

(*ii*) Temperature

(*iii*) Pressure

(1) (*i*) and (*iii*) at constant T

(2) (*i*) and (*ii*) at constant p

(3) Only (*iii*)

(4) Both (1) and (2)

28. Intermolecular forces between two benzene molecules are nearly of same strength as those between two toluene molecules. For a mixture of benzene and toluene, which of the following is/are not true?

(1) $\Delta_{mix} H$ = zero

(2) $\Delta_{mix} V$ = zero

(3) These will form maximum boiling azeotrope

(4) These will form ideal solution

29. Relative lowering of vapour pressure is a colligative property because:

(1) It depends on the concentration of a non-electrolyte solute in solution and does not depend on the nature of the solute molecules.

(2) It does not depend on number of particles of electrolyte solute in solution and does not depend on the nature of the solute particles.

(3) It depends on the concentration of a non-electrolyte solute in solution as well as on the nature of the solute molecules.

(4) It depends on the concentration of an electrolyte or non-electrolyte solute in solutions as well as depend on the nature of solute molecules.

30. Van't Hoff factor (*i*) is given by the expression:

(1) $i = \dfrac{\text{normal molar mass}}{\text{abnormal molar mass}}$

(2) $i = \dfrac{\text{abnormal molar mass}}{\text{normal molar mass}}$

(3) $i = \dfrac{\text{observed colligative property}}{\text{calculated colligative property}}$

(4) $i = \dfrac{\text{calculated colligative property}}{\text{observed colligative property}}$

31. Isotonic aqueous solutions must have the same:

(1) Solute

(2) Density

(3) Elevation in boiling point

(4) Both (1) and (2)

32. Which of the following binary mixtures will have same composition in liquid and vapour phase?

(1) Benzene-toluene

(2) Water-HNO_3

(3) Water-ethanol

(4) *n*-hexane – *n*-heptane

33. Discounting economic considerations, which of the following would be the best to shrink an icy road, in quantities proportion to their respective formula weights:

(1) NaCl

(2) $CaCl_2$

(3) $CuSO_4.5H_2O$

(4) $Al_2(SO_4)_3$

34. Van't Hoff factor of Hg_2Cl_2 in its aqueous solution will be: (Hg_2Cl_2 is 80% ionized in the solution)

(1) 1.6

(2) 2.6

(3) 3.6

(4) 4.6

35. Which of the following solutions will have the highest boiling point?

(1) 1% of glucose in water

(2) 1% sucrose in water

(3) 1% NaCl in water

(4) 1% $CaCl_2$ in water

36. Benzoic acid is dissolved in benzene, van't Hoff factor will be:

(1) 1

(2) 0.5

(3) 1.5

(4) 2

37. The freezing point depression constant for water is 1.86 K kg mol^{-1}. If 5.00 g Na_2SO_4 is dissolved in 45.0 g H_2O, the freezing point is changed by –3.82°C. Calculate the van't Hoff factor for Na_2SO_4:

(1) 0.381

(2) 2.05

(3) 2.63

(4) 3.11

38. The van't Hoff factor (*i*) for a compound which undergoes dissociation in one solvent and association in other solvent is respectively:

(1) Greater than one and greater than one

(2) Less than one and less greater than one

(3) Less than one and less than one

(4) Greater than one and less than one

39. What is the freezing point of a solution containing 8.2 g of HBr in 100 g water, assuming the acid to be 90% ionised? (K_f for water = 1.86 K kg mol^{-1})

(1) 0.85°C

(2) –3.622°C

(3) 0°C

(4) –0.35°C

40. Maximum relative lowering of vapour pressure is observed in the case of:

(1) 0.1 M glucose

(2) 0.1 M $BaCl_2$

(3) 0.1 M $MgSO_4$

(4) 0.1 M NaCl

PARIKSHIT EXERCISE-3 (MULTICONCEPT)

MATCH THE COLUMN MCQs

1. Match the list-I with list-II.

List-I		List-II	
A.	Roult's law	P.	$x'_A = \frac{P_A}{P_T}$
B.	Henry's law	Q.	$P_A = P_A^o.x$
C.	Dalton's law	R.	$P = K_H x$
D.	Van't Hoff	S.	Abnormal molecular wt.

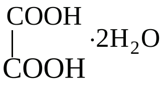
(1) A-(S); B-(P); C-(Q); D-(R)

(2) A-(S); B-(P); C-(Q); D-(R, S)

(3) A-(Q); B-(R); C-(P); D-(S)

(4) A-(S); B-(P, R); C-(Q); D-(R)

2. Match the list-I with list-II.

List-I		List-II	
A.	$[Co(NH_3)_6]Cl_3$	P.	i = 1
B.	$C_6H_{12}O_6$	Q.	i = 4
C.	 $\underset{COOH}{\overset{COOH}{\vert}} \cdot 2H_2O$	R.	i = 3
D.	$[Co(NH_3)_3Cl]Cl_2$	S.	i = 2

(1) A-(Q); B-(P); C-(S); D-(R)

(2) A-(R); B-(S); C-(P); D-(Q)

(3) A-(P); B-(Q); C-(S); D-(R)

(4) A-(S); B-(P); C-(Q); D-(R)

3. Match the list-I with list-II.

List-I		List-II	
A.	$HClO_4$ (aq.)	P.	i = 5
B.	CH_3COOH (In Benzene)	Q.	i = 2
C.	$K_4[Fe(CN)_6]$ (aq)	R.	i = 1/2
D.	$NaClO_3$ (In Hexane)	S.	i = 1

(1) A-(Q); B-(R); C-(P); D-(S)

(2) A-(Q); B-(S); C-(P); D-(R)

(3) A-(P); B-(R); C-(Q); D-(S)

(4) A-(Q); B-(R); C-(P); D-(P)

4. Match the list-I with list-II.

List-I		List-II	
A.	Soda water	P.	A solution of gas in solid
B.	Sugar solution	Q.	A solution of gas in gas
C.	German silver	R.	A solution of solid in liquid
D.	Air	S.	A solution of solid in solid
E.	Hydrogen gas in palladium	T.	A solution of gas in liquid
		U.	A solution of liquid in solid

(1) A-(T); B-(R); C-(S); D-(Q); E-(P)

(2) A-(Q); B-(P); C-(R); D-(T); E-(S)

(3) A-(T); B-(S); C-(R); D-(Q); E-(P)

(4) A-(P); B-(T); C-(U); D-(Q); E-(R)

5. Match the list-I with list-II.

List-I		List-II	
A.	Partial vapour pressure of liquid	P.	Denoted by $i = \frac{\text{Particles after association or dissociation}}{\text{Initial number of particles}}$
B.	Vapour composition	Q.	$P_A = P_A^o \cdot x_A$
C.	Depression in Freezing point	R.	$X'_A = \frac{P_A}{P_T}$
D.	Van't Hoff factor	S.	$\Delta T_f = k_f xm$

(1) A-(Q); B-(R); C-(S); D-(P)

(2) A-(P); B-(Q); C-(R); D-(S)

(3) A-(P); B-(S); C-(P); D-(R)

(4) A-(P); B-(S); C-(P); D-(R)

6. p_A = partial pressure of component A in liquid mixture, P_A° = vapour pressure of A, χ_A = mole fraction of A in liquid mixture

List-I		List-II	
A.	$C_2H_5OH + H_2O$	P.	Azeotropic mixture
B.	$C_2H_5Br + C_2H_5I$	Q.	Obeys Raoult's law
C.	$p_A = \chi_A P_A^\circ$	R.	Non-ideal solution with positive deviation
D.	$H_2O + H_2SO_4$	S.	Non-ideal solution with negative deviation
		T.	Ideal solution

(1) A-(Q, T); B-(P, R); C-(P, S); D-(P, Q)

(2) A-(P, R); B-(Q, T); C-(Q, T); D-(P, S)

(3) A-(Q, Q); B-(P, S); C-(P, R); D-(Q, T)

(4) A-(P); B-(P, R); C-(Q, S); D-(P, R)

7. Match the list-I with list-II.

List-I		List-II	
A.	$P^\circ - P_s$	P.	$\frac{\text{Observed colligative property}}{\text{Normal colligative property}}$
B.	$P^\circ \times \chi_A = P_A$	Q.	Lowering in vapour pressure
C.	Mixture that boils like pure solvent	R.	Azeotropic mixture
D.	Van't Hoff factor	S.	Raoult's law

(1) A-(Q); B-(S); C-(R); D-(P)
(2) A-(S); B-(R); C-(P); D-(Q)
(3) A-(P); B-(Q); C-(S); D-(R)
(4) A-(R); B-(P); C-(Q); D-(S)

8. Mw_N = Normal molecular mass of solute
Mw_2 = Observed molecular of solute from colligative property measurement

List-I		List-II	
A.	$Mw_2 < Mw_N$	P.	0.1 M CH_3 COOH in benzene
B.	$Mw_2 \approx (Mw_N)/3$	Q.	0.1 M urea in water
C.	$Mw_2 > Mw_N$	R.	0.05 M barium chloride in water
D.	$Mw_2 = Mw_N$	S.	0.1 CH_3 COOH in water

(1) A-(R, S); B-(R); C-(P); D-(Q)
(2) A-(R); B-(P); C-(Q); D-(S)
(3) A-(P); B-(R, S); C-(R); D-(P)
(4) A-(Q); B-(P); C-(S); D-(R)

9. Match the list-I with list-II.

List-I		List-II	
A.	Saturated solution	P.	Solution having same osmotic pressure at a given temperature as that of given solution
B.	Binary solution	Q.	A solution whose osmotic pressure is less than that of another.
C.	Isotonic solution	R.	Solution with two components
D.	Hypotonic solution	S.	A solution which contains maximum amount of solute that can be dissolved in a given amount of solvent at a given temperature
E.	Solid solution	T.	A solution whose osmotic pressure is more than that of another
F.	Hypertonic solution	U.	A solution in solid phase

(1) A-(P); B-(R); C-(Q); D-(S); E-(T); F-(U)
(2) A-(Q); B-(R); C-(U); D-(T); E-(P); F-(S)
(3) A-(S); B-(R); C-(P); D-(Q); E-(U); F-(T)
(4) A-(S); B-(R); C-(Q); D-(P); E-(T); F-(U)

10. Match the list-I with list-II.

List-I		List-II	
A.	Raoult's law	P.	Effect of pressure on the solubility of gas in liquid
B.	Henry's law	Q.	$\frac{P^\circ - P_s}{P^\circ} = \chi_B$
C.	Ethyl alcohol + Water	R.	Ideal solution
D.	Benzene + Toluene	S.	Azeotropic mixture

(1) A-(P); B-(Q); C-(R); D-(S)
(2) A-(R); B-(S); C-(P); D-(Q)
(3) A-(Q,R); B-(P); C-(S); D-(R)
(4) A-(S); B-(R); C-(Q); D-(P)

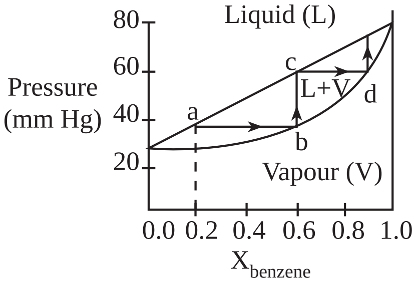
CORRECT-INCORRECT STATEMENT MCQs

11. If mole fraction of solvent in solution decreases, then which of the following statement is correct?
(1) Vapour pressure of solution increases
(2) B.P. decreases
(3) Osmotic pressure increases
(4) All are correct

12. There are some of the characteristics of the supersaturated solution:
A. Equilibrium exists between solutions and solute.
B. If a crystal of solute is added to supersaturated solution, crystallization occurs rapidly.
C. Supersaturated solutions contain more solute than they should at a particular temperature.

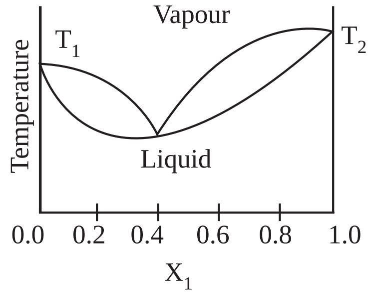
Correct characteristics of supersaturated solutions are:
(1) A, B, C
(2) B, C
(3) A, C
(4) A, B

13. A graph is plotted between the vapour pressure and mole fraction of a solution containing benzene and toluene. Choose the incorrect options.

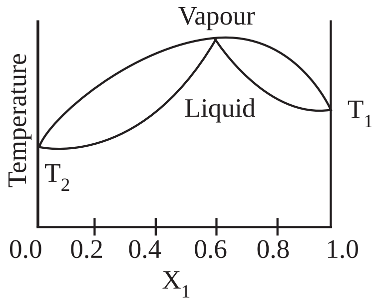


(1) At the point a, the mole fraction of toluene is 0.80.
(2) b → c represents condensation
(3) c → d represents vaporization
(4) c → d represents vaporization as well as condensation

14. The following two graphs are plotted between the temperature and mole fraction of the component of two different azeotropic mixtures. (X_1 = mole fraction of solvent).



Graph A



Graph B

Choose the correct options

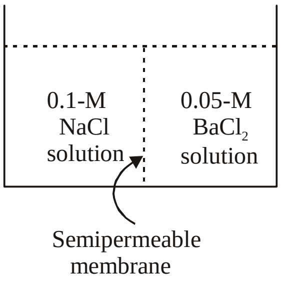
(1) Graph A represents minimum boiling point and maximum vapour pressure.

(2) Graph B represent minimum boiling point and minimum vapour pressure.

(3) Graph A represents maximum boiling point and minimum vapour pressure.

(4) Graph B represents minimum boiling point and maximum vapour pressure.

15. Study the following figure, and choose the correct options.



(1) There will be no movement of any solution across the membrane.

(2) Solvent of $BaCl_2$ will flow towards the NaCl solution.

(3) NaCl will flow towards the $BaCl_2$ solution.

(4) The osmotic pressure of 0.1 M NaCl is lower than the osmotic pressure of 0.05 M $BaCl_2$, assuming complete dissociation of the electrolyte.

16. Incorrect statement is:

(1) Vapour pressure should be measured only at equilibrium.

(2) Vapour pressure increases with increasing temperature.

(3) Vapour pressure does not depends on open surface area of liquid.

(4) Vapour pressure of liquid decreases with increasing temperature.

17. At 35°C, the vapour pressure of CS_2 is 512 mm Hg, and of acetone is 344 mm Hg. A solution of CS_2 and acetone in, which the mol fraction of CS_2 is 0.25, has a total vapour pressure of 600 mm Hg. Which of the following statement is/are correct?

(1) A mixture of 100 mL of acetone and 100 mL of CS_2 has a volume of 200 mL.

(2) When acetone and CS_2 are mixed at 35°C, heat must be absorbed in order to produce a solution at 35°C.

(3) When acetone and CS_2 are mixed at 35°C, heat is released.

(4) There is negative deviation from Raoult's law.

18. Which of the following statements is correct, if the intermolecular forces in liquids A, B and C are in the order $A < B < C$?

(1) B evaporates more readily than A

(2) B evaporates less readily than C

(3) A and B evaporate at the same rate

(4) A evaporates more readily than C

19. Acetone and chloroform interact feebly to give weak hydrogen bond. Which one of the following is correct for this solution?

(1) The solution obeys Raoult's law

(2) The solution shows –ve deviation from Raoult's law.

(3) The solution shows +ve deviation from the Raoult's law.

(4) There is a slight increases in volume.

20. If 0.1 M solution of glucose and 0.1 M urea solution are placed on two sides of a semipermeable membrane to equal heights, then it will be correct to say that-

(1) There will be no net movement across the membrane

(2) Glucose will flow towards urea solution

(3) Urea will flow towards glucose solution

(4) Water will flow from urea solution towards glucose solution

STATEMENT BASED MCQs

(1) Both Statement-I and Statement-II are correct.

(2) Both Statement-I and Statement-II are incorrect.

(3) Statement-I is correct & Statement-II is incorrect.

(4) Statement-I is incorrect & Statement-II is correct.

21. **Statement-I:** The mass of acetic acid molecule in benzene is more than the actual value of the solute.

Statement-II: Molecules of acetic acid dimerise in benzene due to hydrogen bonding.

22. **Statement-I:** Henry's law and Raoult's law are not independent, i.e., one can be derived from the other.

    Statement-II: The partial pressure is directly proportional to the mole fraction of the concerned species for ideal solutions.

23. **Statement-I:** The osmotic pressure of 0.1 M urea solution is less than 0.1 M NaCl solution.

    Statement-II: Osmotic pressure is not a colligative property.

24. **Statement-I:** van't Hoff factor for electrolytes is always more than unity.

    Statement-II: The number of particles increases in solution due to electrolytic dissociation.

25. **Statement-I:** Non-ideal solutions form an azeotropic mixture

    Statement-II: The boiling point of an azeotropic mixture is only higher than boiling points of both components

26. **Statement-I:** Ebulliscopy or cryoscopy is generally not used for the determination of Mol. wt. of polymers.

    Statement-II: High molecular weight solute leads to very low value of ΔT_b or ΔT_f.

27. **Statement-I:** Near the freezing point of an aqueous solution of a non-volatile solute only ice separates out.

    Statement-II: The remaining solution shows equilibrium between solid solvent-liquid solvent.

28. **Statement-I:** Vapour pressure of 0.5 M sugar solution is more than 0.5 M KCl solution.

    Statement-II: Relative lowering of vapour pressure is directly proportional to the number of species present in the solution.

29. **Statement-I:** On adding NaCl to water its vapour pressure increase.

    Statement-II: Addition of non-volatile solute decreases the vapour pressure.

30. **Statement-I:** Osmotic pressure of non-aqueous solutions can be determined by Berkeley-Hartley method.

    Statement-II: The semipermeable membrane used in Berkeley-Harley method is $Cu_2[Fe(CN)_6]$.

ASSERTION & REASON MCQs

(1) Assertion (A) is true, Reason (R) is true; Reason (R) is a correct explanation for Assertion (A).

(2) Assertion (A) is true, Reason (R) is true; Reason (R) is not a correct explanation for Assertion (A).

(3) Assertion (A) is true, Reason (R) is false.

(4) Assertion (A) is false, Reason (R) is true.

31. **Assertion (A):** 0.1 M solution of NaCl has greater osmotic pressure than 0.1 M solution of glucose at same temperature.

    Reason (R): In solution, NaCl dissociates to produce more number of particles.

32. **Assertion (A):** Relative lowering of vapour pressure is equal to mole fraction of the solvent.

    Reason (R): Relative lowering of vapour pressure is a colligative property.

33. **Assertion (A):** Two solutions having same osmotic pressures will also have same vapour pressures.

    Reason (R): Relative lowering of vapour pressure is a colligative property.

34. **Assertion (A):** Cooking time is reduced in pressure cooker.

    Reason (R): Boiling point of water inside the pressure cooker is elevated.

35. **Assertion (A):** Larger the value of cryoscopic constant of the solvent, lesser will be the freezing point of the solution.

    Reason (R): Depression in freezing point depends only on the nature of solvent.

36. **Assertion (A):** Molarity and molality of 111 mg $CaCl_2$ in/kg H_2O is nearly same.

    Reason (R): In dilute aqueous solution molarity and molality are apporimately equal.

37. **Assertion (A):** The freezing point of water is depressed by the addition of glucose.

    Reason (R): Entropy of solution is less than entropy of pure solvent.

38. **Assertion (A):** Molal elevation constant depends on the nature of solvent.

    Reason (R): Molal elevation constant is the elevation in boiling point when 1 mole of the non volatile solute is dissolved in 1 kg of solvent.

39. **Assertion (A):** 1 molal aqueous solution is always more concentrated than 1 molar aqueous solution.

    Reason (R): A molal solution contains one mole of solute in 1000 gm. of solvent.

40. **Assertion (A):** At ice $\rightleftharpoons$ water equilibrium, on increasing the pressure freezing point of water decreases.

    Reason (R): Ice have low density so equilibrium shift in forward direction when pressure is increased.

PYQ's EXERCISE-4 (NEET PAST YEAR QUESTIONS)

1. Given below are two statements: one is labelled as Assertion A and the other is labelled as Reason R: **(2023)**

Assertion (A): Helium is used to dilute oxygen in diving apparatus.

Reasons (R): Helium has high solubility in O_2. In the light of the above statements, choose the correct answer from the options given below:

(1) (A) is false but (R) is true.

(2) Both (A) and (R) are true and (R) is the correct explanation of (A).

(3) Both (A) and (R) are true and (R) is NOT the correct explanation of (A).

(4) (A) is true but (R) is false.

2. In one molal solution that contains 0.5 mole of a solute, there is: **(2022)**

(1) 1000 g of solvent (2) 500 mL of solvent

(3) 500 g of solvent (4) 100 mL of solvent

3. Which one is not correct mathematical equation for Dalton's Law of partial pressure? Here p = total pressure of gaseous mixture. **(2022)**

(1) $p_i = x_i p_i^o$, where x_i = mole fraction of ith gas in gaseous mixture

p_i^o = pressure of ith gas in pure state

(2) $p = p_1 + p_2 + p_3$

(3) $p = n_1\frac{RT}{V} + n_2\frac{RT}{V} + n_3\frac{RT}{V}$

(4) $p_i = x_i p$, where p_i = partial pressure of ith gas

x_i = mole fraction of ith gas in gaseous mixture

4. The following solutions were prepared by dissolving 10g of glucose ($C_6H_{12}O_6$) in 250 ml of water (P_1), 10g of urea (CH_4N_2O) in 250 ml of water (P_2) and 10g of sucrose ($C_{12}H_{22}O_{11}$) in 250 ml of water (P_3). The right option for the decreasing order of osmotic pressure of these solutions is: **(2021)**

(1) $P_1 > P_2 > P_3$ (2) $P_2 > P_3 > P_1$

(3) $P_3 > P_1 > P_2$ (4) $P_2 > P_1 > P_3$

5. The correct option for the value of vapour pressure of a solution at 45°C with benzene to octane in molar ratio 3 : 2 is:

[At 45°C vapour pressure of benzene is 280 mm Hg and that of octane is 420 mm Hg. Assume Ideal gas] **(2021)**

(1) 168 mm of Hg (2) 336 mm of Hg

(3) 350 mm of Hg (4) 160 mm of Hg

6. The mixture which shows positive deviation from Raoult's law is: **(2020)**

(1) Benzene + Toluene

(2) Acetone + Chloroform

(3) Chloroethane + Bromoethane

(4) Ethanol + Acetone

7. The freezing point depression constant (K_f) of benzene is 5.12 K kg mol^{-1}. The freezing point depression for the solution of molality 0.078 m containing a non-electrolyte solute in benzene is (rounded off upto two decimal places): **(2020)**

(1) 0.80 K (2) 0.40 K (3) 0.60 K (4) 0.20 K

8. If 8 g of a non-electrolyte solute is dissolved in 114 g of n-octane to reduce its vapour pressure to 80%, the molar mass (in g mol^{-1}) of the solute is

[Given that molar mass of n-octane is 114 g mol^{-1}] **(2020-Covid)**

(1) 60 (2) 80 (3) 20 (4) 40

9. Isotonic solutions have same: **(2020-Covid)**

(1) Freezing temperature (2) Osmotic pressure

(3) Boiling temperature (4) Vapour pressure

10. For an ideal solution, the correct option is: **(2019)**

(1) $\Delta_{mix} S = 0$ at constant T and P

(2) $\Delta_{mix} V \neq 0$ at constant T and P

(3) $\Delta_{mix} H = 0$ at constant T and P

(4) $\Delta_{mix} G = 0$ at constant T and P

11. The mixture that forms maximum boiling azeotrope is: **(2019)**

(1) Water + Nitric acid

(2) Ethanol + Water

(3) Acetone + Carbon disulphide

(4) Heptane + Octane

12. If molality of the dilute solution is doubled, the value of molal depression constant (K_f) will be: **(2017-Delhi)**

(1) Unchanged (2) Doubled

(3) Halved (4) Tripled

13. Which of the following is dependent on temperature? **(2017-Delhi)**

(1) Weight percentage (2) Molality

(3) Molarity (4) Mole fraction

14. Toluene in the vapour phase is in equilibrium with a solution of benzene and toluene having mole fraction of toluene 0.50. If vapour pressure of pure benzene is 119 torr and that of toluene is 37.0 torr at the same temperature, mole fraction of toluene in vapour phase will be: **(2017-Gujarat)**

(1) 0.325 (2) 0.462

(3) 0.237 (4) 0.506

15. Which one of the following is incorrect for ideal solution? **(2016-II)**

(1) $\Delta P = P_{obs} - P_{\text{calculated by Raoult's law}} = 0$

(2) $\Delta G_{mix} = 0$

(3) $\Delta H_{mix} = 0$

(4) $\Delta U_{mix} = 0$

16. The van't Hoff factor (i) for a dilute aqueous solution of the strong electrolyte barium hydroxide is: **(2016-II)**

(1) 2 (2) 3 (3) 0 (4) 1

17. At 100°C, the vapour pressure of a solution of 6.5g of a solute in 100g water is 732 mm. If $K_b = 0.52$, the boiling point of this solution will be: **(2016-I)**

(1) 103° C (2) 101° C

(3) 100° C (4) 102° C

18. Which of the following statements about the composition of the vapour over an ideal 1 : 1 molar mixture of benzene and toluene is correct? Assume that the temperature is at 25°C.

(Given, vapour pressure data at 25°C, benzene = 12.8 kPa, toluene = 3.85 kPa) **(2016-I)**

(1) The vapour will contain equal amounts of benzene and toluene

(2) Not enough information is given to make a prediction

(3) The vapour will contain a higher percentage of benzene

(4) The vapour will contain a higher percentage of toluene

19. What is the mole fraction of the solute in a 1.00 m aqueous solution? **(2015 Re)**

(1) 0.0177 (2) 0.177

(3) 1.770 (4) 0.0354

20. Which one of the following electrolytes has the same value of van't Hoff's factor (*i*) as that of $Al_2(SO_4)_3$ (if all are 100% ionised)? **(2015)**

(1) $K_3[Fe(CN)_6]$ (2) $Al(NO_3)_3$

(3) $K_4[Fe(CN)_6]$ (4) K_2SO_4

21. Which one is not equal to zero for an ideal solution? **(2015)**

(1) ΔS_{mix} (2) ΔV_{mix}

(3) $\Delta P = P_{observed} - P_{Raoult}$ (4) ΔH_{mix}

22. The boiling point of 0.2 mol kg^{-1} solution of X in water is greater than equimolal solution of Y in water. Which one of the following statements is true in this case? **(2015)**

(1) Molecular mass of X is greater than the molecular mass of Y.

(2) Molecular mass of X is less than the molecular mass of Y.

(3) Y is undergoing dissociation in water while X undergoes no change.

(4) X is undergoing dissociation in water.

23. Of the following 0.10 m aqueous solutions, which one will exhibit the largest freezing point depression? **(2014)**

(1) $C_6H_{12}O_6$ (2) $Al_2(SO_4)_3$

(3) K_2SO_4 (4) KCl

Answer Key

CONCEPT APPLICATION

1. 5.8 ppm **2.** (*a*) 37.92 %, (*b*) 0.065, (*c*) Molality of Na^+ = 7.73 m, Molality of $S_2O_3^{2-}$ = 3.86 m **3.** (1) **4.** (4)
5. (3) **6.** (1) **7.** (2) **8.** (4) **9.** 0.52 K kg mol^{-1} **10.** (4) **11.** (3) **12.** w = 494.6 g
13. w = 247.31 g **14.** 0.22167 atm **15.** 59.99 g mol^{-1} **16.** (4) **17.** 46.3334°C

BOARD LEVEL PROBLEMS

Multiple Choice Questions

1. (1) **2.** (2) **3.** (3) **4.** (4) **5.** (4) **6.** (2) **7.** (4) **8.** (3) **9.** (1) **10.** (1)

Assertion and Reason Questions

1. (4) **2.** (1)

Match the Column Type Questions

1. (4) **2.** (1)

Case Based Study Type

1. (4) **2.** (4) **3.** (1) **4.** (3)

PRARAMBH EXERCISE-1 (TOPICWISE)

1. (3) **2.** (3) **3.** (1) **4.** (2) **5.** (1) **6.** (1) **7.** (3) **8.** (1) **9.** (1) **10.** (2)
11. (4) **12.** (2) **13.** (3) **14.** (2) **15.** (4) **16.** (4) **17.** (2) **18.** (1) **19.** (1) **20.** (3)
21. (4) **22.** (3) **23.** (4) **24.** (3) **25.** (2) **26.** (3) **27.** (1) **28.** (3) **29.** (2) **30.** (2)
31. (1) **32.** (1) **33.** (1) **34.** (1) **35.** (4) **36.** (2) **37.** (2) **38.** (3) **39.** (3) **40.** (4)
41. (1) **42.** (3) **43.** (2) **44.** (3) **45.** (1) **46.** (1) **47.** (2) **48.** (1) **49.** (2) **50.** (3)
51. (4) **52.** (1) **53.** (1) **54.** (1) **55.** (4) **56.** (3) **57.** (2) **58.** (2) **59.** (4) **60.** (3)
61. (1) **62.** (2) **63.** (2) **64.** (3) **65.** (1) **66.** (1) **67.** (3) **68.** (1) **69.** (4) **70.** (3)
71. (4) **72.** (4) **73.** (3) **74.** (4) **75.** (1) **76.** (1) **77.** (2) **78.** (3) **79.** (1) **80.** (3)
81. (2) **82.** (3) **83.** (3) **84.** (4) **85.** (1) **86.** (3) **87.** (4) **88.** (3) **89.** (2) **90.** (2)
91. (3) **92.** (2) **93.** (4) **94.** (2) **95.** (3) **96.** (2) **97.** (3) **98.** (1) **99.** (1) **100.** (1)
101. (1) **102.** (1) **103.** (3) **104.** (1) **105.** (4) **106.** (4) **107.** (1) **108.** (2) **109.** (4) **110.** (3)
111. (1) **112.** (1) **113.** (1) **114.** (1) **115.** (3)

PRABAL EXERCISE-2 (LEARNING PLUS)

1. (1) **2.** (4) **3.** (3) **4.** (2) **5.** (3) **6.** (2) **7.** (1) **8.** (2) **9.** (2) **10.** (1)
11. (3) **12.** (4) **13.** (1) **14.** (1) **15.** (2) **16.** (2) **17.** (1) **18.** (2) **19.** (2) **20.** (3)
21. (2) **22.** (1) **23.** (2) **24.** (4) **25.** (1) **26.** (3) **27.** (4) **28.** (3) **29.** (1) **30.** (1,3)
31. (3) **32.** (2,3) **33.** (4) **34.** (2) **35.** (4) **36.** (2) **37.** (3) **38.** (4) **39.** (2) **40.** (2)

PARIKSHIT EXERCISE-3 (MULTICONCEPT)

1. (3) **2.** (1) **3.** (1) **4.** (1) **5.** (1) **6.** (2) **7.** (1) **8.** (1) **9.** (3) **10.** (3)
11. (3) **12.** (2) **13.** (4) **14.** (1) **15.** (2) **16.** (4) **17.** (2) **18.** (4) **19.** (2) **20.** (1)
21. (1) **22.** (1) **23.** (3) **24.** (1) **25.** (3) **26.** (1) **27.** (1) **28.** (1) **29.** (4) **30.** (4)
31. (1) **32.** (4) **33.** (4) **34.** (1) **35.** (3) **36.** (1) **37.** (3) **38.** (2) **39.** (4) **40.** (1)

PYQ'S EXERCISE-4 (NEET PAST YEAR QUESTIONS)

1. (4) **2.** (3) **3.** (1) **4.** (4) **5.** (2) **6.** (4) **7.** (2) **8.** (4) **9.** (2) **10.** (3)
11. (1) **12.** (1) **13.** (3) **14.** (3) **15.** (2) **16.** (2) **17.** (2) **18.** (3) **19.** (1) **20.** (3)
21. (1) **22.** (4) **23.** (2)