CBSE (XII) 2025

Chapter and Topic-Wise
Solved Papers
2011-2024

Chemistry

(All Sets : Delhi & All India)

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Launcher

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▶ PREFACE

Chemistry can be unnerving. Your basic concepts of Chemistry need to be in place if you want to excel in the Board Examination. At Career Launcher, our goal is not only to help you maximize your scores in Class XII Chemistry Board Exam, but also to lay a strong foundation in the subject to help you get ahead in your college and professional career. Over the last decade, we all have seen how the question paper pattern of Class XII Chemistry paper has kept changing. Bearing in mind this unpredictable nature of Class XII board papers, we've come up with Chapter-wise Solved Papers for Chemistry for Class XII - to help you prepare better and face the Boards with confidence.

Exclusively designed for the students of CBSE Class XII by highly experienced teachers, the book provides solution to all actual questions of Chemistry Board Exams conducted from 2011 to 2024. The solutions have been prepared exactly in coherence with the latest marking pattern; after a careful evaluation of previous year trends of the questions asked in Class XII Boards and actual solutions provided by CBSE.

The book follows a three-pronged approach to make your study more focused. The questions are arranged Chapter-wise so that you can begin your preparation with the areas that demand more attention. These are further segmented topic-wise and eventually the break-down is as per the marking pattern. This division will equip you with the ability to gauge which questions require more emphasis and answer accordingly.

We hope the book provides the right exposure to Class XII students so that you not only ace your Boards but mold a better future for yourself. And as always, Career Launcher's school team is behind you with its experienced gurus to help your career take wings.

Let's face the Boards with more confidence!

Wishing you all the best,

Team CL

Blueprint & Marks Distribution

Class 12th Chemistry 2024-25 Analysis Unit Wise

Time : 3 Hours   **70 Marks**

S.No.	Title	No. of Periods	Marks
1	Solutions	10	7
2	Electrochemistry	12	9
3	Chemical Kinetics	10	7
4	d -and f -Block Elements	12	7
5	Coordination Compounds	12	7
6	Haloalkanes and Haloarenes	10	6
7	Alcohols, Phenols and Ethers	10	6
8	Aldehydes, Ketones and Carboxylic Acids	10	8
9	Amines	10	6
10	Biomolecules	12	7
	Total	**108**	**70**

UNIT I: SOLUTIONS   10 PERIODS

Types of solutions, expression of concentration of solutions of solids in liquids, solubility of gases in liquids, solid solutions, Raoult's law, colligative properties - relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmotic pressure, determination of molecular masses using colligative properties, abnormal molecular mass, Van't Hoff factor.

UNIT II: ELECTROCHEMISTRY   12 PERIODS

Redox reactions, EMF of a cell, standard electrode potential, Nernst equation and its application to chemical cells, Relation between Gibbs energy change and EMF of a cell, conductance in electrolytic solutions, specific and molar conductivity, variations of conductivity with concentration, Kohlrausch's Law, electrolysis and law of electrolysis (elementary idea), dry cell-electrolytic cells and Galvanic cells, lead accumulator, fuel cells, corrosion.

UNIT III: CHEMICAL KINETICS   10 PERIODS

Rate of a reaction (Average and instantaneous), factors affecting rate of reaction: concentration, temperature, catalyst; order and molecularity of a reaction, rate law and specific rate constant, integrated rate equations and half-life (only for zero and first order reactions), concept of collision theory (elementary idea, no mathematical treatment), activation energy, Arrhenius equation.

UNIT IV: D AND F BLOCK ELEMENTS   12 PERIODS

General introduction, electronic configuration, occurrence and characteristics of transition metals, general trends in properties of the first-row transition metals - metallic character, ionization enthalpy, oxidation states, ionic radii, colour, catalytic property, magnetic properties, interstitial compounds, alloy formation, preparation and properties of $K_2Cr_2O_7$ and $KMnO_4$.

Lanthanoids - Electronic configuration, oxidation states, chemical reactivity and lanthanoid contraction and its consequences.

Actinoids - Electronic configuration, oxidation states and comparison with lanthanoids.

UNIT V: COORDINATION COMPOUNDS   12 PERIODS

Coordination compounds - Introduction, ligands, coordination number, colour, magnetic properties and shapes, IUPAC nomenclature of mononuclear coordination compounds. Bonding, Werner's theory, VBT, and CFT; structure and stereoisomerism, the importance of coordination compounds (in qualitative analysis, extraction of metals and biological system).

UNIT VI: HALOALKANES AND HALOARENES.   10 PERIODS

Haloalkanes: Nomenclature, nature of C-X bond, physical and chemical properties, optical rotation mechanism of substitution reactions.

Haloarenes: Nature of C-X bond, substitution reactions (Directive influence of halogen in monosubstituted compounds only). Uses and environmental effects of - dichloromethane, trichloromethane, tetrachloromethane, iodoform, freons, DDT.

UNIT VII: ALCOHOLS, PHENOLS AND ETHERS   10 PERIODS

Alcohols: Nomenclature, methods of preparation, physical and chemical properties (of primary alcohols only), identification of primary, secondary and tertiary alcohols, mechanism of dehydration, uses with special reference to methanol and ethanol.

Phenols: Nomenclature, methods of preparation, physical and chemical properties, acidic nature of phenol, electrophilic substitution reactions, uses of phenols.

Ethers: Nomenclature, methods of preparation, physical and chemical properties, uses.

UNIT VIII: ALDEHYDES, KETONES AND CARBOXYLIC ACIDS   10 PERIODS

Aldehydes and Ketones: Nomenclature, nature of carbonyl group, methods of preparation, physical and chemical properties, mechanism of nucleophilic addition, reactivity of alpha hydrogen in aldehydes, uses.

Carboxylic Acids: Nomenclature, acidic nature, methods of preparation, physical and chemical properties; uses.

UNIT IX: AMINES   10 PERIODS

Amines: Nomenclature, classification, structure, methods of preparation, physical and chemical properties, uses, identification of primary, secondary and tertiary amines.

Diazonium salts: Preparation, chemical reactions and importance in synthetic organic chemistry.

UNIT X: BIOMOLECULES   12 PERIODS

Carbohydrates - Classification (aldoses and ketoses), monosaccharides (glucose and fructose), D-L configuration oligosaccharides (sucrose, lactose, maltose), polysaccharides (starch, cellulose, glycogen); Importance of carbohydrates.

Proteins - Elementary idea of - amino acids, peptide bond, polypeptides, proteins, structure of proteins - primary, secondary, tertiary structure and quaternary structures (qualitative idea only), denaturation of proteins; enzymes. Hormones - Elementary idea excluding structure.

Vitamins - Classification and functions.

Nucleic Acids: DNA and RNA.

Solutions

Topic 1: Types of Solutions, Expressing Concentration of Solutions and Solubility

Summary

- **Solution:** A homogeneous mixture of two (or more) substances.
- **Binary solution:** A solution consisting of two components. The component which is present in larger quantity is called **solvent** and the component which is small in quantity is called **solute.**

Solute	Solvent	Example
Gas	Gas	Air
Gas	Liquid	Aerated water
Gas	Solid	Hydrogen in palladium
Liquid	Liquid	Alcohol in water, benzene in toluene
Liquid	Solid	Mercury in zinc amalgam
Liquid	Gas	CO_2 dissolved in water
Solid	Liquid	Sugar in water, common salt in water
Solid	Gas	Smoke
Solid	Solid	Various alloys

Types of solutions:

- **Unsaturated solution:** A solution in which more solute can be dissolved without raising temperature.
  - * **Saturated solution:** A solution in which no solute can be dissolved any more at a given temperature.
  - * **Supersaturated solution:** A solution which contains more solute than that would be required to do saturation at a given temperature.
  - * **Aqueous solution:** In this type of solution, water is present as solvent. For example, salt solution.
  - * **Non-aqueous solution:** In this type of solution, there is another solvent apart from water. For example, iodine dissolved in alcohol.

- **Solubility:** The maximum amount of a solute that can be dissolved in a given amount of solvent at a given temperature.

  The solubility of a solute in a solvent depends upon the following:
  - * Nature of the solute
  - * Nature of the solvent
  - * **Temperature of the solution:** If the dissolution process is endothermic, solubility of solid in liquid increases with increase in temperature, and in endothermic process, solubility decreases.
  - * **Pressure (in case of gases):** Solubility of gases increase with increase in pressure but it has no effect on solids in liquids.

Methods of Expressing Concentration of Solutions:

- **Mass Percentage (W / w)**

$$W/w\% = \frac{\text{Mass of solute}}{\text{Total mass of solution}} \times 100$$

- **Percentage by volume (V / v%)**

$$V/v\% = \frac{\text{Volume of solute}}{\text{Total volume of solution}} \times 100$$

- **Mass by volume percentage (w/v)**

$$w / v\% = \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

- **Mole fraction (x):** It is defined as the ratio of the number of moles of a component to the total number of moles of all the components. For a binary solution, if the number of moles of A and B are n_A and n_B respectively, the mole fraction of A will be

$$\chi_A = \frac{n_A}{n_A + n_B}, \chi_B = \frac{n_B}{n_A + n_B}$$

- **Parts per million (ppm):** It is defined as the parts of a component per million parts of the solution.

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

It can be expressed in different ways like mass to mass, volume to volume and mass to volume.

$$ppm\left(\text{mass to mass}\right) = \frac{\text{Mass of a component}}{\text{Total mass of solution}} \times 10^6$$

$$ppm\left(\text{volume to volume}\right) = \frac{\text{Volume of a component}}{\text{Total volume of solution}} \times 10^6$$

$$ppm\left(\text{mass to volume}\right) = \frac{\text{Mass of a component}}{\text{Volume of solution}} \times 10^6$$

- **Molarity (M):** It is the number of moles of solute present in 1L (dm³) of the solution.

$$M = \frac{\text{Number of moles of solute}}{\text{Volume of solution}} = \frac{W_B \times 1000}{M_B \times V\left(ml\right)}$$

- **Molality (m):** It is the number of moles of solute per kilogram of the solvent.

$$m = \frac{\text{Number of moles of solute}}{\text{Mass of solvent}} = \frac{W_B \times 1000}{W \times W_A}$$

- **Normality (N):** The number of gram equivalents of solute present in 1 L of solution.

$$\text{Normality} = \frac{\text{Number of gram equivalent of solute}}{\text{Volume of solution in L}}$$

Number of gram equivalents of solute

$$= \frac{\text{Mass of solute in gram}}{\text{Equivalent weight}}$$

- **Relationship between Molarity and Molality:**

$$m = \frac{1000M}{M \times M_B - 1000d}$$

- **Henry's law**: The partial pressure of a gas in vapour phase (p) is proportional to the mole fraction of the gas (χ) in a solution. It is a special case of Raoult's law.

$\rho = K_H \chi$, K_H is the Henry's constant

Higher the value of K_H, lower the solubility of gas in the liquid.
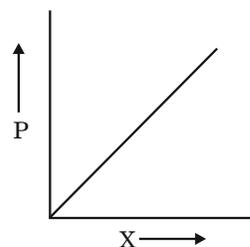
Slope of the line gives the value of K_H

- **Limitations of Henry's law:** This law is applicable only when
  * The law does not apply for gases which undergo association or dissociation in the solution.
  * This law is not applied for gases at high pressure and low temperature.
  * The law does not apply for gases which undergo any chemical change.
- **Applications of Henry's law:**
  * At high altitudes, low blood oxygen makes people weak and cause a problem called anoxia.
  * Bottles of soft drinks are sealed under high pressure to increase the solubility of CO_2
  * Scuba divers use air diluted with helium, nitrogen and oxygen to avoid toxic effects of nitrogen in blood.

PREVIOUS YEARS'

EXAMINATION QUESTIONS
TOPIC 1

▶ 1 Mark Questions

1. Give one example each of lyophobic sol and lyophilic sol. **[DELHI 2014]**

2. Select the most appropriate answer from the option given below:

   Assertion (A): A raw mango placed in a saline solution loses water and shrivel into pickle.

   Reason (R): Through the process of reverse osmosis, raw mango shrivel into pickle.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true. **[TERM I 2022]**

3. Which one of the following pairs will **not** form an ideal solution?

(a) Benzene and Toluene

(b) Nitric acid and Water

(c) Hexane and Heptane

(d) Ethyl chloride and Ethyl bromide

[DELHI 2023]

▷ 2 Mark Questions

4. State Henry's law. What is the effect of temperature on the solubility of a gas in a liquid.   **[DELHI 2014]**

5. Define an ideal solution and write, one of its characteristics.   **[DELHI 2014]**

6. State Henry's law correlating the pressure of a gas and its solubility in a solvent and mention two applications for the law.   **[DELHI 2016]**

7. (i) Gas (A) is more soluble in water than Gas (B) at the same temperature. Which of the two gases will have the higher value of K_H (Henry's constant) and why?

(ii) In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes?   **[ALL INDIA 2016]**

▷ 5 Mark Questions

8. (a) Differentiate between molality and molarity of a solution. How does a change in temperature influence their values?

(b) 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 g) (K_f for water $= 1.86 K\ kgmol^{-1}$)

OR

(a) Define the terms osmosis and osmotic pressure. Is the osmotic pressure of a solution a colligative property? Explain

(b) Calculate the boiling point of a solution prepared by adding 15.00 g of NaCl to 250.0 g of water. (K_b for water $= 0.512 K\ kgmol^{-1}$, Molar mass of $NaCl = 58.44 g$)

[DELHI 2011]

9. (a) State the following:

1. Henry's law about partial pressure of a gas in a mixture.

2. Raoult's law in its general form in reference to solutions.

(b) 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 torr at 25°C. Assuming the gene fragment is non-electrolyte, find its molar mass.

OR

(a) Difference between molarity and molality in a solution. What is the effect of temperature change on molarity and molality in a solution?

(b) What would be the molar mass of a compound if 6.21 g of it is dissolved in 24.0g of chloroform to form a solution that has a boiling point of 68.04°C. The boiling point of pure chloroform is 61.7°C and the boiling point elevation constant, for chloroform is 3.63°C/m.   **[DELHI 2011]**

10. (a) Define the following terms:

(i) Ideal solution

(ii) Azeotrope

(iii) Osmotic pressure

(b) A solution of glucose $\left(C_6H_{12}O_6 \right)$ in water is labelled as 10% by weight. What would be the molality of the solution? (Molar mass of glucose $= 180\ g\ mol^{-1}$)

[ALL INDIA 2013]

11. (a) Define the following terms :

(i) Molarity

(ii) Molal elevation constant (K_b)

(b) A solution containing 15 g urea (molar mass = 60 $g\ mol^{-1}$) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 190 $g\ mol^{-1}$) in water. Calculate the mass of glucose present in one litre of its solution.

OR

(a) What type of deviation is shown by a mixture of ethanol and acetone? Give reason.

(b) A solution of glucose (molar mass = 180 $g\ mol^{-1}$) in water is labeled as 10% (by mass). What would be the molality and molarity of the solution? (Density of solution = 1.2 $g\ mL^{-1}$)   **[DELHI 2015]**

12. (a) A 10% solution (by mass) of sucrose in water has a freezing point of 269.15 K.

Calculate the freezing point of 10% glucose in water if the freezing point of pure water is 273.15 K. Given: (Molar mass of sucrose = 342 $g\ mol^{-1}$)

(Molar mass of glucose = 180 $g\ mol^{-1}$)

(b) Define the following terms:

(i) Molality (m)

(ii) Abnormal molar mass

[ALL INDIA 2017]

🔑 **Solutions**

1. Lyophobic sol: Metal sol or metal sulphide. Lyophilic sol: Gum, Starch, gelatin. **[1]**

2. (c) When a raw mango is placed in saline solution to prepare pickle, it loses water due to osmosis and gets shrivel. **[1]**

3. (b) This pair shows negative deviation. For ideal solution, the enthalpy of mixing of the pure components to form the solution is zero and the volume of mixing is also zero. **[1]**

4. Henry's law states that "the partial pressure of the gas in vapour phase (p) is directly proportional to the mole fraction of gas (x) in the solution." **[1]**

$p = K_H x$ (K_H—Henry's law constant)
The solubility of a gas in liquid decreases with rise in temperature as dissolution of a gas in a liquid is an exothermic process. **[1]**

5. A solution which obeys Raoult's law at all temperatures and concentrations is called an ideal solution **[1]**

i.e. $P_A = P^o_A$ and $P_B = P^o_B$

Where, P = Total pressure and P_A, P_B, P^o_A, P^o_B and X_A, X_B are partial pressure, pressure of pure component and mole fraction of component A and B respectively.

Characteristics: In ideal solution, no volume change or enthalpy change takes place while mixing to form such a solution, **[1]**

i.e., $\Delta H_{mix} = 0\ and\ \Delta V_{mix} = 0$

6. Henry's law states that at a constant temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas over the solution. **[1]**

Applications:

(i) To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure. **[½]**

(ii) Scuba divers must cope with high concentrations of dissolved nitrogen with breathing air at high pressure underwater. To avoid this air is diluted with He. **[½]**

(iii) At high altitudes, the partial pressure of oxygen is less than that at the ground level. Low blood oxygen causes hypoxia.

7. (i) As per Henry's law, the solubility of a gas is inversely related to the Henry's constant (K_H) for that gas. Hence gas (B) being less soluble, would have a higher K_H value. **[1]**

(ii) A maximum boiling azeotrope shows negative deviation from the Raoult's law. **[1]**

8. (a) Molarity is the number of moles of solute dissolved in 1 litre of solution. It is temperature dependent. **[1]**

$$M = \frac{W \times 1000}{\text{Molecular mass} \times V}$$

Molality is the number of moles of solute dissolved per 1 kg of the solvent. It is temperature independent.

$$M = \frac{W \times 1000}{M_2 \times W}$$

Molality is independent of temperature, whereas molarity is a function of temperature because volume depends on temperature and mass does not. **[1]**

(b) Since $MgBr_2$ is an isotonic compound. Hence undergoes complete dissociation

$$MgBr_2 \longrightarrow Mg^{2+} + 2Br^-$$
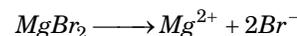
Initial moles	1	0	0
After Dissociation	0	1	2

Total number of moles = 1 + 2 = 3 **[1]**

Thus, $i = \dfrac{3}{1} = 3$

Using the formula

$\Delta T_f = iK_f m \qquad\qquad T_f^° - T_f = iK_f m$

$0°C - T_f = 3 \times 1.86 \times \dfrac{10.50}{184} \times \dfrac{1000}{200}$ **[1]**

$-T_f = \dfrac{58590}{30800} = 1.59°C$

$T_f = -1.59°C\ or\ 271.41K$ **[1]**

OR

(a) Osmosis is the phenomenon of flow of solvent through a semi-permeable membrane from the region of higher concentration to the region of lower concentration. **[1]**

The osmotic pressure of a solution is the excess pressure that must be applied to the solution to prevent the passage of solvent molecule through a semi-permeable membrane into the solution.

Yes, osmotic pressure is a colligative property as it depends only on the amount of solute present in the solution. **[1]**

(b) Initial moles after dissociation

$$NaCl \longrightarrow Na^+ + Cl^-$$

1	0	0	
0	1	1	

[1]
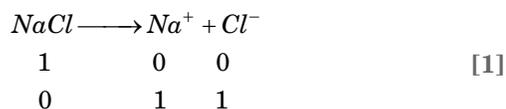
(Total no. of moles 1 + 2 = 2)

$$\therefore i = \frac{2}{1} = 2$$

We know that, **[1]**

$$\Delta T_b = iK_b m$$

$$T_b - T_b^{\circ} = 2 \times 0.512 \times \frac{15 \times 1000}{58.44 \times 250}$$

$$T_b - 373K = \frac{15360}{14610} = 1.05K$$

$$T_b = 1.05K + 373K$$

$$\therefore T_b = 374.05K$$ **[1]**

9. (a)
1. Henry's law states that the partial pressure of gas in vapour phase is directly proportional to its mole fraction in the solution **[1]**
2. Raoult's law states that for a solution with volatile components, the partial vapour pressure of each component present in the solution is proportional to its mole fraction in the solution. **[1]**

(b) Given: $w_2 = 8.95\,mg = 8.95 \times 10^{-3}\,g$ **[1]**

$$V = 35\,mL$$

$$\pi = 0.335\,torr$$

$$T = 25^{\circ}C = 298K$$
$$M_2 = ?$$

Substituting all the values in the given formula

$$\pi = CRT$$ **[1]**

$$\pi = \frac{w_2 RT}{M_2 V}$$

$$\text{Or } M_2 = \frac{w_2 RT}{\pi V}$$

$$M_2 = \frac{8.95 \times 10^{-3} \times 0.0821 \times 298 \times 760}{0.335 \times 35}$$

So, Molar mass,

$$M_2 = 1.42 \times 10^4\,g\,mol^{-1}$$ **[1]**

OR

(a) Molarity is defined as the number of moles of solute present in 1 liter of solution, while molality is defined as the number of moles of solute present in 1 kg of solvent. **[1]**

Molality does not have any effect of change in temperature because mass does not change with temperature, whereas molarity changes with temperature. **[1]**

(b) Given: $w_2 = 6.21\,g$ **[1]**

$$w_1 = 24\,g$$

$$K_b = 3.63^{\circ}C/m$$

$$\Delta T_b = T_b - T_b^{\circ} = 68.04 - 61.7 = 6.34^{\circ}C$$

$$M_2 = ?$$

From the formula,

$$M_2 = \frac{1000 \times K_b \times w_2}{\Delta T_b \times w_1}$$ **[1]**

$$= \frac{1000 \times 3.63 \times 6.21}{6.34 \times 24} = 148.14\,g\,mol^{-1}$$

So, molar mass of the compound,

$$M = 148.14\,g\,mol^{-1}$$ **[1]**

10. (a)

(i) **Ideal solution:** Ideal solution is that solution which follows Raoult's law. In ideal solutions like force of attraction are equals to unlike force of attraction and therefore

(i) $\Delta H_{mixing} = 0$

(ii) $\Delta V_{mixing} = 0$

(iii) $\Delta S_{mixing} > 0$

(i) **Azeotrope:** At a particular conc. the mixture of two or more than two components boils at constant temp. Such mixture is called as azeotropic mixture. The components of the azeotropic mixture cannot be separated by distillation.

(ii) **Osmotic pressure:** When two solution (of same solvent) having different conc. are separated by semipermeable membrane the solvent particles moves from less conc. to more conc. It results in rising of liquid level on more conc. side so amount of external pressure required to be applied on more conc. side to stop the movement of solvent particles in called as osmotic pressure.

(b) Molality = $\dfrac{\% \, by \, wt}{mol. \, mass} \times \dfrac{1000}{\left(100 - \% \, \frac{w}{w}\right)}$

$= \dfrac{10}{180} \times \dfrac{(1000)}{(100 - 10)}$

$= \dfrac{10}{180} \times \dfrac{1000}{90} = 0.617 \, m$

11. (a)

(i) **Molarity (M):** Molarity can be defined as no. of moles of solute dissolved per litre of solution   **[1]**

Molarity M $= \dfrac{\text{Moles of solute}}{\text{Volume of solution}\,(\text{litre})}$

(ii) Molal elevation constant $\left(K_b\right)$: When 1 molal solution is prepared, the elevation in boiling point is called as molal boiling point elevation constant.   **[1]**

(b) For isotonic solution:

$\pi_1 = \pi_2$ **[1]**

$C_1 = C_2$ {at same temp.}

or $n_1 = n_2$ (As volume is same)

$\therefore \dfrac{15}{60} = \dfrac{x}{180}$ **[1]**

$x = 45 \, g$, mass of glucose per liter of solution.   **[1]**

OR

(a) Ethanol and acetone shows positive deviation because both are non polar compounds and after mixing force of attraction decreases   **[1]**

Like particle force of attraction > unlike particle force of attraction   **[1]**

(b) Molarity $= \dfrac{10}{180} \times \dfrac{1000}{180} = 0.66M$ **[1]**

Molality $= \dfrac{\% \, \text{mass}}{\text{mol. mass of solute}}$

Molality $= \dfrac{\% \, \text{mass}}{\text{mol. mass of solute}} \times \dfrac{100}{100 - \% \, \text{Mass}}$ **[1]**

$= \dfrac{10}{180} \times \dfrac{1000}{90}$

$= 0.617m$ **[1]**

12. (a) For Sucrose:

$n = \dfrac{10}{342} = 0.0292 \, mol$ **[1]**

$n = 0.292 \, mol$

Now, $m = \dfrac{0.0292 \times 1000}{90} = 0.3244$

We know that,

$K_f = \dfrac{\Delta T_f}{m} = \dfrac{4}{0.3244}$

$= 12.33$ kg/mol

Now for glucose,

$n = \dfrac{10}{180} = 0.055$ mol

Now, $m = \dfrac{0.055 \times 1000}{90}$

$= 0.6160$ mol/kg   **[1]**

Again we know that,

$\Delta T_f = K_f \times m$

$= 12.33 \times 0.616 = 7.60$

$T_f = 273.15 \quad 7.60 \quad 265.55$ K

So, freezing point of 10% glucose in water is 265.55 K   **[1]**

(b)

(i) Molality is defined as the number of moles of solute per kilogram of solvent. The SI unit for molality is mol/kg.   **[1]**

(ii) Abnormal molar masses for the solute which undergo association or dissociation. Observed value of colligative property is different from the calculated value of colligative property.   **[1]**

OR

(a) Vapour pressure of water,

$p_1 = 23.8 \, mm \, of \, Hg$

Weight of water = 846 g

Weight of urea = 30 g

Molecular weight of water

$\left(H_2O\right) = 1 \times 2 + 16 = 18 \, g \, mol^{-1}$

Molecular weight of urea

$(NH_2CONH_2) = 2N + 4H + C + O$

$= 2 \times 14 + 4 \times 1 + 12 + 16$

$= 60$ g mol^{-1} **[1]**

Number of moles of water, $n_1 = \dfrac{846}{18} = 47$

Number of mole of urea, $n_2 = \dfrac{30}{60} = 0.5$ [1]

Now, we have to calculate vapour pressure of water in the solution. We take vapour pressure as p_1.

Use the formula of Raoult's law

$$\dfrac{\left(P_1^{\,0} - P_1\right)}{P_1^{\,0}} = \dfrac{n_2}{\left(n_1 - n_2\right)}$$

Plug the values we get

$$\dfrac{\left(23.8 - P_1\right)}{23.8} = \dfrac{0.5}{\left(47 + 0.5\right)}$$

$$\dfrac{\left(23.8 - P_1\right)}{23.8} = 0.5106$$

After cross multiply

$23.8 - p_1 = 23.8 \times 0.5106$

Solving it, we get $p_1 = 11.6\ mm\ Hg$

So, Vapour pressure of water in the given solution = $11.6\ mm\ of\ Hg$ [1]

(b) **Ideal Solution**: Obey Raoult's law at every range of concentration. Non-ideal Solution: Do not obey Raoult's law.   [1]

Neither heat is evolved nor absorbed during dissolution of Ideal Solution for N_m ideal solution.

$\Delta H_{mixing} > 0$ or < 0.   [1]

MULTIPLE CHOICE QUESTIONS

1. The solubility of a gas in water depends on
   (a) Nature of the gas
   (b) Temperature
   (c) Pressure of the gas
   (d) All of the above.

2. The solution of sugar in water contains
   (a) Free atoms
   (b) Free ions.
   (c) Free molecules
   (d) Free atom and molecules.

3. The amount of anhydrous Na_2CO_3 present in 250 ml of 0.25 M solution is
   (a) 6.225 g   (b) 66.25 g
   (c) 6.0 g   (d) 6.625 g

4. The molarity of 0.006 mole of NaCl in 100 ml solution is
   (a) 0.6   (b) 0.06
   (c) 0.006   (d) 0.066

5. Which of the following has maximum number of molecules
   (a) 16 gm of O_2 (b) 16 gm of NO_2
   (c) 7 gm of N_2 (d) 2 gm of H_2

6. Molarity is expressed as.
   (a) Gram/litre   (b) Moles/litre
   (c) Litre/mole   (d) Moles/1000 gms.

7. 10 litre solution of urea contains 240 g urea. The active mass of urea will be
   (a) 0.04   (b) 0.02
   (c) 0.4   (d) 0.2

8. The sum of the mole fraction of the components of a solution is
   (a) 0
   (b) 1
   (c) 2
   (d) 4

Answer Keys

1. (d)   2. (c)   3. (d)   4. (b)   5. (d)
6. (b)   7. (c)   8. (b)

🔑 Solutions

1. The solubility of a gas in water depends on nature of the gas, temperature and pressure of the gas.   [1]

2. The solution of sugar in water contains free molecules.   [1]

3. $M = \dfrac{w}{m \times V(I)} \Rightarrow 0.25 = \dfrac{w}{106 \times 0.25}$

   $\Rightarrow w = 0.25 \times 106 \times 0.25 = 6.625$ g.   [1]

4. $M = \dfrac{n}{V} = \dfrac{0.006}{0.1} = 0.06$ [1]

5. 2 gm Hydrogen has maximum number of molecules than others.   [1]

6. Molarity is expressed as moles/litre.   [1]

7. $\because$ 10 litre of urea solution contains 240 gm of urea

   $\therefore$ Active mass $= \dfrac{240}{60 \times 10} = 0.4$ [1]

8. The sum of the mole fraction of the components of a solution is always 1.   [1]

Topic 2: Vapour Pressure of Liquid Solutions, Ideal and Non-ideal Solutions

Summary

- **Vapour Pressure:** Vapour pressure of a liquid solution is the amount of pressure that the vapours exert on the liquid solvent when they are in equilibrium and at a fixed temperature. It changes with the temperature of the surroundings and the nature of the liquid.

- **Raoult's Law:** The law states that the partial pressure is directly proportional to the mole fraction of the solute component. So, according to Raoult's Law, the partial pressure of A will be

$$P_A \propto x_A$$

$$P_A = P_A^{\,0} x_A$$

Where $P_A^{\,0}$ is the vapour pressure of pure liquid component A.

Similarly partial pressure of B will be

$$P_B \propto x_B$$

$$P_B = P_B^{\,0} x_B$$

Where $P_B^{\,0}$ is the vapour pressure of pure liquid component B. The total pressure (P_{total}) of the solution placed in a container is the sum of partial pressures of its respective components. That is

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

$$P_{total} = P_A^{\,0} x_a + P_B^{\,0} x_B$$

- **Raoult's Law as a Special Case of Henry's Law:**

According to Raoult's law, vapour pressure of volatile component is given by, $p_i = x_i p_i^o$

According to Henry's law, the gaseous component is volatile that it exist as a gas and solubility depends on Henry's law:

$$p_A = K_H x_A$$

- **Positive and negative deviation from Raoult's law:**

Positive deviation leads to increase in vapour pressure. In positive deviation, A-B interactions are weaker than interaction between B-B or A-B. Examples: Acetic acid and toluene, Methanol and chloroform, etc.
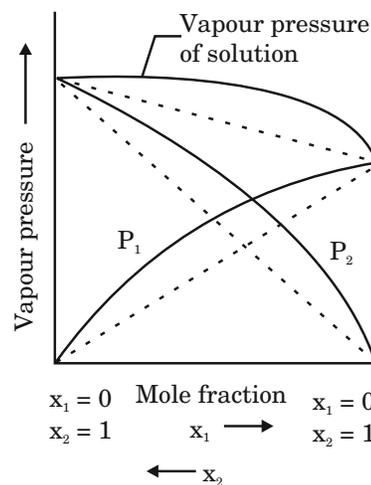
Negative deviation leads to decrease in vapour pressure. In negative deviation, A-A and B-B intermolecular forces are weaker than interaction between A-B. Examples: Chloroform and benzene, chloroform and methyl acetate, etc.
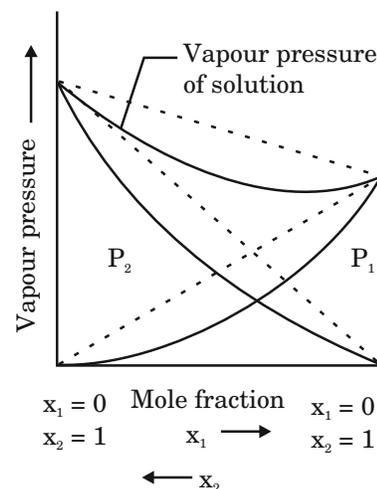
- **Ideal Solution:** These are the solutions which obey Raoult's law over the entire range of concentration.

Two properties of Raoult's law:

$$\Delta_{mix} H = 0 \text{ and } \Delta_{mix} V = 0$$

Examples of ideal solutions are: Ethyl bromide and ethyl chloride, benzene and toluene.

- **Non-ideal Solutions:** These solutions do not obey Raoult's law over the range of concentration.

If the vapour pressure of such a solution is higher, then the solution exhibits positive deviation and if it is lower, then the solution exhibits negative deviation.

- **Azeotropes:** Binary mixtures which have same composition in liquid and vapour phase and boil at constant temperature are called azeotropes.

- **Minimum boiling azeotrope:** Solutions which show large positive deviation from Raoult's law. For example: Ethanol-water mixture.

- **Maximum boiling azeotrope:** Solutions which show large negative deviation from Raoult's law. For example: Nitric acid and water.

# PREVIOUS YEARS'

EXAMINATION QUESTIONS
TOPIC 2

▷ 1 Mark Questions

1. Some liquids on mixing form 'azeotropes'. What are 'azeotropes'? **[DELHI 2014]**

2. Identify which liquid will have a higher vapour pressure at 90°C if the boiling points of two liquids A and B are 140°C and 180°C, respectively. **[DELHI 2020]**

3. Which one of the following pairs will form an ideal solution?

   (a) Chloroform and acetone

   (b) Ethanol and acetone

   (c) n-hexane and n-heptane

   (d) Phenol and aniline **[TERM I 2022]**

4. Which of the following formula represents Raoult's law for a solution containing non-volatile solute?

   (a) $p_{solute} = p°_{solute}.x_{solute}$

   (b) $p = K_H.x$

   (c) $p_{Total} = p_{solvent}$

   (d) $p_{solute} = p°_{solvent}.x_{solvent}$ **[TERM I 2022]**

5. An azeotropic solution of two liquids has a boiling point lower than either of the two when it

   (a) shows a positive deviation from Raoult's law.

   (b) shows a negative deviation from Raoult's law.

   (c) shows no deviation from Raoult's law.

   (d) is saturated **[TERM I 2022]**

6. On mixing 20 mL of acetone with 30 mL of chloroform, the total volume of the solution is

   (a) < 50 mL   (b) = 50 mL

   (c) > 50 mL   (d) = 10 mL
   [TERM I 2022]

7. An unknown gas 'X' is dissolved in water at 2.5 bar pressure and has mole fraction 0.04 in solution. The mole fraction of 'X' gas when the pressure of gas is doubled at the same temperature is

   (a) 0.08   (b) 0.04

   (c) 0.02   (d) 0.92
   [TERM I 2022]

8. In the following diagram point, 'X' represents
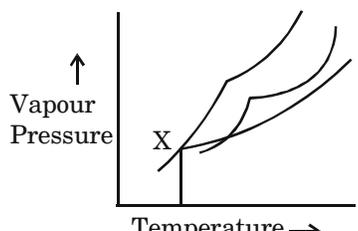
   (a) Boiling point of solution

   (b) Freezing point of solvent

   (c) Boiling point of solvent

   (d) Freezing point of solution **[TERM I 2022]**

9. An azeotropic mixture of two liquids has a boiling point higher than either of the two liquids when it:

   (*a*) shows large negative deviation from Raoult's law.

   (*b*) shows no deviation from Raoult's law.

   (*c*) shows large positive deviation from Raoult's law.

   (*d*) obeys Raoult's law. **[DELHI 2023]**

▷ 2 Mark Questions

10. State the following:

    (*i*) Raoult's law in its general form in reference to solutions.

    (*ii*) Henry's law about partial pressure of a gas in a mixture. **[ALL INDIA 201]**

11. State Raoult's law for the solution containing volatile components. What is the similarity between Raoult's law and Henry's law?

    [DELHI 2014]

12. What is meant by positive deviations from Raoult's law? Give an example. What is the sign of $\Delta_{mix}H$ for positive deviation?

    OR

    Define azeotropes. What type of azeotrope is formed by positive deviation from Raoult's law? Give an example.   **[DELHI 2015]**

13. Non-ideal solutions exhibit either positive or negative deviations from Raoult's law. What are these deviations and why are they caused? Explain with one example of each type.

    [DELHI 2016]

14. State Raoult's law for a solution containing volatile components. Write two characteristics of the solution which obeys Raoult's law at all concentrations.   **[DELHI 2019]**

15. For a 5% solution of urea (Molar mass = 60 g/mol), calculate the osmotic pressure at 300 K.

    [R = 0.0821 L atm K^{-1} mol^{-1}]   **[DELHI 2020]**

16. What type of deviation from Raoult's law is shown by a mixture of ethanol and acetone? Give reason.   **[DELHI 2023]**

▶ 3 Mark Questions

17. (*a*) In reference to Freundlich adsorption isotherm, write the expression for adsorption of gases on solids in the form of an equation.

    (*b*) Write an important characteristic of lyophilic sols.

    (*c*) Based on type of particles of dispersed phase, give one example each of associated colloid and multi molecular colloid.

    [DELHI 2014]

18. A solution prepared by dissolving 1.25 g of oil of wintergreen (methyl salicylate) in 99.0 g of benzene has a boiling point of 80.31°C and K$_b$ for benzene = 2.53°C *kg mol*$^{-1}$

▶ 5 Mark Questions

19. (*a*) State Raoult's law for a solution containing volatile components. How does Raoult's law become a special case of Henry's law?

(*b*) 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40 K. Find the molar mass of the solute. (K$_f$ for benzene = 5.12 *K kg mol*$^{-1}$)

[ALL INDIA 2013]

🔑 Solutions

1. Azeotropes are mixtures with fixed concentrations of components such that they boil at constant temperatures and distil out unchanged in their composition. e.g. :- A mixture of ethanol and water containing 95.4% of ethanol forms an azeotrope with boiling point 351.15 K. i.e.95% ethanol and 5% water by mass mixture.   **[1]**

2. Vapour pressure correlates with boiling point inversely. In the given liquid A has a lower boiling point and thus will have higher vapour pressure. Since liquid A has a lower boiling point you can assume that its inter-molecular forces are weaker. Therefore, it is much more likely to become a vapour at lower temperatures and move vapour means more pressure.   **[1]**

3. (c) n-hexane and n-heptane form an ideal solution.   **[1]**

4. (d) When the solute is non-volatile, only the solvent molecules are present in vapour phase and contribute to vapour pressure.   **[1]**

5. (a) The solutions which show a large positive deviation from Raoult's law form minimum boiling azeotrope at a specific composition. **[1]**

6. (a) The solution shows negative deviation from Raoult's law. For such type of solution, there is a decrease in volume. Hence, the final volume will be <50 mL.   **[1]**

7. (a) Mole fraction of gas in the solution is proportional to the partial pressure of the gas. Over the solution.

    $x \propto P$

    or, $\dfrac{x}{P} = $ constant

    or, $\dfrac{x_1}{P_1} = \dfrac{x_2}{P_2}$

    Where,

    x_1 = initial mole fraction of gas

    P_1 = Partial pressure of gas

x_2 = Final mole fraction of gas

P_2 = Final partial pressure of gas.

∵ Here only one gas

∴ Partial pressure of gas = Pressure of gas.

Therefore,

$$\frac{0.04}{2.5} = \frac{x_2}{2 \times (2.5)}$$

$$\Rightarrow x_2 = \frac{0.04 \times 2 \times 2.5}{2.5}$$

$$\Rightarrow x_2 = 0.08 \qquad [1]$$

8. (d) Here, X represents freezing point of the solution. [1]

9. (a) The solutions that show large negative deviation from Raoult's law form maximum boiling azeotrope at a specific composition. [1]

10. (*i*) Raoult's law states that for a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction. [1]

    (*ii*) Henry's law states that at a constant temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas over the solution. i.e. "The partial pressure of a gas in vapour phase (p) is proportional to the mole fraction of the gas (χ) in a solution." [1]

    $P \propto x$

    $P = K_H x$

    where, K_H = Henry's law constant

11. Raoult's law states that the partial pressure of the vapour of a volatile component in a solution is directly proportional to its mole fraction in the solution. [1]

    Raoult's law is a special case of Henry's law. Both Henry's law and Raoult's law describe the relationship between a solution and its vapour that is in equilibrium with each other. [1]

12. Positive deviation from Raoult's law means that the observed vapour pressure is greater than expected, and it occurs when A — B attractions are weaker than the average of the attractions in the pure component of the mixture. For example: A mixture of ethanol and acetone shows a positive deviation from Raoult's law. [1]

In case of solutions showing positive deviations, absorption of heat takes place;

i.e., $\Delta_{mix}H$ has a positive (+) sign. [1]

OR

Azeotropes are the binary mixtures which have the same composition in liquid and vapour phases and boil at a constant temperature. [1]

A minimum-boiling azeotrope is formed by solutions showing a large positive deviation from Raoult's law at a specific composition. Example: $C_2H_5OH + H_2O$ [1]
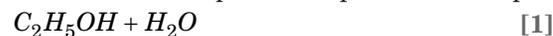
(An ethanol-water mixture)

13. For non-ideal solutions, vapour pressure is either higher or lower than that predicted by Raoult's law. If it is higher the solution exhibits positive deviation and if it is lower it exhibits negative deviation from Raoult's law.

Positive Deviation	Negative Deviation
When solute – solvent interactions are weaker than solute – solute or solvent-solvent interactions, vapour pressure increases which result in positive deviation	When solute solvent interactions are stronger than solute – solute or solvent – solvent interactions, vapour pressure decreases which result in negative deviation.
Eg : Ethanol +Acetone. for a solution showing positive deviation $P_A > P^o{}_A X_A$ and $P_B > P°_B X_B$	Eg: Chloroform + Acetone. for a solution showing negative deviation $P_A < P^o{}_A X_A$ and $P_B < P^0{}_B X_B$
ΔH_{mix} = positive and ΔV_{mix} = positive	ΔH_{mix} = negative and ΔV_{mix} = negative

[2]

14. **Raoult's Law** → For a solution of volatile liquids, the partial pressure of each component in a solution is directly proporional to its mole fraction.

    Let P_1 be the vapour pressure of the solvent, x_1 be its mole fraction and $P_1^°$ be its vapour pressure in pure state. Then, $P_1 \propto x_1$

    $$\Rightarrow P_1 = X_1\ P_1^° \qquad [1]$$

Following are the two characteristics of the solution which obeys this law at all concentrations :–

1. The enthalpy of mixing of the pure components to form the solution is zero. i.e. D_{mix} H = 0. No heat change.
2. The volume of mixing is also zero i.e. D_{mix} V = 0. Volume of solution would be equal to sum of volumes of two.   [1]

15. The osmotic pressure is given by the formula:

    p = i × C × R × T

    Where,

    i = Van't-Hoff factor

    = 1 (for non-electrolyte solution)

    C = Concentration of solute

    R = Gas constant = 0.082 L.atm/mol.K

    T = Temperature

    5% of urea = 5 g of urea in 100 ml of solution

    $$Mole = \frac{(Given\ Weight)}{(Molecular\ Weight)}$$

    On substituting the values, we get,

    $$Moles = \frac{5}{60} = 0.083\ mol \qquad [½]$$

    Now, the concentration of urea is given by the formula:

    $$Molarity = \frac{(Moles\ of\ urea)}{(Volume\ of\ solution)} \times 1000$$

    $$Molarity = \frac{0.083}{100}\ 1000$$

    Molarity = 0.83 M   [½]

    Now, the osmotic pressure is:

    p = 1 × 0.83 × 0.082 × 300

    ∴   p = 20.418 atm   [1]

16. Positive deviation from Raoult's law is shown by mixture of ethanol and acetone.   [1]

    Reason : Different interactions between solvent and solute particles cause deviation from ideal behaviour. In positive deviations, solute–solvent interactions are weaker than the interactions between solute-solute and solvent-solvent particles.   [1]

17. (a) Expression for Freundlich adsorption isotherm- $\frac{x}{m} = K_p^{\frac{1}{n}}$ (Where n>1)   [1]

    Where, x = mass of the gas adsorbate

    m = mass of the adsorbent (solid)

    p = pressure of the gas

    n and k are constants, which depend on the nature of the adsorbate and adsorbent. n is greater than 1.

    (b) Lyophilic sols are stable and reversible in nature i.e., if two constituents of the sol are separated by any means (such as evaporation), then the sol can be prepared again by simply mixing the dispersion medium with the dispersion phase and shaking the mixture.   [1]

    (c) **Associated colloid**: Soap solution/ detergent solution
    Multi molecular colloid: Sulphur sol/ Gold sol.   [1]

18. Elevation of boiling point,

    $$\Delta T_b = \frac{K_b \times 1000 \times w_2}{M_2 \times w_1} \qquad \ldots (Eq.\ 1) \quad [1]$$

    Here solute is methyl salicylate and solvent is benzene, thus

    W_2 = 1.25 g

    W_1 = 99.0 g

    Boiling point of solution (i.e. methyl salicylate in benzene), (T_b) = 80.31°C. Boiling point of pure solvent (benzene), (T_b) = 80.0°C

    K_b = 2.53°C $kg\ mol^{-1}$

    $\Delta T = T_b - T_b^o = 80.31°C - 80.10°C = 0.21°C$ [1]

    From Eq. 1,

    $$M_2 = \frac{K_b \times 1000 \times w_2}{\Delta T_b \times w_1}$$

    $$M_2 = \frac{2.53 \times 10^3 °C\ g\,mol^{-1} \times 1000 \times 1.25\,g}{0.21°C \times 99.0\,g}$$

    $$M_2 = 152.11 \times 10^3\ g\,mol^{-1} \qquad [1]$$

19. (a) According to Raoult's law vapour pressure of a component is directly proportional to its mole fraction at a particular temperature   [1]

    $P_A \propto x_A$

    $P_A = P_A^o X_A$

Similarly, $P_B = P_B^o X_B$

$\Ss P_T \quad P_A^o X_A \quad P_B^o X_B$

In Henry's law mole fraction of a gas at a particular temp. is proportional to the pressure exerted over gas   **[1]**

$P_{gas} = K_H X_{gas}$

∴We can says for volatile substance it is a special case of Henry's law.

(b) $\Delta T_f = K_f m$

$\Delta T_f = K_f \dfrac{w_B}{M_B} \times \dfrac{1000}{W_A}$ **[1]**

$0.40 = 5.12 \times \dfrac{1}{M_B} \times \dfrac{1000}{50}$ **[1]**

$M_B = \dfrac{512}{2} = 256 \, g/mol$ **[1]**

MULTIPLE CHOICE QUESTIONS

1. When mercuric iodide is added to the aqueous solution of potassium iodide, the
    (a) Freezing point is raised
    (b) Freezing point is lowered
    (c) Freezing point does not change
    (d) Boiling point does not change

2. An aqueous solution of methanol in water has vapour pressure
    (a) Equal to that of water
    (b) Equal to that of methanol
    (c) More than that of water
    (d) Less than that of water

3. Which has maximum vapour pressure
    (a) HI   (b) HBr
    (c) HCl   (d) HF

4. 18 g of glucose ($C_6H_{12}O_6$) is added to 178.2 g of water. The vapour pressure of water for this aqueous solution at 100° C is
    (a) 759.00 Torr
    (b) 7.60 Torr
    (c) 76.00 Torr
    (d) 752.40 Torr

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

    (a) Benzene-toluene
    (b) Water-ethyl alcohol
    (c) Water-nitric acid
    (d) Water-hydrochloric acid

6. All form ideal solutions except
    (a) C_2H_5Br and C_2H_5I
    (b) C_6H_5Cl and C_6H_5Br
    (c) C_6H_6 and $C_6H_5CH_3$
    (d) C_2H_5I and C_2H_5OH

7. Which of the following is not current for ideal solution.
    (a) $\Delta S_{mix} = 0$
    (b) $\Delta H_{mix} = 0$
    (c) It Obeys Raoult's law
    (d) $\Delta V_{mix} = 0$

Answer Keys

   1. (b)   2. (c)   3. (c)   4. (d)   5. (a)
   6. (d)   7. (a)

🔑 Solutions

1. HgI_2 although insoluble in water but shows complex formation with KI and freezing point is decreased   **[1]**

2. Methanol has low boiling point than H_2O lower is boiling point of solvent more is vapour pressure.   **[1]**

3. The lower is boiling point more is vapour pressure; boiling point order, HCl < HBr < HI < HF   **[1]**

4. $X_{solute} = \dfrac{P_o - P}{P_o}$ **[1]**

    $= \dfrac{\dfrac{18}{180}}{\dfrac{18}{180} + \dfrac{178.2}{18}} = \dfrac{760 - P}{760}$

    ∴ P = 752.40 Torr   **[1]**

5. Aromatic compound generally separated by fractional distillation e.g. Benzene + Toluene.   **[1]**

6. C_2H_5I and C_2H_5OH do not form ideal solution.   **[1]**

7. For the ideal solution ΔS_{mix} is not equal to zero.
    ∴ $\Delta S_{mix} = 0$ **[1]**

Topic 3: Colligative Properties, Determination of Molecular Mass and Abnormal Molar Mass

Summary

Colligative properties depend on the number of solute particles but do not depend on its chemical identity. When a non volatile solute is added to volatile solvent, vapour pressure decreases. The properties of such solutions are:

- **Relative lowering of vapour pressure of solvent:** A relation between vapour pressure of solution, mole fraction and vapour pressure of the solvent is as follows:

$$p_i = x_i p_i^o$$

Reduction in vapour pressure of solvent is given by:

$$\Delta p_i = (1 - x_i) p_i^o = x_j p_i^o$$

$$\frac{\Delta p_i}{p_i^o} = \frac{p_i^o - p_i}{p_i^o} = x_j$$

This expression is called relative lowering of vapour pressure which equals mole fraction of the solute.

- **Elevation of boiling point:** Boiling point of a solution is always higher than the boiling point of the pure solvent. The elevation of boiling point depends on the number of solute molecules.

The difference between the boiling point of solution and boiling point of pure solvent gives the elevation of boiling point.

$$\Delta T_b = T_b - T_b^o$$

For dilute solutions, $\Delta T_b = K_b m$, where K_b is called Boiling Point Elevation Constant, and m is molality.

Boiling point of Solvent Solution
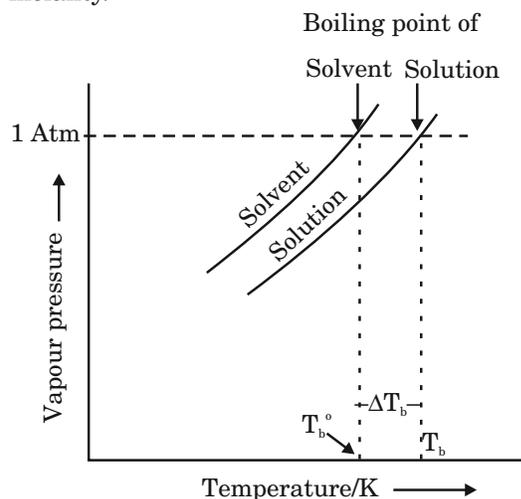
ΔT_b denotes elevation of boiling point of solvent

- **Depression of freezing point:** Lowering of vapour pressure causes depression of freezing point. The difference between the freezing point of pure solvent and freezing point of solvent when non volatile solute is dissolved in it gives the depression in freezing point.
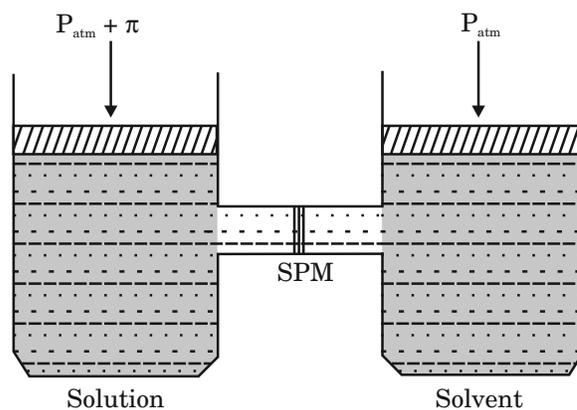
$$\Delta T_f = T_f^o - T_f$$

For dilute solutions, $\Delta T_f = K_f m$, where K_f is the freezing point depression constant
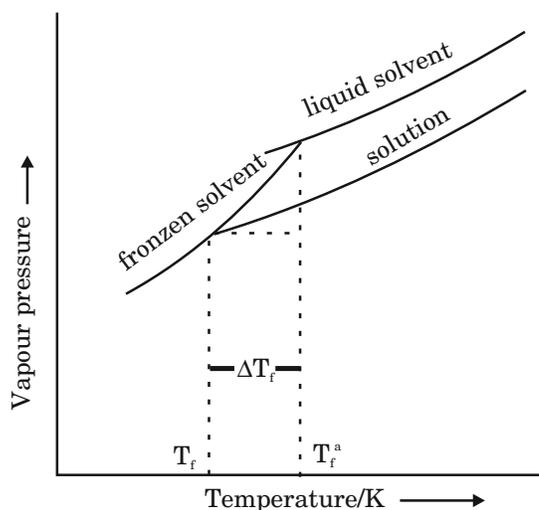
- **Osmosis:** The flow of solvent molecules from pure solvent to solution is called osmosis. Some extra pressure applied which just stops the flow of solvent is called osmotic pressure.

Osmotic pressure of solution

$$\pi = \frac{n}{VRT}, \text{ where } \pi = CRT \text{ as the osmotic pressure}$$

Excess pressure is equal to the osmotic pressure

- **Isotonic solutions:** Any two solutions having same osmotic pressure are called isotonic solutions. No osmosis occurs between such solutions which are separated by semi permeable membrane.

- **Hypertonic and hypotonic solutions:** When cells shrink due to water flowing out of the cell due to more salt concentration, then the solution is called hypertonic solution. When water flows into the cell due to less salt concentration, then the solution is called hypotonic solution.

- **Reverse Osmosis:** Pressure larger than the osmotic pressure when applied on the solution side causes reverse osmosis. It is used for water purification.
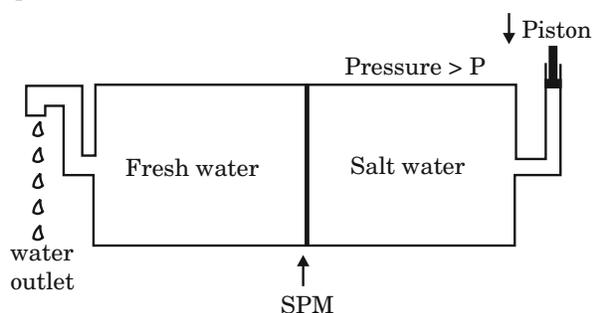
- **Abnormal Molar Mass:** A molar mass higher or lower than the normal molar mass is called abnormal molar mass.

- **Van't Hoff factor:** The Van't Hoff factor is the ratio between the actual concentration of particles produced when the substance is dissolved, and the concentration of a substance as calculated from its mass.

$$i = \frac{\text{observed (experimental) value of a colligative property}}{\text{Normal (calculated) value of the same colligative property}}$$

PREVIOUS YEARS'

EXAMINATION QUESTIONS
TOPIC 3

▶ 1 Mark Questions

1. What are isotonic solutions? **[DELHI 2014]**

2. Out of $BaCl_2$ and KCl, which one is more effective in causing coagulation of a negatively charged colloidal sol? Give reason.

[DELHI 2015]

3. Elevation of boiling point is inversely proportional to
   (a) Molal elevation constant (K_b)
   (b) Molality (m)
   (c) molar mass of solute (M)
   (d) weight of solute (W) **[TERM I 2022]**

4. The boiling point of a 0.2 m solution of a non-electrolyte in water is (K_b for water = 0.52 K kg mol^{-1})
   (a) 100°C
   (b) 100.52°C
   (c) 100.104 °C
   (d) 100.26°C **[TERM I 2022]**

▶ 2 Mark Questions

5. A 1.00 molal aqueous solution of trichloroacetic acid (CCl_3COOH) is heated to its boiling point. The solution has the boiling point of 100.18 °C. Determine the Van't Hoff factor for trichloroacetic acid. (K_b for water = 0.512 $K\ kg\ mol^{-1}$)

   OR

   Define the following terms:
   1. Mole fraction
   2. Isotonic solutions
   3. Van't Hoff factor
   4. Ideal solution **[ALL INDIA 2012]**

6. Write the dispersed phase and dispersion medium of the following colloidal system?
   (*i*) Smoke (*ii*) Milk.

   OR

   What are lyophilic and lyophobic colloids? Which of these, sols can be easily coagulated on addition of small amounts of electrolytes?

   [DELHI 2013]

7. Calculate the mass of compound (molar mass = 256 g mol^{-1}) to be dissolved in 75 g of benzene to lower its freezing point by 0.48 K (K_f = 5.12 $K\ kg\ mol^{-1}$)

   [DELHI 2014]

8. Calculate the freezing point of a solution containing 60 g of glucose (Molar mass = 180 g mol^{-1}) in 250g of water. (K_f of water = 1.86 K kg/mol^{-1})

   [ALL INDIA 2018]

9. Visha took two aqueous solutions — one containing 7.5 g of urea (Molar mass = 60 g/mol) and the other containing 42.75 g of substance Z in 100 g of water, respectively. It was observed that both the solutions froze at the same temperature. Calculate the molar mass of Z.

[DELHI 2020]

▶ 3 Mark Questions

10. Calculate the amount of KCl which must be added to 1kg of water so that the freezing point is depressed by 2K.

(K_f for water = 1.86 K kg/mol^{-1})

[ALL INDIA 2011]

11. Determine the osmotic pressure of a solution prepared by dissolving 2.5×10^{-2} g of K_2SO_4 in 2 L of water at 25°C, assuming that it is completely dissociated.

($R = 0.0821\,L\,atm\,K^{-1}\,mol^{-1}$, Molar mass of K_2SO_4 = 174 g mol^{-1}) **[DELHI 2013]**

12. 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the Van't Hoff factor and predict the nature of solute (associated or dissociated). (Given: Molar mass of benzoic acid = 122 g mol^{-1}, K_f for benzene = $4.9\ K\ kg\ mol^-$)

[DELHI 2015]

13. Vapour pressure of water at 20ºC is 17.5 mm Hg. Calculate the vapour pressure of water at 20ºC when 15 g of glucose (Molar mass = 180 g mol^{-1}) is dissolved in 150 g of water.

[ALL INDIA 2015]

14. Calculate the boiling point of solution when 4g of $MgSO_4$ (M = 120 g mol^{-1}) was dissolved in 100 g of water. Assuming $MgSO_4$ undergoes complete ionization. **[DELHI 2015]**

(K_b for water = $0.52\ K\ kg\ mo1^{-1}$)

15. Calculate the temperature at which a solution containing 54 g of glucose, $\left(C_6H_{12}O_6\right)$, in 250 g of water will freeze. **[DELHI 2016]**

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

16. Give reasons for the following:

(a) Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers

(b) Aquatic animals are more comfortable in cold water than warm water

(c) Elevation of boiling point of 1M KCl solution is nearly double than that of 1M sugar solution

[DELHI 2016]

17. A 4 % solution (w/w) of sucrose (M = 342 g mol^{-1}) in water has a freezing point of 271.15 K. Calculate the freezing point of 5 % glucose (M =180 g mol^{-1}) in water.

(Given : Freezing point of pure water = 273.15 K) **[DELHI 2019]**

18. Calculate the mass of ascorbic acid (Molar mass = 176 g mol^{-1}) to be dissolved in 75 g of acetic acid, to lower its freezing point by 1.5°C. (K_f = 3.9 K kg mol^{-1}) **[DELHI 2020]**

19. 0.3 g of acetic acid (M = 60 g mol^{-1}) dissolved in 30 g of benzene shows a depression in freezing point equal to 0.45°C. Calculate the percentage association of acid if it forms a dimer in the solution. (Given: K_f for benzene = 5.12 K kg mol^{-1}) **[DELHI 2023]**

▶ 5 Mark Questions

20. (a) Define the terms osmosis and osmotic pressure. Is the osmotic pressure of a solution a colligative property? Explain

(b) Calculate the boiling point of a solution prepared by adding 15.00 g of NaCl to 250.0 g of water. (K_b for water = $0.512K\ kgmol^{-1}$, Molar mass of $NaCl = 58.44g$)

[DELHI 2011]

21. (a) 30g of Urea (M = 60 $g\ mol^{-1}$) is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg.

(b) Write two difference between ideal solution and non-ideal solutions.

[All INDIA 2017]

22. (a) Define the following terms:

(i) Mole fraction

(ii) Van't Hoff factor

(b) 100 mg of a protein is dissolved in enough water to make 10.0 mL of a solution. If this solution has an osmotic pressure of 13.3 mmHg at 25°C, what is the molar mass of protein?

(R = 0.0821 $L\ atm\ mol^{-1}\ K^{-1}$ and 760 $mmHg$ = 1 atm)

OR

a. What is meant by:

    i. Colligative properties

    ii. Molality of a solution

b. What concentration of nitrogen should be present in a glass of water at room temperature? Assume a temperature of 25°C, a total pressure of 1 atmosphere and mole fraction of nitrogen in air of 0.78.

[K_H for nitrogen = 8.42×10^{-7} *M/mm* Hg]

[DELHI 2017]

🔑 Solutions

1. Two or more solutions having same osmotic pressure are called isotonic solutions, e.g. 0.5 M NaCl, 0.5 M KCl and 1M glucose are isotonic. **[1]**

2. According to the Hardy-Schulze rule, greater the valency of a flocculating ion, the greater is its power to cause precipitation. Between Ba^{2+} (from $BaCl_2$) and K^+ (from KCl), Ba^{2+} has greater valency. Therefore, $BaCl_2$ will be more effective in causing the coagulation of a negatively charged colloidal sol. **[1]**

3. (c) It is inversely proportional to molar mass of solute (M).

$$\ddot{A}T_b = k_b m$$ **[1]**

4. (c) We know that,

$$DT_b = K_b m$$

m = molality.

$$DT_b = 0.104\ K$$

It means –

Boiling point increases by 0.104 K or 0.104°C

Hence,

The boiling point of 0.2 m solution of a non-electrolyte in water will be 100. 104°C **[1]**

5. Given:

$$\Delta T_b = 373.18 - 373 = 0.18K$$

$$K_b = 0.512\,K\,kg\,mol^{-1}$$

$$m = 1$$

$$\Delta T_b = iK_b m$$ **[1]**

$$i = \frac{\Delta T_b}{K_b m} = \frac{0.18}{0.512 \times 1}$$

$$i = 0.35$$ **[1]**

OR

1. Ratio of the number of moles of a component in a mixture to the total number of moles in the mixture is called the mole fraction of that component. It is denoted by *x*. **[½]**

2. Two solutions having the same molar concentration are said to be isotonic solutions, eg: All intravenous injections must be isotonic with body fluids. **[½]**

3. The ratio of observed colligative property to the calculated colligative property is called the Van't Hoff factor. It is denoted by Y.**[½]**

4. Solutions that follow Raoult's law at all temperatures and concentrations are called ideal solutions. **[½]**

6. *(i)* Dispersed phase in smoke: Solid, dispersion medium in smoke: Gas **[1]**

   (ii) Dispersed phase in milk: Fats (liquid), dispersion medium in milk: Water (liquid) **[1]**

OR

Lyophilic colloids (Liquid Loving): These are the colloidal solutions in which dispersed phase has great affinity for dispersion medium. Such solutions are quite stable and are reversible in nature. E.g. starch, proteins, etc. **[1]**

Lyophobic Colloids (Liquid Hating): These are the colloidal solutions in which dispersed phase has very little affinity for the dispersion medium. Such solutions are unstable and are irreversible in nature. **[1]**

Eg. (As_2S_3 Sol).

Lyophobic colloids can be easily coagulated because on addition of small amount of electrolyte, the charge on colloidal particles is removed, as a result the particles will come closer to each other and then aggregate to form a cluster which settle down under the force of gravity.

7. Given,

$$M_B = 256\,g\,mol^{-1}, W_A = 75\,g,$$

$$K_f = 5.12\,kg\,mol^{-1}, \Delta T_f = 0.48K$$

From the formula, $\Delta T_f = K_f \times \dfrac{W_B}{M_B} \times \dfrac{1000}{W_A}$ **[1]**

Mass of solute, $W_B = \dfrac{\Delta T_f \times M_B \times W_A}{K_f \times 1000}$

$= \dfrac{0.48 \times 256 \times 75}{5.12 \times 1000}$

$= \dfrac{(0.48K)(256\,g\,mol^{-1})(0.075\,Kg)}{(5.12\,K\,Kg\,mol^{-1})} = 1.8\,g$ **[1]**

8. We know $\Delta T_f = k_f \times m$

$m = \dfrac{60/180\,mol}{0.25\,kg} = 1.33\,mol\,kg^{-1}$ **[1]**

$\Delta T_f = 1.86 \times 1.33K$

$\Rightarrow \Delta T_f = 2.4738K$

$\Rightarrow T_f^o - T_f = 2.4738K$

$\Rightarrow T_f = T_f^o - 2.4738K$

$= 273 - 2.4738K$

$= 270.5262K$ **[1]**

9. The given values are:

  W_{urea} =7.5g

  W_X = 42.75g

  W_A =100g

  Now using formula,

  $M_{wB} = K_f \times W_B \times \dfrac{1000}{\Delta t_f} \times W_A$ **[1]**

  For urea, $M_{wB} = K_f \times 7.5 \times \dfrac{1000}{\Delta T_f} \times 1000$ ...(i)

  For X$M_{w'B} = K_f \times 42.75 \times \dfrac{1000}{\Delta T_f} \times 1000$ ...(ii)

  Dividing Eq.(i) from (ii), we get

  $\left(\dfrac{60}{M_{w'B}}\right) = \dfrac{7.5}{42.75}$ or $M_{w'B} = 342$ **[1]**

  ∴ Molecular weight of X = 342 gmol⁻¹

10. Given, $K_f = 1.86\,K\,mol^{-1}$

  $i = 2, \Delta T_f = 2K$

  $M = 74.5$

  $\Delta T_f = iK_f M$ **[1]**

$2 = \dfrac{2 \times 1.86 \times \text{Mass of KCl}}{74.5}$ **[1]**

Mass of KCl $= \dfrac{74.5}{1.86} = 40.05\,gm$ **[1]**

11. We know

$\pi = iCRT \Rightarrow \pi = \dfrac{inRT}{V} \Rightarrow \pi = i \times \dfrac{w}{M} \times \dfrac{1}{V}RT$ **[1]**

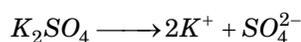Given, $w = 2.5 \times 10^{-2}, g = 0.025g$

$V = 2L, T = 25°C = 298K$

$M = K_2SO_4 = 2 \times 39 + 32 + 4 \times 16 = 174\,g\,mol^{-1}$ **[1]**

K_2SO_4 dissociates completely as

$K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$

Ions produced $= 3$ i.e., $i = 3$

Hence, $\pi = \dfrac{3 \times 0.025g}{174g\,mol^{-1}} \times \dfrac{1}{2L} \times 0.0821 \times 298K$

$\pi = 5.27 \times 10^{-3}$ atm **[1]**

12. Given: Mass of solute (W_B)

  i.e., $C_6H_5COOH = 3.9\,g$

  Mass of solvent $(W_A) = 49\,g = \dfrac{49}{1000}Kg$

  Molar mass of $C_6H_5COOH(M_S) = 122\,g/mol$

  $K_f = 4.9\,K\,Kg\,mol^{-1}$

  $\Delta T_f = 1.62K$

  To find: Vant Hoff factor $(i = ?)$

  We know that the depression in freezing point is given by: **[1]**

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

  $\Delta T_f = i \times K_f \times \dfrac{W_B}{M_S} \times \dfrac{1}{W_A(Kg)}$

  $i = \dfrac{\Delta T_f \times M_S \times W_A(Kg)}{K_f \times W_B}$

  $i = \dfrac{1.62 \times 122 \times 49}{4.9 \times 3.9 \times 1000}$ **[1]**

  $i = 0.5067$

  Since, $i < 1$, hence solute benzoic acid (C_6H_5COOH) will undergo association in benzene **[1]**

13. $$\frac{p^o - p}{p^o} = \frac{w_b \times M_A}{M_b \times w_A}$$ [1]

Here $w_b = 15\,g$ (glucose)

$M_A = 15g\,(water)$

$M_b = 150\,(glucose)$

$w_A = 150\,(water)$

$$\frac{17.5 - p}{17.5} = \frac{15 \times 18}{180 \times 150}$$ [1]

$17.5P = 17.5 \times 0.01$

$P = 17.325\,mmHg$ [1]

14. Given: $K_b = 0.52K\,kg\,mol^{-1}$

Mass of solute, $MgSO_4 = 4\,g$

Mass of solvent, water $= 100\,g$

So, Molarity of solution,

$$m = \frac{4}{120} \times \frac{1000}{100}$$ [1]

$m = 0.33\,mol\,/\,L$

Also, $MgSO_4$ undergoes complete isolation, thereby yielding 2 moles of constituent ions for every mole of $MgSO_4$ [1]

Therefore, $i = 2$

Now, **elevation in boiling point** is given as,

$\Delta T_b = iK_b m$

$= 2 \times 0.52 \times 0.33 = 0.34$

$T_b = 373.15 + 0.34 = 373.49K$

Therefore, the **new boiling point of the solution is** $373.49\,K$. [1]

15. $\Delta T_f = K_f m$

No. of moles of glucose $= \dfrac{54g}{180\,g\,mol^{-1}}$ [1]

Molarity of Glucose solution

$= \dfrac{54}{180}mol^{-1} \times \dfrac{1000}{250\,kg} = 1.20\,mol\,kg^{-1}$

$\Delta T_f = K_f m$

$= 1.86\,K\,kgmol^{-1} \times 1.20\,mol\,kg^{-1} = 2.23\,K$ [1]

Temperature at which solutions freezes

$= 273.15 - 223\,K$

$= 270.77$ K or $2.23°C$

or $(273.000 - 2.23)\,K = 270.7$ K [1]

16. (*a*) Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers because: [1]

1. Osmotic pressure can be measured at room temperature whereas other colligative properties need either high temp or low temp conditions.

2. Most of the macromolecules get denatured in high temp so this can be avoided.

3. Values of other colligative properties are so small that a small error can account to large difference.

(*b*) Aquatic animals are more comfortable in cold water than warm water because the amount of dissolved oxygen in water decreases with rise in the water's temperature. Cold water has more dissolved oxygen per unit area than warm water [1]

(*c*) Elevation of boiling point of 1M KCl solution is nearly double than that of 1M sugar solution because KCl gets dissociated completely into K⁺ and Cl⁻ ions and as the number of particles get doubled, the colligative properties get doubled. Therefore KCl have double the boiling point of that of sugar solution [1]

17. 4 % Solution of sucrose :

$W_B = 4$ g (mass of solute),

$M_B = 342$ g /mol

$W_S = 100$ g [mass of solution],

$W_A = 100 - 4 = 96$ g (mass of solvent)

$$T_F = k_f \times \left[\frac{W_B}{m_B} \times \frac{1000}{W_A} \right]$$

$T_F = 273.15\,K - 271.15\,K = 2\,K$

$$2 = k_f \times \left[\frac{4}{342} \times \frac{96}{96} \right] \times 100$$

$$k_f = \frac{342 \times 2 \times 96}{4000} = \frac{171 \times 96}{1000} = 16.416$$ [1]

5 % solution (by mass) of Glucose :

$W_B = 5$ g (mass of solute), $W_S = 100$ g (mass of solution)

$m_B = 180$ g / mol, $W_A = 100 - 5 = 95$ g (mass of solvent) [1]

Molality (m) $= \dfrac{5 \times 1000}{180 \times 95}$ mol kg^{-1}

$\Rightarrow T_f = K_f m$

$\Rightarrow T_f = 16.416 \times \dfrac{5 \times 1000}{180 \times 95} K = 16.416 \times \dfrac{5000}{17100} K$

$= 16.416 \times 0.29 K = 4.8 K$

Hence, Freezing point of Glucose $= 273.15 K - 4.8$ K $= 268.35 K$ [1]

18. As given that:

Mass of acetic acid, $w_1 = 75$ g

Molar mass of ascorbic acid ($C_6H_8O_6$), M_2

     $= 6 \times 12 + 8 \times 1 + 6 \times 16 = 176$ g mol^{-1}
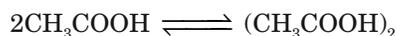
Lowering of melting point,

     $DT_f = 1.5 K.$

We know,

     $DT_f = \dfrac{K_f \times w_2 \times 1000}{M_2 \times w_1}$ [1]

$\Rightarrow w_2 = \dfrac{\Delta T_f \times M_2 \times w_1}{K_f \times 1000}$

     $= \dfrac{1.5 \times 176 \times 75}{3.9 \times 1000} = 5.08$ g

Hence required mass o ascorbic acid

     $W_2 = 5.08$ g   [2]

19. Let the degree of association of acetic acid (CH_3COOH) in benzene is a, then

     $2CH_3COOH \rightleftharpoons (CH_3COOH)_2$

Initial moles   1   O

Moles at equilibrium $1 - a$ $\dfrac{a}{2}$

$\therefore$ Total moles $= 1 - a + \dfrac{a}{2} = 1 - \dfrac{a}{2}$

or $i = 1 - \dfrac{a}{2}$ [1]

Now, depression in freezing point (DT$_f$) is given as

     $DT_f = i\, K_f m$ ...(i)

Where, K_f – molal depression constant or cryoscopic constant.

m = Molality

Molality $= \dfrac{\text{number of moles of solute}}{\text{weight of solvent (in kg)}}$

     $= \dfrac{0.3}{60} \times \dfrac{100}{30}$ [1]

Putting the values in Eq. (i)

$\therefore$ $0.45 = \left[1 - \dfrac{a}{2}\right](5.12)\left[\dfrac{1000}{30}\right]$

     $1 - \dfrac{a}{2} = \dfrac{0.45 \times 60 \times 30}{5.12 \times 0.3 \times 1000}$

$\Rightarrow$ $1 - \dfrac{a}{2} = 0.527$

$\Rightarrow$ $\dfrac{a}{2} = 1 - 0.527$

$\therefore$ $a = 0.946$ [1]

Thus, percentage of association = 94.6%

20. (a) Osmosis is the phenomenon of flow of solvent through a semi-permeable membrane from the region of higher concentration to the region of lower concentration.

The osmotic pressure of a solution is the excess pressure that must be applied to the solution to prevent the passage of solvent molecule through a semi-permeable membrane into the solution.

Yes, osmotic pressure is a colligative property as it depends only on the amount of solute present in the solution.

(b) Initial moles after dissociation we know that,

     $NaCl \longrightarrow Na^+ + Cl^-$

       1   0   0

       0   1   1
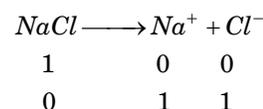
(Total no. of moles $1 + 2 = 2$)

$\therefore i = \dfrac{2}{1} = 2$

Initial moles after dissociation we know that,

$\Delta T_b = iK_b m$

$T_b - T_b° = 2 \times 0.512 \times \dfrac{15 \times 1000}{58.44 \times 250}$

$T_b - 373K = \dfrac{15360}{14610} = 1.05K$

$T_b = 1.05K + 373K$

$\therefore T_b = 374.05K$

21. (a) Vapour pressure of water,

     $p_1 = 23.8$ mm of Hg

Weight of water = 846 g

Weight of urea = 30 g

Molecular weight of water

$(H_2O) = 1 \times 2 + 16 = 18 \ g \ mol^{-1}$

Molecular weight of urea

$(NH_2CONH_2) = 2N + 4H + C + O$

$= 2 \times 14 + 4 \times 1 + 12 + 16$

$= 60 \ g \ mol^{-1}$

Number of moles of water, $n_1 = \dfrac{846}{18} = 47$

Number of mole of urea, $n_2 = \dfrac{30}{60} = 0.5$

Now, we have to calculate vapour pressure of water in the solution. We take vapour pressure as p_1.

Use the formula of Raoult's law

$$\dfrac{\left(P_1^{\ 0} - P_1\right)}{P_1^{\ 0}} = \dfrac{n_2}{\left(n_1 - n_2\right)}$$

Plug the values we get

$$\dfrac{\left(23.8 - P_1\right)}{23.8} = \dfrac{0.5}{\left(47 + 0.5\right)}$$

$$\dfrac{\left(23.8 - P_1\right)}{23.8} = 0.5106$$

After cross multiply

$23.8 - p_1 = 23.8 \times 0.5106$

Solving it, we get $p_1 = 11.6 \ mm \ Hg$

So, Vapour pressure of water in the given solution = $11.6 \ mm \ of \ Hg$

(b) **Ideal Solution**: Obey Raoult's law at every range of concentration. Non-ideal Solution:

Do not obey Raoult's law.

$\Delta H_{mixing} < 0$

Neither heat is evolved nor absorbed during dissolution.

$\Delta H_{mixing} > 0$

Endothermic dissolution; heat is absorbed.

22. (a)

(i) Mole fraction of a component is the ratio of number of moles of the component to the total number of moles of all the components. [1]

(ii) Van't Hoff factor is the ratio of normal molar mass to the abnormal molar mass. Van't Hoff factor is the ratio of observed value of colligative property to calculated value of colligative property assuming no association or dissociation. [1]

(b) Mass of protein = 100 mg = 0.1 g [1]

V = 10 ml

$\pi = 13.3 \, mm = \dfrac{13.3}{760}$ atm

$\pi V = nRT$

Number of moles, $n = \dfrac{0.1}{M}$ [1]

$\dfrac{13.3}{760} \times 0.01 = \dfrac{0.1}{M} \times 0.0821 \times 298$

$M = 13980 \ g = 13.98 \ kg$

Molar mass of protein = 13.98 kg [1]

OR

(a)

(i) All the properties which depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are known as colligative properties. [1]

(ii) Molality of solution is the number of moles of solute present in 1 kilogram of solvent. [1]

(b) $\rho_{N_2} = \chi_{N_2} \times \rho_{total}$

$= 0.78 \times 760 \ mm \ Hg$ [1]

$= 592.8 \ mm \ Hg$

$K_H = 8.42 \times 10^{-7} \ M/mmHg$

$\chi_{N_2} = ?$

$\chi_{N_2} = K_H \times \rho_{N_2}$ [1]

[Since K_H is given in M/mmHg therefore this formula is used]

$\chi_{N_2} = 8.42 \times 10^{-7} \times 592.8$

$\chi_{N_2} = 4.991 \times 10^{-10}$ [1]

MULTIPLE CHOICE QUESTIONS

1. Which of the following is a colligative property
   (a) Osmotic pressure
   (b) Boiling point
   (c) Vapour pressure
   (d) Freezing point

2. Which of the following is not a colligative property
   (*a*) Osmotic pressure
   (*b*) Elevation in B.P.
   (*c*) Vapour pressure
   (*d*) Depression in freezing point

3. Which of the following solutions is water possesses the lowest vapour pressure.
   (*a*) 0.1 (*M*) NaCl   (*b*) 0.1 (*N*) $BaCl_2$
   (*c*) 0.1 (*M*) KCl   (*d*) None of these

4. When benzoic acid dissolve in benzene, the observed molecular mass is.
   (*a*) 244   (*b*) 61
   (*c*) 366   (*d*) 122

5. Which of the following compounds corresponds van't Hoff factor 'i' to be equal to 2 for dilute solution.
   (*a*) K_2SO_4 (*b*) $NaHSO_4$
   (*c*) Sugar   (*d*) $MgSO_4$

6. The Van't Hoff factor 'i' for a 0.2 molal aqueous solution of urea is
   (*a*) 0.2   (*b*) 0.1
   (*c*) 1.2   (*d*) 1.0

7. Acetic acid dissolved in benzene shows a molecular weight of
   (*a*) 60   (*b*) 120
   (*c*) 180   (*d*) 240

8. Which of the following aqueous solutions containing 10 gm of solute in each case has highest B.P.
   (*a*) NaCl solution   (*b*) KCl solution
   (c) Sugar solution   (d) Glucose solution

Answer Keys

   1. (*a*)   **2.** (*c*)   **3.** (*b*)   **4.** (*a*)   **5.** (*d*)
   6. (*d*)   **7.** (*b*)   **8.** (*a*)

🔑 Solutions

1. Osmotic pressure is a colligative property. **[1]**
2. Vapour pressure is not a colligative property. **[1]**
3. $BaCl_2$ gives maximum ion hence it shows lowest vapour pressure. **[1]**
4. Benzoic acid in benzene undergoes association through intermolecular hydrogen bonding. **[1]**
   ∴ The observed molecular mass is 244.
5. $MgSO_4$ dissociates to give 2 ions. **[1]**
6. Urea does not give ion in the solution. **[1]**
7. Molecular weight of CH_3COOH = 60
   Hence the molecular weight of acetic acid in benzene = 2 × 60 = 120 **[1]**
8. NaCl contain highest boiling point than others compound. **[1]**