AITS Advance Preparatory Guide

Solution and Surface Chemistry

Advanced Level for IIT JEE Advanced

All India Test Series (AITS)

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Contents

1 Introduction

Solution and Surface Chemistry is a pivotal chapter for IIT JEE Advanced, delving into the behavior of solutions, their properties, and surface phenomena like adsorption and catalysis. This guide provides deeply expanded theoretical discussions, advanced examples with solutions, rigorous exercises, and JEE-style MCQs, enriched with illustrative diagrams to clarify complex concepts. The vibrant format, complete solutions, and focus on multi-step problem-solving ensure aspirants master topics like colligative properties, colloids, adsorption, and ideal/non-ideal solutions.

This booklet is designed to be a comprehensive resource, covering both foundational and advanced concepts. It includes detailed derivations, practical applications, and a variety of problems to enhance problem-solving skills, making it an essential tool for JEE preparation. The inclusion of diagrams and real-world examples helps bridge theoretical knowledge with practical understanding, ensuring aspirants are well-prepared for the exams challenges.

2 Types of Solutions and Concentration Terms

2.1 Theory

A **solution** is a homogeneous mixture of two or more substances, typically consisting of a **solute** (dissolved substance) and a **solvent** (dissolving medium). Solutions are classified based on the physical state of solute and solvent: gas in gas (e.g., air), liquid in liquid (e.g., ethanol in water), solid in liquid (e.g., sugar in water), etc. For JEE, liquid solutions, especially aqueous ones, are most relevant due to their frequent appearance in problems involving colligative properties and reactions. Solutions can also be **binary** (two components), **ternary** (three components), or higher, with binary solutions being the focus for most JEE questions.

Concentration terms are critical for quantifying the amount of solute in a solution, and JEE often tests conversions between these terms: - **Molarity (M)**: Moles of solute per liter of solution, $M = \frac{\text{moles of solute}}{\text{volume of solution (L)}}$. It is temperature-dependent due to volume expansion. - **Molality (m)**: Moles of solute per kilogram of solvent, $m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$. It is temperature-independent, making it ideal for colligative property calculations. - **Mole fraction (x)**: Ratio of moles of a component to total moles, $x_A = \frac{n_A}{n_A+n_B}$, also temperature-independent. - **Mass percentage**: Mass % $= \left(\frac{\text{mass of solute}}{\text{mass of solution}}\right) \times 100$, commonly used in practical applications.

Understanding the differences between these concentration terms is crucial for JEE, as problems often involve switching between them or using them in dilution calculations. For instance, molarity changes with temperature, requiring careful consideration in problems involving temperature variations, while molality remains constant, making it preferred for precise measurements in colligative property problems. Additionally, JEE questions may involve ppm (parts per million) or normality, though these are less common in this chapter. The diagram below illustrates a binary solution with solute particles dispersed in a solvent.

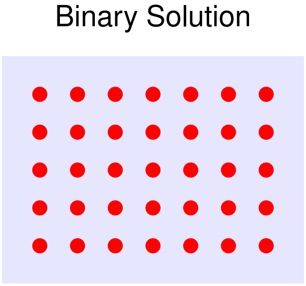

Figure 1: A binary solution showing solute particles (red) dispersed in a solvent (blue).

2.2 Example 1: Molarity Calculation

Calculate the molarity of a solution prepared by dissolving 5 g of NaOH (molar mass 40 g/mol) in water to make 250 mL of solution.

Solution: Moles of NaOH: $n = \frac{\text{mass}}{\text{molar mass}} = \frac{5}{40} = 0.125\,\text{mol}$. Volume of solution: $V = 250\,\text{mL} = 0.25\,\text{L}$. Molarity:

$$M = \frac{n}{V} = \frac{0.125}{0.25} = 0.5\,\text{M}$$

Thus, the molarity is 0.5 M.

2.3 Example 2: Molality Calculation

Find the molality of a solution made by dissolving 18 g of glucose (molar mass 180 g/mol) in 500 g of water.

Solution: Moles of glucose: $n = \frac{18}{180} = 0.1\,\text{mol}$. Mass of solvent: 500 g = 0.5 kg. Molality:

$$m = \frac{n}{\text{mass of solvent (kg)}} = \frac{0.1}{0.5} = 0.2\,\text{mol/kg}$$

Thus, the molality is 0.2 m.

2.4 Example 3: Mole Fraction in a Binary Solution

Calculate the mole fraction of ethanol in a solution containing 46 g of ethanol (molar mass 46 g/mol) and 18 g of water (molar mass 18 g/mol).

Solution: Moles of ethanol: $n_{\text{ethanol}} = \frac{46}{46} = 1\,\text{mol}$. Moles of water: $n_{\text{water}} = \frac{18}{18} = 1\,\text{mol}$. Total moles: $1 + 1 = 2$. Mole fraction of ethanol:

$$x_{\text{ethanol}} = \frac{n_{\text{ethanol}}}{n_{\text{total}}} = \frac{1}{2} = 0.5$$

Thus, the mole fraction of ethanol is 0.5.

2.5 Example 4: Conversion Between Concentration Terms

A solution has a molarity of 0.1 M and a density of 1.02 g/mL. If the molar mass of the solute is 58.5 g/mol (NaCl), calculate the molality of the solution (solvent is water).

Solution: Molarity: 0.1 M means 0.1 moles of NaCl per liter of solution. Mass of NaCl in 1 L: $0.1 \cdot 58.5 = 5.85\,\text{g}$. Mass of solution: $1000\,\text{mL} \cdot 1.02\,\text{g/mL} = 1020\,\text{g}$. Mass of water (solvent): $1020 - 5.85 = 1014.15\,\text{g} = 1.01415\,\text{kg}$. Molality:

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{0.1}{1.01415} \approx 0.0986\,\text{mol/kg}$$

Thus, the molality is approximately 0.099 m.

3 Colligative Properties

3.1 Theory

Colligative properties depend on the number of solute particles in a solution, not their nature, making them critical for JEE problems involving molecular weight determination or solution behavior. These properties include: - **Relative lowering of vapor pressure**: Raoults law states $\frac{p_0-p}{p_0} = x_{\text{solute}}$, where p_0 is the vapor pressure of the pure solvent, p is the vapor pressure of the solution, and x_{solute} is the mole fraction of the solute. - **Elevation of boiling point**: $\Delta T_b = K_b \cdot m \cdot i$, where K_b is the molal boiling point elevation constant, m is molality, and i is the vant Hoff factor. - **Depression of freezing point**: $\Delta T_f = K_f \cdot m \cdot i$, where K_f is the molal freezing point depression constant. - **Osmotic pressure**: $\pi = CRT$, where C is molarity, R is the gas constant (0.0821 L atm/mol K), and T is the temperature in Kelvin.

For electrolytes, the vant Hoff factor i accounts for dissociation (e.g., $i = 2$ for NaCl, $i = 3$ for $CaCl_2$). These properties are often used in JEE to determine the molecular weight of unknown solutes, especially in osmosis or freezing point depression experiments. For example, osmotic pressure is directly proportional to molarity, making it a preferred method for macromolecules due to measurable pressure differences. Additionally, JEE questions may involve abnormal colligative properties due to association or dissociation of solutes, requiring careful calculation of i. The diagram below illustrates osmosis through a semipermeable membrane, a key concept for understanding osmotic pressure.

Colligative properties also have practical applications, such as in antifreeze solutions (lowering freezing point) or desalination (reverse osmosis). JEE Advanced often tests these concepts in multi-step problems, combining concentration calculations with colligative effects, or comparing ideal vs. non-ideal behavior in electrolyte solutions.

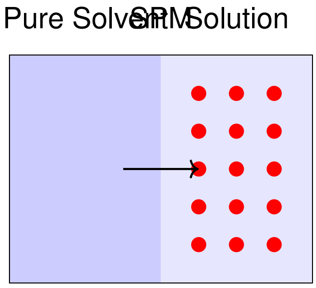

Figure 2: Osmosis: solvent flows from pure solvent to solution through a semipermeable membrane (SPM).

3.2 Example 1: Relative Lowering of Vapor Pressure

A solution contains 18 g of glucose (molar mass 180 g/mol) in 90 g of water (molar mass 18 g/mol). Calculate the relative lowering of vapor pressure.

Solution: Moles of glucose: $n_{\text{glucose}} = \frac{18}{180} = 0.1\,\text{mol}$. Moles of water: $n_{\text{water}} = \frac{90}{18} = 5\,\text{mol}$. Mole fraction of glucose:

$$x_{\text{glucose}} = \frac{0.1}{0.1+5} = \frac{0.1}{5.1} \approx 0.0196$$

Relative lowering of vapor pressure: $\frac{p_0-p}{p_0} = x_{\text{glucose}} \approx 0.0196$. Thus, the relative lowering is 0.0196.

3.3 Example 2: Elevation of Boiling Point

Calculate the boiling point elevation of a 0.1 m aqueous solution of NaCl ($K_b = 0.52\,\text{K kg/mol}$).

Solution: For NaCl, $i = 2$ (dissociates into Na$^+$ and Cl$^-$). Molality $m = 0.1$ mol/kg. Elevation of boiling point:

$$\Delta T_b = K_b \cdot m \cdot i = 0.52 \cdot 0.1 \cdot 2 = 0.104\,\text{K}$$

Thus, the boiling point elevation is 0.104 K.

3.4 Example 3: Osmotic Pressure

Find the osmotic pressure of a 0.01 M glucose solution at 300 K ($R = 0.0821$ L atm/mol K).

Solution: Osmotic pressure: $\pi = CRT$. Given $C = 0.01$ M, $R = 0.0821$ L atm/mol K, $T = 300$ K:

$$\pi = 0.01 \cdot 0.0821 \cdot 300 \approx 0.2463\,\text{atm}$$

Thus, the osmotic pressure is approximately 0.246 atm.

3.5 Example 4: Molecular Weight Determination Using Freezing Point Depression

A 1.2 g sample of a non-volatile solute is dissolved in 50 g of water, lowering the freezing point by 0.372 K ($K_f = 1.86$ K kg/mol). Calculate the molar mass of the solute.

Solution: Freezing point depression: $\Delta T_f = K_f \cdot m$. Given $\Delta T_f = 0.372$ K, $K_f = 1.86$ K kg/mol, mass of solvent = 0.05 kg. Molality:

$$m = \frac{\Delta T_f}{K_f} = \frac{0.372}{1.86} = 0.2\,\text{mol/kg}$$

Moles of solute: moles $= m \cdot$ mass of solvent (kg) $= 0.2 \cdot 0.05 = 0.01$ mol. Molar mass:

$$\text{Molar mass} = \frac{\text{mass of solute}}{\text{moles}} = \frac{1.2}{0.01} = 120\,\text{g/mol}$$

Thus, the molar mass is 120 g/mol.

4 Colloids and Their Properties

4.1 Theory

Colloids are heterogeneous mixtures where the particle size of the dispersed phase ranges from 1 nm to 1000 nm, intermediate between true solutions (< 1 nm) and suspensions (> 1000 nm). Colloids are classified based on the dispersed phase and medium: sols (solid in liquid, e.g., paint), emulsions (liquid in liquid, e.g., milk), foams (gas in liquid, e.g., whipped cream), aerosols (liquid in gas, e.g., fog), etc. They exhibit unique properties critical for JEE: - **Tyndall effect**: Scattering of light by colloidal particles, distinguishing them from true solutions. - **Brownian motion**: Random movement of colloidal particles due to collisions with solvent molecules. - **Electrophoresis**: Movement of charged colloidal particles in an electric field, used to determine their charge.

Colloids are prepared by condensation methods (e.g., chemical reactions like hydrolysis) or dispersion methods (e.g., mechanical grinding), and purified by dialysis, ultrafiltration, or ultracentrifugation. The **coagulation** of colloids occurs when their stability is disrupted, often by adding electrolytes (Hardy-Schulze rule: higher the charge of the ion, greater its coagulating power). For example, adding NaCl to a negatively charged As_2S_3 sol causes coagulation by neutralizing the charge. JEE problems often involve identifying colloidal types, their properties, preparation methods, or calculating coagulation values. The diagrams below illustrate the Tyndall effect and electrophoresis in colloidal solutions.

Colloids have significant applications, such as in medicine (colloidal gold for drug delivery), food industry (emulsions like mayonnaise), and environmental science (aerosols in air pollution). JEE Advanced may test these applications alongside theoretical concepts, requiring a deep understanding of colloidal behavior.

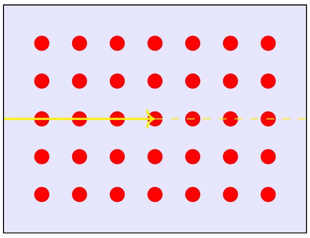

Figure 3: Tyndall effect: light scattering by colloidal particles in a solution.

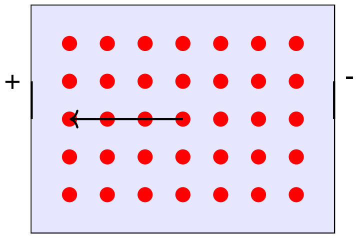

Figure 4: Electrophoresis: negatively charged colloidal particles move toward the positive electrode.

4.2 Example 1: Tyndall Effect Identification

Which of the following shows the Tyndall effect: (a) Salt solution, (b) Milk, (c) Sugar solution?

Solution: The Tyndall effect is shown by colloids due to the scattering of light by particles of size 11000 nm. (a) Salt solution: True solution, particle size < 1 nm, no Tyndall effect. (b) Milk: Emulsion (colloid), particle size in colloidal range, shows Tyndall effect. (c) Sugar solution: True solution, no Tyndall effect. Thus, milk shows the Tyndall effect.

4.3 Example 2: Electrophoresis

A colloidal solution of As_2S_3 is negatively charged. Predict the direction of particle movement in an electric field.

Solution: In electrophoresis, charged colloidal particles move under an electric field. Since As_2S_3 particles are negatively charged, they will move toward the positive electrode (anode). Thus, the particles move toward the anode.

4.4 Example 3: Coagulation Value

The coagulation value of NaCl for a negatively charged sol is 52 mmol/L. How many grams of NaCl are needed to coagulate 1 L of the sol?

Solution: Coagulation value is the minimum concentration of electrolyte needed to coagulate a sol. For NaCl, 52 mmol/L = 0.052 mol/L. Mass of NaCl (molar mass 58.5 g/mol) in 1 L:

$$\text{Mass} = 0.052 \cdot 58.5 \approx 3.042\,\text{g}$$

Thus, 3.042 g of NaCl is needed.

4.5 Example 4: Hardy-Schulze Rule Application

Compare the coagulating power of NaCl and $AlCl_3$ for a negatively charged sol.

Solution: According to the Hardy-Schulze rule, the coagulating power of an electrolyte depends on the charge of the ion causing coagulation. For a negatively charged sol, the coagulating ions are Na^+ (from NaCl, charge +1) and Al^{3+} (from $AlCl_3$, charge +3). Coagulating power is proportional to the fourth power of the ions charge: $(\text{charge})^4$. For Na^+, $(1)^4 = 1$; for Al^{3+}, $(3)^4 = 81$. Thus, $AlCl_3$ has 81 times greater coagulating power than NaCl.

5 Adsorption and Catalysis

5.1 Theory

Adsorption is the accumulation of a substance (adsorbate) on the surface of a solid or liquid (adsorbent), distinct from absorption (penetration into the bulk). It is classified as **physical adsorption** (weak van der Waals forces, reversible, multilayer) and **chemical adsorption** (strong chemical bonds, irreversible, monolayer). The extent of adsorption is often described by the Freundlich isotherm: $\frac{x}{m} = kP^{1/n}$, where x/m is the mass of adsorbate per unit mass of adsorbent, P is pressure, and k, n are constants ($n > 1$). The Langmuir isotherm, $\frac{x}{m} = \frac{aP}{1+bP}$, assumes monolayer adsorption and is also relevant for JEE.

Catalysis involves a substance (catalyst) that increases the rate of a reaction by lowering the activation energy without being consumed. Catalysts are classified as **homogeneous** (same phase as reactants, e.g., H_2SO_4 in esterification), **heterogeneous** (different phase, e.g., Fe in Habers process), or **enzyme catalysts** (biological, e.g., invertase in sucrose hydrolysis). Catalysts work by providing an alternative reaction pathway, often through intermediate formation. JEE problems may involve adsorption isotherms, catalyst identification, or enzyme stoichiometry. The diagrams below show the Freundlich adsorption isotherm and the effect of a catalyst on activation energy.

Adsorption has applications in gas masks (activated charcoal adsorbs toxic gases), while catalysis is crucial in industrial processes like ammonia synthesis (Habers process) and petroleum cracking. JEE Advanced often tests these concepts in numerical problems or conceptual questions involving reaction mechanisms or surface phenomena.

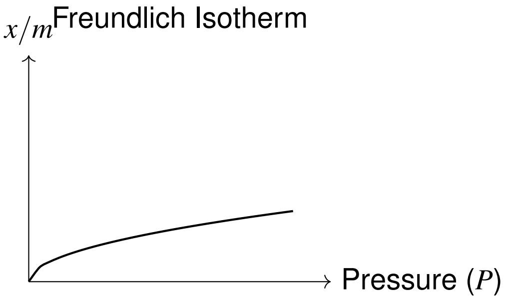

Figure 5: Freundlich adsorption isotherm: x/m vs. pressure P.

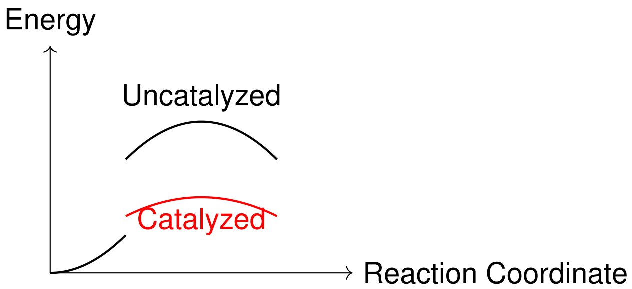

Figure 6: Effect of a catalyst: lowering the activation energy of a reaction.

5.2 Example 1: Freundlich Isotherm

The adsorption of a gas on a solid follows the Freundlich isotherm with $\frac{x}{m} = 0.1P^{0.5}$. Calculate x/m at $P = 4\,\text{atm}$.

Solution: Given: $\frac{x}{m} = 0.1P^{0.5}$. At $P = 4\,\text{atm}$:

$$\frac{x}{m} = 0.1 \cdot (4)^{0.5} = 0.1 \cdot 2 = 0.2$$

Thus, $\frac{x}{m} = 0.2$.

5.3 Example 2: Catalyst Identification

Identify the type of catalyst in the reaction: $2SO_2(g) + O_2(g) \xrightarrow{\text{V}_2\text{O}_5} 2SO_3(g)$.

Solution: In the reaction, V_2O_5 is a solid, while the reactants (SO_2, O_2) are gases. Since the catalyst is in a different phase than the reactants, it is a heterogeneous catalyst. Thus, V_2O_5 is a heterogeneous catalyst.

5.4 Example 3: Enzyme Catalysis

An enzyme catalyzes the conversion of sucrose to glucose and fructose. If 34.2 g of sucrose (molar mass 342 g/mol) is converted, calculate the moles of glucose produced.

Solution: The reaction is: $C_{12}H_{22}O_{11} + H_2O \xrightarrow{\text{invertase}} C_6H_{12}O_6 + C_6H_{12}O_6$. Moles of sucrose: $n = \frac{34.2}{342} = 0.1\,\text{mol}$. Since 1 mole of sucrose produces 1 mole of glucose, moles of glucose = 0.1 mol.

5.5 Example 4: Langmuir Isotherm

The adsorption of a gas follows the Langmuir isotherm: $\frac{x}{m} = \frac{2P}{1+0.5P}$. Calculate $\frac{x}{m}$ at $P = 2\,\text{atm}$.

Solution: Given: $\frac{x}{m} = \frac{2P}{1+0.5P}$. At $P = 2\,\text{atm}$:

$$\frac{x}{m} = \frac{2 \cdot 2}{1 + 0.5 \cdot 2} = \frac{4}{1+1} = \frac{4}{2} = 2$$

Thus, $\frac{x}{m} = 2$.

6 Raoults Law and Ideal/Non-Ideal Solutions

6.1 Theory

Raoults Law states that the partial vapor pressure of a component in an ideal solution is equal to the vapor pressure of the pure component multiplied by its mole fraction: $P_A = P_A^0 x_A$, where P_A^0 is the vapor pressure of pure component A, and x_A is its mole fraction. For a binary solution, the total vapor pressure is $P = P_A^0 x_A + P_B^0 x_B$. **Ideal solutions** obey Raoults Law over the entire composition range, with intermolecular forces between components similar to those within each component (e.g., benzene-toluene). **Non-ideal solutions** deviate from Raoults Law due to differing intermolecular forces, showing **positive deviation** (e.g., ethanol-water, higher vapor pressure than expected) or **negative deviation** (e.g., acetone-chloroform, lower vapor pressure).

Deviations arise from interactions: positive deviation occurs when A-B interactions are weaker than A-A or B-B (e.g., ethanol-water, hydrogen bonding in water is disrupted), leading to a maximum boiling azeotrope. Negative deviation occurs when A-B interactions are stronger (e.g., acetone-chloroform, hydrogen bonding between components), leading to a minimum boiling azeotrope. JEE problems often involve calculating vapor pressures, identifying deviations, or determining azeotrope compositions. The diagram below illustrates positive and negative deviations from Raoults Law.

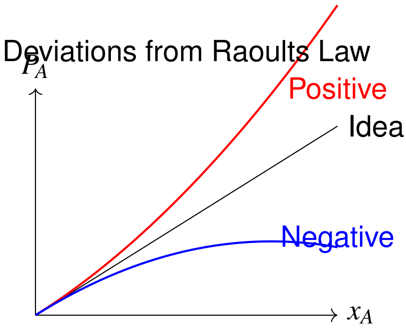

Figure 7: Raoults Law: Positive (red) and negative (blue) deviations vs. ideal behavior.

6.2 Example 1: Vapor Pressure of Ideal Solution

A solution contains 0.5 mole of benzene ($P^0_{\text{benzene}} = 100\,\text{mmHg}$) and 0.5 mole of toluene ($P^0_{\text{toluene}} = 50\,\text{mmHg}$). Calculate the total vapor pressure.

Solution: Total moles: $0.5 + 0.5 = 1$. Mole fraction of benzene: $x_{\text{benzene}} = \frac{0.5}{1} = 0.5$. Mole fraction of toluene: $x_{\text{toluene}} = 0.5$. Total vapor pressure:

$$P = P^0_{\text{benzene}} x_{\text{benzene}} + P^0_{\text{toluene}} x_{\text{toluene}} = 100 \cdot 0.5 + 50 \cdot 0.5 = 50 + 25 = 75\,\text{mmHg}$$

Thus, the total vapor pressure is 75 mmHg.

6.3 Example 2: Positive Deviation

A solution of ethanol and water shows positive deviation from Raoults Law. If the vapor pressure of pure ethanol is 60 mmHg and pure water is 20 mmHg, and the mole fraction of ethanol is 0.4, estimate the vapor pressure if the actual pressure is 10% higher than ideal.

Solution: Mole fraction of ethanol: $x_{\text{ethanol}} = 0.4$, water: $x_{\text{water}} = 0.6$. Ideal vapor pressure:

$$P_{\text{ideal}} = 60 \cdot 0.4 + 20 \cdot 0.6 = 24 + 12 = 36\,\text{mmHg}$$

Actual pressure (10% higher): $P_{\text{actual}} = 36 \cdot 1.1 = 39.6\,\text{mmHg}$. Thus, the vapor pressure is 39.6 mmHg.

6.4 Example 3: Negative Deviation

A solution of acetone and chloroform shows negative deviation. If the ideal vapor pressure is 200 mmHg and the actual vapor pressure is 180 mmHg, calculate the percentage deviation.

Solution: Percentage deviation:

$$\text{Deviation \%} = \left(\frac{P_{\text{ideal}} - P_{\text{actual}}}{P_{\text{ideal}}}\right) \times 100 = \left(\frac{200 - 180}{200}\right) \times 100 = 10\%$$

Thus, the percentage deviation is 10% (negative).

6.5 Example 4: Azeotrope Composition

A binary solution forms a maximum boiling azeotrope at 60 mol% of component A. If the vapor pressure of pure A is 300 mmHg and pure B is 100 mmHg, calculate the ideal vapor pressure at this composition.

Solution: Mole fraction of A: $x_A = 0.6$, B: $x_B = 0.4$. Ideal vapor pressure (though azeotrope deviates, we calculate ideal for comparison):

$$P = 300 \cdot 0.6 + 100 \cdot 0.4 = 180 + 40 = 220\,\text{mmHg}$$

Thus, the ideal vapor pressure is 220 mmHg.

7 Exercises

7.1 Exercise 1

Calculate the mass percentage of a solution made by dissolving 20 g of NaCl in 80 g of water.

Solution: Mass of solution = 20 g (NaCl) + 80 g (water) = 100 g. Mass percentage:

$$\text{Mass \%} = \left(\frac{\text{mass of NaCl}}{\text{mass of solution}}\right) \times 100 = \left(\frac{20}{100}\right) \times 100 = 20\%$$

Thus, the mass percentage is 20%.

7.2 Exercise 2

Find the freezing point depression of a 0.2 m aqueous solution of KCl ($K_f = 1.86\,\text{K}$ kg/mol).

Solution: For KCl, $i = 2$ (dissociates into K^+ and Cl^-). Molality $m = 0.2\,\text{mol/kg}$. Freezing point depression:

$$\Delta T_f = K_f \cdot m \cdot i = 1.86 \cdot 0.2 \cdot 2 = 0.744\,\text{K}$$

Thus, the freezing point depression is 0.744 K.

7.3 Exercise 3

Which of the following is a colloidal solution: (a) Sugar in water, (b) Blood, (c) NaCl in water?

Solution: Colloids have particle sizes between 1 nm and 1000 nm. (a) Sugar in water: True solution, particle size < 1 nm, not a colloid. (b) Blood: Contains suspended particles (e.g., red blood cells) in the colloidal range, so it is a colloid. (c) NaCl in water: True solution, not a colloid. Thus, blood is a colloidal solution.

7.4 Exercise 4

In the Freundlich isotherm $\frac{x}{m} = 0.5P^{0.25}$, calculate P when $\frac{x}{m} = 1$.

Solution: Given: $\frac{x}{m} = 0.5P^{0.25}$. Set $\frac{x}{m} = 1$:

$$1 = 0.5P^{0.25} \implies P^{0.25} = \frac{1}{0.5} = 2 \implies P = 2^4 = 16\,\text{atm}$$

Thus, $P = 16\,\text{atm}$.

7.5 Exercise 5

Calculate the osmotic pressure of a 0.05 M solution of $CaCl_2$ at 27řC ($R = 0.0821\,$L atm/mol K).

Solution: For $CaCl_2$, $i = 3$ (dissociates into Ca^{2+} and $2Cl^-$). Effective molarity: $C_{\text{eff}} = 0.05 \cdot 3 = 0.15\,\text{M}$. Temperature: $T = 27 + 273 = 300\,\text{K}$. Osmotic pressure:

$$\pi = C_{\text{eff}} \cdot R \cdot T = 0.15 \cdot 0.0821 \cdot 300 \approx 3.6945\,\text{atm}$$

Thus, the osmotic pressure is approximately 3.69 atm.

7.6 Exercise 6

A solution of acetone and chloroform has a vapor pressure of 250 mmHg, while the ideal vapor pressure is 280 mmHg. Identify the type of deviation.

Solution: Actual vapor pressure (250 mmHg) is less than ideal (280 mmHg), indicating negative deviation from Raoults Law. This occurs because acetone and chloroform form stronger intermolecular interactions (e.g., hydrogen bonding) than expected, reducing the vapor pressure. Thus, the solution shows negative deviation.

8 Multiple Choice Questions

8.1 MCQ 1

Which concentration term is temperature-independent? Molarity, Molality, Mole fraction, Mass percentage

A. Molarity **B.** Molality **C.** Mole fraction **D.** Mass percentage

Answer: B

Solution: Molarity depends on volume, which changes with temperature, so it is temperature-dependent. Molality depends on the mass of the solvent, which is temperature-independent. Mole fraction and mass percentage are also temperature-independent, but molality is the most common answer in this context for JEE. Thus, the answer is molality.

8.2 MCQ 2

Vant Hoff factor of $CaCl_2$ in water? 1, 2, 3, 4
A. 1 **B.** 2 **C.** 3 **D.** 4

Answer: C

Solution: $CaCl_2$ dissociates as: $CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$, so $i = 1 + 2 = 3$. Thus, the vant Hoff factor is 3.

8.3 MCQ 3

Which shows Brownian motion? True solution, Suspension, Colloid, All of these
A. True solution **B.** Suspension **C.** Colloid **D.** All of these

Answer: C

Solution: Brownian motion is the random movement of particles due to collisions with solvent molecules, observed in colloids (particle size 11000 nm). True solutions have particles too small, and suspensions have particles too large to show significant Brownian motion. Thus, colloids show Brownian motion.

8.4 MCQ 4

Catalyst in Habers process? Fe, Ni, V_2O_5, Pt
A. Fe **B.** Ni **C.** V_2O_5 **D.** Pt

Answer: A

Solution: Habers process ($N_2 + 3H_2 \rightarrow 2NH_3$) uses iron (Fe) as a heterogeneous catalyst, often with promoters like Mo. Thus, the catalyst is Fe.

8.5 MCQ 5

Which pair shows positive deviation from Raoults Law? Benzene-Toluene, Ethanol-Water, Acetone-Chloroform, Chloroform-Benzene
A. Benzene-Toluene **B.** Ethanol-Water **C.** Acetone-Chloroform **D.** Chloroform-Benzene

Answer: B

Solution: Positive deviation occurs when A-B interactions are weaker than A-A or B-B. Ethanol-water shows positive deviation due to weaker hydrogen bonding between ethanol and water compared to within each component. Benzene-toluene is ideal, acetone-chloroform shows negative deviation, and chloroform-benzene also shows negative deviation. Thus, ethanol-water is the correct pair.

8.6 MCQ 6

Which method is used to purify a colloidal solution? Filtration, Distillation, Dialysis, Crystallization

A. Filtration **B.** Distillation **C.** Dialysis **D.** Crystallization

Answer: C

Solution: Colloidal solutions are purified by dialysis, which removes small ions and impurities through a semipermeable membrane. Filtration is for suspensions, distillation for true solutions, and crystallization for solids. Thus, dialysis is the correct method.

9 Conclusion

This guide, with expanded theory, numerous examples, diagrams, exercises, and MCQs, equips JEE Advanced aspirants to excel in **Solution and Surface Chemistry**. The addition of topics like ideal/non-ideal solutions ensures a holistic understanding of the chapter. Practice diligently to master these concepts and succeed in the exam. This booklet aims to be a one-stop resource, bridging theoretical knowledge with practical problem-solving skills, preparing you for the diverse challenges of JEE Advanced.