UP Board Class 12 Chemistry 2026 Set 347 EA Question Paper with Solutions

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General Instructions

(i) This booklet contains 26 questions, each provided with a complete, step-by-step solution.

(ii) It comprises 6 single-correct multiple-choice questions.

(iii) Attempt each question on your own before reviewing the given solution.

1. What will be the Nernst equation of the cell for the following reaction?

$2Cr(s) + 3Cd^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 3Cd(s)$

(A) $E_{cell} = E^\circ_{cell} - \frac{RT}{6F} \ln \frac{[Cd^{2+}]^3}{[Cr^{3+}]^2}$

(B) $E_{cell} = E^\circ_{cell} - \frac{RT}{6F} \ln \frac{[Cr^{3+}]^2}{[Cd^{2+}]^3}$

(C) $E_{cell} = E^\circ_{cell} + \frac{RT}{6F} \ln \frac{[Cr^{3+}]^2}{[Cd^{2+}]^3}$

(D) $E_{cell} = E^\circ_{cell} + \frac{RT}{2F} \ln \frac{[Cd^{2+}]^3}{[Cr^{3+}]^2}$

Correct Answer: (B) $E_{cell} = E^\circ_{cell} - \frac{RT}{6F} \ln \frac{[Cr^{3+}]^2}{[Cd^{2+}]^3}$

Solution:

Step 1: Recall the Nernst equation.

For any cell reaction the Nernst equation is $E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \ln Q$, where n is the number of electrons transferred and Q is the reaction quotient (products over reactants, pure solids taken as 1).

Step 2: Find n.

Oxidation: $Cr \rightarrow Cr^{3+} + 3e^-$, for 2 Cr this is 6 electrons.
Reduction: $Cd^{2+} + 2e^- \rightarrow Cd$, for 3 Cd this is 6 electrons.
So $n = 6$.

Step 3: Write Q.

Solids Cr and Cd are omitted, so $Q = \frac{[Cr^{3+}]^2}{[Cd^{2+}]^3}$.

Step 4: Substitute.

$E_{cell} = E^\circ_{cell} - \frac{RT}{6F} \ln \frac{[Cr^{3+}]^2}{[Cd^{2+}]^3}$, which is option (ii).

Why others are wrong: Options with + sign invert the correct thermodynamic form; option (iv) also uses a wrong $n = 2$ and inverted Q.

$$\boxed{E_{cell} = E^\circ_{cell} - \frac{RT}{6F} \ln \frac{[Cr^{3+}]^2}{[Cd^{2+}]^3}}$$

Quick Tip: Count electrons transferred (n = 6) and write Q as products over reactants, then apply $E = E^\circ - \frac{RT}{nF} \ln Q$.

2. If the rate law for a reaction is $\text{rate} = K[A]^2[B]^0$, then what will be the order of the reaction?

(A) Zero order

(B) First order

(C) Second order

(D) Third order

Correct Answer: (C) Second order

Solution:

Step 1: Define order of reaction.
The overall order of a reaction is the sum of the powers (exponents) of the concentration terms in the experimentally determined rate law.

Step 2: Read the exponents.
Given $\text{rate} = K[A]^2[B]^0$. Power of $[A]$ is 2 and power of $[B]$ is 0.

Step 3: Add the powers.
Order $= 2 + 0 = 2$.

Conclusion: The reaction is second order (it does not depend on $[B]$ since $[B]^0 = 1$). This is option (iii).

$$\boxed{\text{Order} = 2}$$

Quick Tip: Order equals the sum of the exponents in the rate law; $[B]^0$ contributes 0.

3. For which of the following ions is the magnetic moment (μ) the highest?

(A) Zn^{2+}

(B) Fe^{2+}

(C) Co^{2+}

(D) Ni^{2+}

Correct Answer: (B) Fe^{2+}

Solution:

Step 1: Formula used.

Spin-only magnetic moment $\mu = \sqrt{n(n+2)}$ BM, where n is the number of unpaired electrons. More unpaired electrons means higher μ.

Step 2: Find d-electron count and unpaired electrons.

Zn^{2+}: $3d^{10}$, $n = 0$.

Fe^{2+}: $3d^{6}$, $n = 4$.

Co^{2+}: $3d^{7}$, $n = 3$.

Ni^{2+}: $3d^{8}$, $n = 2$.

Step 3: Compare.

Fe^{2+} has the maximum unpaired electrons (4), so $\mu = \sqrt{4(4+2)}$ $= \sqrt{24} \approx 4.90$ BM, the highest.

Conclusion: Option (ii), Fe^{2+}.

$$\boxed{Fe^{2+},\ n = 4}$$

Quick Tip: Magnetic moment rises with the number of unpaired d-electrons; count them for each ion.

4. The increasing order of reactivity of the following compounds in S_N1 reaction is:

A. $(CH_3)_3CBr$

B. $CH_3CH_2CH_2CH_2Br$

C. $(CH_3)_2CHCH_2Br$

D. $CH_3CH(Br)CH_2CH_3$

(A) A < B < C < D

(B) B < C < D < A

(C) D < C < B < A

(D) B < D < A < C

Correct Answer: (B) B < C < D < A

Solution:

Step 1: Concept.

S_N1 reactions go through a carbocation intermediate. The rate depends on how stable that carbocation is: more stable carbocation means faster S_N1. Stability order of carbocations is $3° > 2° > 1°$.

Step 2: Classify each halide.

A $(CH_3)_3CBr$ is tertiary (gives a stable $3°$ carbocation) - most reactive.

D $CH_3CH(Br)CH_2CH_3$ is secondary (gives $2°$ carbocation).

B $CH_3CH_2CH_2CH_2Br$ is a straight-chain primary halide.

C $(CH_3)_2CHCH_2Br$ is primary too, but its cation can rearrange (hydride shift) to a stable $3°$ cation, so it is slightly more reactive than the plain primary B.

Step 3: Arrange in increasing order.

Least to most reactive: B < C < D < A.

Conclusion: Option (ii).

$$\boxed{B < C < D < A}$$

Quick Tip: S_N1 rate follows carbocation stability $3° > 2° > 1°$; watch for possible rearrangement in the isobutyl halide.

5. Which of the following is most acidic?

(I) 4-methoxybenzoic acid ($-COOH$ with para $-OCH_3$)

(II) benzoic acid

(III) 4-nitrobenzoic acid ($-COOH$ with para $-NO_2$)

(A) (I)

(B) (II)

(C) (III)

(D) None of these

Correct Answer: (C) (III)

Solution:

Step 1: Concept of acid strength.

A carboxylic acid is stronger when its conjugate base (carboxylate ion) is more stable. Electron-withdrawing groups (EWG) pull electron density away and stabilise the carboxylate, increasing acidity. Electron-donating groups (EDG) do the opposite.

Step 2: Classify the para substituents.

$-NO_2$ is a strong electron-withdrawing group. $-OCH_3$ is an electron-

donating group (via resonance). $-H$ (benzoic acid) is the reference.

Step 3: Rank acidity.
EWG $-NO_2$ raises acidity, EDG $-OCH_3$ lowers it. Hence 4-nitrobenzoic acid > benzoic acid > 4-methoxybenzoic acid.

Conclusion: Most acidic is (III), 4-nitrobenzoic acid. Option (iii).

$$\boxed{\text{4-nitrobenzoic acid}}$$

Quick Tip: Electron-withdrawing groups like $-NO_2$ at the para position increase acid strength; $-OCH_3$ decreases it.

6. Which of the following is temperature independent?

(A) Molality

(B) Molarity

(C) Normality

(D) None of these

Correct Answer: (A) Molality

Solution:

Step 1: Recall the definitions.
$\text{Molality} = \dfrac{\text{moles of solute}}{\text{mass of solvent in kg}}$. $\text{Molarity} = \dfrac{\text{moles of solute}}{\text{volume of solution in L}}$.
$\text{Normality} = \dfrac{\text{gram equivalents}}{\text{volume of solution in L}}$.

Step 2: See which quantities change with temperature.
Mass does not change with temperature, but volume of a solution

expands or contracts as temperature changes.

Step 3: Apply this.
Molarity and Normality use volume, so they change with temperature. Molality uses only masses (moles and kg of solvent), so it is independent of temperature.

Conclusion: Molality is temperature independent. Option (i).

Molality

Quick Tip: Terms based on mass are temperature independent; terms based on volume are not.

7. Explain whether the half-life of a first order reaction depends or not on the initial concentration of the reactants.

Correct Answer: —

Solution:

Step 1: Write the integrated rate law for a first order reaction.
For a first order reaction, $k = \frac{2.303}{t} \log \frac{[A]_0}{[A]}$, where $[A]_0$ is the initial concentration and $[A]$ the concentration at time t.

Step 2: Apply the half-life condition.
At the half-life $t = t_{1/2}$, half the reactant is used up, so $[A] = \frac{[A]_0}{2}$.

Step 3: Substitute.

$$k = \frac{2.303}{t_{1/2}} \log \frac{[A]_0}{[A]_0/2} = \frac{2.303}{t_{1/2}} \log 2.$$

Step 4: Solve for the half-life.

$$t_{1/2} = \frac{2.303 \times 0.301}{k} = \frac{0.693}{k}.$$

Conclusion: $t_{1/2} = \frac{0.693}{k}$ contains only the rate constant. It does NOT contain $[A]_0$, so the half-life of a first order reaction is independent of the initial concentration of the reactant.

$$\boxed{t_{1/2} = \frac{0.693}{k} \text{ (independent of } [A]_0)}$$

Quick Tip: Derive $t_{1/2} = 0.693/k$ from the first order integrated law and note that $[A]_0$ cancels out.

8. Define electrode potential and emf of a cell.

Correct Answer: —

Solution:

Step 1: Electrode potential.

When a metal electrode is dipped in a solution of its own ions, a potential difference develops between the metal and the solution due to the tendency of the metal to lose or gain electrons. This potential difference is called the **electrode potential**. It can be an oxidation potential (tendency to lose electrons) or a reduction potential (tendency to gain electrons). When the ion concentration is 1 M, temperature 298 K and pressure 1 bar, it is called the standard electrode potential E°.

Step 2: emf of a cell.
A galvanic cell has two electrodes, an anode (oxidation) and a cathode (reduction). The **electromotive force (emf)** of the cell is the potential difference between the two electrodes when no current is drawn (open circuit).

Step 3: Express emf.
$E_{cell} = E_{cathode} - E_{anode}$ (both as reduction potentials), or $E_{cell} = E_{right} - E_{left}$.

Conclusion: Electrode potential is the potential of a single electrode relative to its solution; emf is the net potential difference between the two electrodes of the cell measured with no current flowing.

$$\boxed{E_{cell} = E_{cathode} - E_{anode}}$$

Quick Tip: Electrode potential is a single-electrode property; emf is the potential difference between two electrodes at zero current, $E_{cell} = E_{cathode} - E_{anode}$.

9. $[NiCl_4]^{2-}$ is paramagnetic, while $[Ni(CO)_4]$ is diamagnetic although both are tetrahedral. Why?

Correct Answer: —

Solution:

Step 1: Oxidation state and d-configuration of Ni in each complex.
In $[NiCl_4]^{2-}$: each Cl^- is -1, overall charge -2, so Ni is $+2$. Ni^{2+}

$= 3d^8$.
In $[Ni(CO)_4]$: CO is neutral, so Ni is in the **0** oxidation state. $Ni(0)$ $= 3d^8 4s^2$.

Step 2: Nature of the ligand (spectrochemical series).
Cl^- is a **weak field (high spin)** ligand; it cannot pair up the d-electrons.
CO is a **strong field** ligand; it forces electrons to pair up.

Step 3: $[NiCl_4]^{2-}$.
$Ni^{2+}(3d^8)$ with weak Cl^- keeps 2 unpaired electrons. Hybridisation is sp^3 (tetrahedral). Since there are unpaired electrons, the complex is **paramagnetic** ($\mu = \sqrt{2(2+2)} = \sqrt{8} \approx 2.83$ BM).

Step 4: $[Ni(CO)_4]$.
Strong CO forces the two $4s$ electrons into the $3d$ sub-shell, giving $3d^{10}4s^0$ with no unpaired electrons. The empty $4s$ and $4p$ orbitals form sp^3 hybrids (tetrahedral). With no unpaired electrons the complex is **diamagnetic**.

Conclusion: Both are sp^3 tetrahedral, but the ligand field decides the magnetism: weak Cl^- leaves 2 unpaired electrons (paramagnetic) whereas strong CO pairs all electrons (diamagnetic).

$$\boxed{Cl^- : \text{ 2 unpaired (para)}; \quad CO : \text{ 0 unpaired (dia)}}$$

Quick Tip: Find Ni oxidation state in each, then use the spectrochemical series: weak Cl^- leaves unpaired electrons, strong CO pairs them all up.

10. Give the IUPAC names of the following organic compounds:

i) $CH_3 - CH_2 - CO - CH_2 - CH(CH_3) - CH_3$

ii) $C_6H_5 - CH = CH - CHO$

Correct Answer: —

Solution:

Part (i): $CH_3 - CH_2 - CO - CH_2 - CH(CH_3) - CH_3$

Step 1: Identify the functional group.

The $> C = O$ (CO) lies between two carbon atoms, so it is a ketone; the suffix is "-one".

Step 2: Choose and number the longest chain containing the carbonyl.

Longest chain: $CH_3(1) - CH_2(2) - CO(3) - CH_2(4) - CH(5) - CH_3(6)$, a chain of 6 carbons (hexanone). Number from the end that gives the C=O the lowest locant: from the left the carbonyl is at C-3, from the right it would be C-4, so we number from the left.

Step 3: Locate substituents.

A methyl group is attached at C-5.

Step 4: Assemble the name.

5-methylhexan-3-one.

Part (ii): $C_6H_5 - CH = CH - CHO$

Step 1: Identify the functional group.

$-CHO$ is an aldehyde; suffix "-al", and the aldehyde carbon is always C-1.

Step 2: Number the chain.

$CHO(1) - CH(2) = CH(3) - C_6H_5$: a 3-carbon chain with a double bond between C-2 and C-3 and a phenyl group on C-3.

Step 3: Assemble the name.

3-phenylprop-2-enal (common name: cinnamaldehyde).

Conclusion:

$$\boxed{\text{i) 5-methylhexan-3-one} \qquad \text{ii) 3-phenylprop-2-enal}}$$

Quick Tip: (i) is a hexanone with a methyl branch; (ii) is an unsaturated aldehyde (cinnamaldehyde) with a phenyl group. Number to give the functional group the lowest locant.

11. What is the van't Hoff factor? Write the equation for colligative properties including the van't Hoff factor.

Correct Answer: —

Solution:

Step 1: Definition.

The **van't Hoff factor** (i) accounts for the association or dissociation of a solute in solution. It is defined as:

$$i = \frac{\text{observed (experimental) colligative property}}{\text{calculated (normal) colligative property}}$$

Equivalently, $i = \dfrac{\text{normal molar mass}}{\text{observed molar mass}}$

$$= \frac{\text{number of particles after dissociation/association}}{\text{number of particles before}}.$$

Step 2: Meaning of its value.

$i = 1$: no association or dissociation (e.g. glucose).

$i > 1$: solute dissociates (e.g. NaCl gives $i \approx 2$).

$i < 1$: solute associates (e.g. benzoic acid in benzene forms dimers).

Step 3: Modified colligative property equations (multiply each by i).

Relative lowering of vapour pressure: $\frac{p^\circ - p_s}{p^\circ} = i \cdot x_{solute}$

Elevation of boiling point: $\Delta T_b = i K_b m$

Depression of freezing point: $\Delta T_f = i K_f m$

Osmotic pressure: $\pi = iCRT$

Conclusion: The van't Hoff factor corrects colligative property formulae for solutes that split into or combine into a different number of particles.

$$\boxed{i = \frac{\text{observed colligative property}}{\text{calculated colligative property}}}$$

Quick Tip: i = observed colligative property divided by calculated value; insert i as a multiplier in $\Delta T_b, \Delta T_f, \pi$ and vapour-pressure lowering.

12. Why do the transition metals and many of their compounds act as catalysts? Explain.

Correct Answer: —

Solution:

Step 1: Variable oxidation states.

Transition metals show many oxidation states because the energies of $(n-1)d$ and ns electrons are close. They can readily gain or lose electrons, forming intermediates and providing an alternative reaction path of lower activation energy. For example, in the Contact process V_2O_5 cycles between V^{5+} and V^{4+}; Fe in the Haber process cycles between oxidation states.

Step 2: Formation of unstable intermediate compounds.
They form loosely bound intermediate complexes with the reactants, bringing the reacting molecules together and lowering the activation energy; the catalyst is regenerated at the end.

Step 3: Large surface area and adsorption (heterogeneous catalysis).
Transition metals like Ni, Pt and Pd have partially filled d-orbitals that adsorb reactant gas molecules on their surface. This increases the concentration of reactants at the surface and weakens the bonds within the reactant molecules, speeding up the reaction (e.g. hydrogenation of oils with Ni).

Step 4: Ability to form complexes.
Vacant d-orbitals let them form coordinate bonds with reactants, activating them.

Conclusion: Variable oxidation states, formation of intermediate compounds/complexes, and the adsorbing power of partially filled d-orbitals together make transition metals and their compounds effective catalysts.

Variable oxidation states + adsorption + complex formation

Quick Tip: Think of variable oxidation states, formation of unstable intermediates/complexes, and adsorption on partially filled d-orbitals (large surface area).

13. Write the mechanism of the bimolecular nucleophilic substitution reaction (S_N2) of an alkyl halide.

Correct Answer: —

Solution:

Step 1: What S_N2 means. S_N2 stands for bimolecular nucleophilic substitution. "Bimolecular" means the slowest (rate-determining) step involves two species: the alkyl halide and the nucleophile. So the rate depends on the concentration of both.

$$\text{Rate} = k[\text{R-X}][\text{Nu}^-]$$

Step 2: It is a one-step (concerted) reaction. Bond breaking (C-X) and bond making (C-Nu) happen at the same time in a single step. There is no intermediate.

Step 3: Backside attack. The nucleophile (Nu^-) attacks the carbon atom bearing the halogen from the side exactly opposite to the leaving halide group. This is because the halogen blocks the front side.

Step 4: Transition state. In the transition state the central carbon is bonded partially to both the incoming nucleophile and the outgoing halide. The three other groups on the carbon lie in a plane (the carbon is roughly sp^2, giving a trigonal bipyramidal arrangement of five groups).

Step 5: Product and inversion. The halide leaves with the bonding electrons and the new C-Nu bond forms. The three other groups get pushed to the opposite side, so the configuration is turned inside out. This is called Walden inversion (inversion of configuration).

Example:

$$HO^- + CH_3Br \rightarrow CH_3OH + Br^-$$

The hydroxide ion attacks from behind, bromide leaves, and methanol

is formed with inverted configuration.

$$\boxed{S_N2:\ \text{one step, backside attack, rate} = k[R\text{-}X][Nu^-],\ \text{inversion}}$$

Quick Tip: Think one concerted step: the nucleophile attacks the carbon from the side opposite the halogen, giving a five-coordinate transition state and inversion of configuration.

14. What is a peptide bond? Explain with an example.

Correct Answer: —

Solution:

Step 1: Definition. A peptide bond is the amide linkage ($-CO-NH-$) that joins two amino acids. It forms between the carboxyl group ($-COOH$) of one amino acid and the amino group ($-NH_2$) of the next amino acid.

Step 2: How it forms. The two groups react and a molecule of water is removed (a condensation or dehydration reaction). The carbon of the $-COOH$ becomes joined to the nitrogen of the $-NH_2$.

Step 3: Example. When glycine reacts with alanine, the $-COOH$ of glycine joins the $-NH_2$ of alanine, losing water and forming the dipeptide glycylalanine:

$$H_2N-CH_2-COOH + H_2N-CH(CH_3)-COOH \rightarrow H_2N-CH_2-CO-NH-CH(CH_3)-COOH + H_2O$$

Step 4: Point to note. The $-CO-NH-$ group shown in bold in the product is the peptide bond. Many amino acids linked this way build up proteins.

$$\boxed{\text{Peptide bond} = -CO-NH- \text{ amide link between two amino acids}}$$

Quick Tip: It is the amide (-CO-NH-) link formed between the -COOH of one amino acid and the -NH2 of another, with loss of water.

15. i) Write the electronic configuration of an element with atomic number 24.

ii) Find the number of unpaired electrons in the Co^{2+} ion.

iii) Why is the range of oxidation states in the actinoid series greater than in the lanthanoid series?

Correct Answer: —

Solution:

Part i) Element with Z = 24 (Chromium).

Step 1: The expected filling would be $[Ar]\,3d^4\,4s^2$.

Step 2: But a half-filled $3d^5$ set and a half-filled $4s^1$ set give extra stability (exchange energy). So one 4s electron shifts into 3d.

Step 3: Correct configuration:

$$Cr\ (Z = 24) : [Ar]\,3d^5\,4s^1$$

Part ii) Unpaired electrons in Co^{2+}.

Step 1: Cobalt has $Z = 27$: $[Ar]\,3d^7\,4s^2$.

Step 2: To make Co^{2+}, remove 2 electrons; the 4s electrons are lost first, giving $[Ar]\,3d^7$.

Step 3: Fill 5 d-orbitals with 7 electrons by Hund's rule: five orbitals

get one electron each (5 unpaired), then 2 orbitals get a second electron (pairing up). That leaves $5-2=3$ unpaired electrons.

$$\boxed{Co^{2+}:\ 3d^7,\ \text{number of unpaired electrons} = 3}$$

Part iii) Wider oxidation-state range in actinoids.

Step 1: In actinoids the $5f, 6d$ and $7s$ sub-shells lie very close in energy, so all these electrons can take part in bonding.

Step 2: Because more electrons are available for bonding, actinoids show many oxidation states (for example +3 up to +7 for elements like uranium and neptunium).

Step 3: In lanthanoids the $4f$ electrons are buried deep inside and are tightly held (poor participation in bonding), so mostly only the +3 state (with a little +2 and +4) is seen. Hence actinoids have a much greater range of oxidation states than lanthanoids.

Quick Tip: Cr uses half-filled stability (3d5 4s1); Co2+ is 3d7 with 3 unpaired electrons; actinoids have close 5f, 6d, 7s energies allowing more oxidation states than the tightly held 4f lanthanoids.

16. What happens when aniline reacts with the following?

i) Bromine water

ii) $(CH_3CO)_2O$ / Pyridine

iii) HNO_2 + HCl (0°-5°C)

Correct Answer: —

Solution:

Background: In aniline the $-NH_2$ group is strongly activating and directs incoming groups to the ortho and para positions of the benzene ring.

i) With bromine water.

Step 1: The $-NH_2$ group activates the ring so strongly that bromine substitutes at all three positions (2, 4 and 6) at once, without any catalyst.

Step 2: Product is 2,4,6-tribromoaniline, which comes out as a white precipitate.

$$C_6H_5NH_2 + 3Br_2 \rightarrow C_6H_2Br_3NH_2\,(\downarrow) + 3HBr$$

ii) With acetic anhydride $(CH_3CO)_2O$ in pyridine.

Step 1: This is acetylation of the $-NH_2$ group (an amide is formed). Pyridine removes the acid formed and pushes the reaction forward.

Step 2: Product is acetanilide (N-phenylacetamide).

$$C_6H_5NH_2 + (CH_3CO)_2O \xrightarrow{\text{pyridine}} C_6H_5NHCOCH_3 + CH_3COOH$$

iii) With HNO_2 + HCl at 0°-5°C.

Step 1: HNO_2 (from $NaNO_2 + HCl$) reacts with the $-NH_2$ group. This is called diazotisation and is done in cold conditions (273-278 K) because the product is unstable when warm.

Step 2: Product is benzenediazonium chloride.

$$C_6H_5NH_2 + HNO_2 + HCl \xrightarrow{273-278\,K} C_6H_5N_2^+Cl^- + 2H_2O$$

Quick Tip: Bromine water gives 2,4,6-tribromoaniline; acetic anhydride/pyridine acetylates to acetanilide; cold HNO2/HCl diazotises to benzenediazonium chloride.

17. Write the structure of (A), (B) and (C) in the following reaction: phenol (C_6H_5OH) with concentrated HNO_3 gives (C); phenol with dilute HNO_3 gives (A) + (B).

Correct Answer: —

Solution:

Background: The $-OH$ group of phenol is a strong activating, ortho/para directing group. So nitration puts $-NO_2$ at the ortho and para positions.

Step 1: With dilute HNO_3 (mild conditions). Only one $-NO_2$ group enters, going to the ortho and para positions. So a mixture of two products is formed:
(A) = ortho-nitrophenol = 2-nitrophenol ($-OH$ at C1, $-NO_2$ at C2).
(B) = para-nitrophenol = 4-nitrophenol ($-OH$ at C1, $-NO_2$ at C4).

$$C_6H_5OH \xrightarrow{\text{dil. } HNO_3} o\text{-}O_2N\text{-}C_6H_4\text{-}OH + p\text{-}O_2N\text{-}C_6H_4\text{-}OH$$

Step 2: With concentrated HNO_3 (strong conditions). Three $-NO_2$ groups enter, at positions 2, 4 and 6. So:
(C) = 2,4,6-trinitrophenol, commonly called picric acid.

$$C_6H_5OH \xrightarrow{\text{conc. } HNO_3} 2,4,6\text{-}(O_2N)_3C_6H_2OH$$

Summary of structures:

(A) 2-nitrophenol: benzene ring with $-OH$ on C1 and $-NO_2$ on C2.

(B) 4-nitrophenol: benzene ring with $-OH$ on C1 and $-NO_2$ on C4.

(C) picric acid (2,4,6-trinitrophenol): benzene ring with $-OH$ on C1 and $-NO_2$ on C2, C4 and C6.

$$\boxed{A = \text{2-nitrophenol},\ B = \text{4-nitrophenol},\ C = \text{2, 4, 6-trinitrophenol (picric acid)}}$$

Quick Tip: OH is ortho/para directing: dilute HNO3 gives 2-nitrophenol (A) and 4-nitrophenol (B); concentrated HNO3 gives 2,4,6-trinitrophenol, picric acid (C).

18. Write the structure of (A), (B) and (C) in the following reaction:

$$C_6H_5NO_2 \xrightarrow{Fe/HCl} (A) \xrightarrow{NaNO_2+HCl,\ 273\ K} (B) \xrightarrow{H_2O/H^+,\ \Delta} (C)$$

Correct Answer: —

Solution:

Step 1: Nitrobenzene to (A) using Fe/HCl. Iron with hydrochloric acid is a reducing agent. It reduces the nitro group $-NO_2$ to an amino group $-NH_2$.

(A) = aniline, $C_6H_5NH_2$.

$$C_6H_5NO_2 \xrightarrow{Fe/HCl} C_6H_5NH_2$$

Step 2: Aniline to (B) with $NaNO_2$ + HCl at 273 K. $NaNO_2 + HCl$ gives nitrous acid (HNO_2), which converts the $-NH_2$ group into a diazonium group. This step (diazotisation) is done in the cold (273-278 K) because the diazonium salt breaks down when warm.
(B) = benzenediazonium chloride, $C_6H_5N_2^+Cl^-$.

$$C_6H_5NH_2 + HNO_2 + HCl \xrightarrow{273\,K} C_6H_5N_2^+Cl^- + 2H_2O$$

Step 3: (B) to (C) with warm water / H^+. When the diazonium salt is heated with water (dilute acid), the $-N_2^+$ group is replaced by $-OH$, releasing nitrogen gas.
(C) = phenol, C_6H_5OH.

$$C_6H_5N_2^+Cl^- + H_2O \xrightarrow{\Delta} C_6H_5OH + N_2 \uparrow + HCl$$

$$\boxed{A = \text{aniline},\ B = \text{benzenediazonium chloride},\ C = \text{phenol}}$$

Quick Tip: Fe/HCl reduces nitrobenzene to aniline; cold NaNO2/HCl diazotises it to benzenediazonium chloride; warm water/H+ replaces the diazonium group with OH to give phenol.

19. Write the reagent for each of the following reactions:

i) R–OH + …… → R–Cl

ii) R–OH + …… → R–Br

iii) CH_2=CH_2 + …… → BrCH_2–CH_2Br

iv) C_6H_5–CH=CH_2 + …… → C_6H_5–CH_2–CH_2Br

Correct Answer: —

Solution:

Each blank asks for the reagent that converts the given substrate into the product shown.

Step 1 (Part i): An alcohol R–OH is turned into an alkyl chloride R–Cl by replacing –OH with –Cl. The best reagent is thionyl chloride, $SOCl_2$ (the Darzen method), because the by-products SO_2 and HCl are gases and escape, giving a pure product.

$$R\text{-}OH + SOCl_2 \rightarrow R\text{-}Cl + SO_2 \uparrow + HCl \uparrow$$

PCl_5, PCl_3 or conc. HCl with anhydrous $ZnCl_2$ (Lucas reagent) also work.

Step 2 (Part ii): An alcohol R–OH is converted to an alkyl bromide R–Br using phosphorus tribromide, PBr_3 (usually made in situ from red phosphorus and bromine, P + Br_2).

$$3\,R\text{-}OH + PBr_3 \rightarrow 3\,R\text{-}Br + H_3PO_3$$

Constant-boiling HBr (NaBr + conc. H_2SO_4) is an alternative.

Step 3 (Part iii): Ethene adds bromine across its double bond to give 1,2-dibromoethane. The reagent is bromine, Br_2, dissolved in an inert solvent such as CCl_4. The red-brown colour of bromine is discharged, a test for unsaturation.

$$CH_2{=}CH_2 + Br_2 \rightarrow BrCH_2\text{-}CH_2Br$$

Step 4 (Part iv): The product C_6H_5–CH_2–CH_2Br has Br on the terminal carbon, i.e. anti-Markovnikov addition. Styrene reacts with HBr in the presence of an organic peroxide (benzoyl peroxide); this is the peroxide or Kharasch effect and gives the anti-Markovnikov product through a free-radical chain.

$$C_6H_5\text{-}CH{=}CH_2 + HBr \xrightarrow{\text{peroxide}} C_6H_5\text{-}CH_2\text{-}CH_2Br$$

Answer: i) $SOCl_2$ ii) PBr_3 (P + Br_2) iii) Br_2/CCl_4 iv) HBr with peroxide.

Quick Tip: OH→Cl uses $SOCl_2$; OH→Br uses PBr_3; C=C + Br_2 gives a vicinal dibromide; and anti-Markovnikov (Br on the far carbon of styrene) needs HBr with a peroxide.

20. What are fuel cells? Draw a labelled diagram of the hydrogen–oxygen fuel cell and give the reactions that occur in the cell.

Correct Answer: —

Solution:

Step 1: Definition of a fuel cell. A fuel cell is a galvanic (voltaic) cell that converts the chemical energy released by the combustion of a fuel (such as H_2, CH_4, CH_3OH) directly and continuously into electrical energy. Unlike an ordinary cell, the reactants (fuel and oxygen) are supplied from outside without a break, so the cell keeps working as long as the fuel is fed.

Step 2: Construction of the H_2–O_2 fuel cell. It has two porous carbon (graphite) electrodes containing a finely divided catalyst (Pt or Pd). The electrolyte between them is a hot concentrated solution of KOH (or NaOH). Hydrogen gas is bubbled at the anode and oxygen gas at the cathode.

Step 3: Labelled diagram (in words).
H_2 in → [porous C anode (–)] | conc. KOH electrolyte | [porous C cathode (+)] ← O_2 in
The two electrodes are joined through an external wire carrying a voltmeter/load; electrons flow from anode to cathode in the wire, water leaves the cell.

Step 4: Electrode reactions.
At the anode (oxidation):

$$2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$$

At the cathode (reduction):

$$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$$

Overall (net) cell reaction:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

Step 5: Note. The only product is water, so the cell is pollution-free, and its efficiency (about 70%) is much higher than a thermal power plant. Such cells were used in the Apollo space programme, where the water produced was used for drinking.

Quick Tip: A fuel cell converts a fuel's combustion energy straight into electricity; for H_2–O_2 in KOH the net reaction is $2H_2 + O_2 \rightarrow 2H_2O$. Recall the two half-cell reactions.

21. Explain molecularity and order of a reaction with the help of an example.

Correct Answer: —

Solution:

Step 1: Molecularity. Molecularity is the number of reacting species (atoms, ions or molecules) that must collide simultaneously in a single elementary step to bring about the reaction. It is a theoretical idea, is always a whole number (1, 2 or 3), can never be zero or fractional,

and is defined only for an elementary (one-step) reaction.

• Unimolecular (molecularity 1): decomposition of ammonium nitrite, $NH_4NO_2 \rightarrow N_2 + 2H_2O$.

• Bimolecular (molecularity 2): $2HI \rightarrow H_2 + I_2$.

Step 2: Order of reaction. Order is the sum of the powers to which the concentration terms are raised in the experimentally determined rate law. It is found by experiment, not from the balanced equation, and may be zero, a whole number, or even a fraction.

For a reaction with rate law

$$\text{rate} = k[A]^x[B]^y$$

the order $= x + y$.

Step 3: Worked example. For the elementary reaction

$$NO_2 + CO \rightarrow NO + CO_2$$

two molecules collide in one step, so its molecularity = 2, and the rate law rate = $k[NO_2][CO]$ gives order = 1 + 1 = 2. Here order and molecularity match because the reaction is a single step.

Step 4: Where they differ. For the acidic hydrolysis of an ester,

$$CH_3COOC_2H_5 + H_2O \xrightarrow{H^+} CH_3COOH + C_2H_5OH$$

two species (ester and water) react, so molecularity = 2, but because water is in large excess its concentration is effectively constant, the observed rate = k'[ester], and the order = 1. Such reactions are called

pseudo first order. This shows molecularity (theoretical, from the mechanism) and order (experimental) need not be equal.

Quick Tip: Molecularity counts colliding species in one elementary step (whole number, theoretical); order is the sum of exponents in the experimental rate law (can be fractional or zero). Compare using ester hydrolysis (pseudo first order).

22. Write a method of preparation of diethyl ether and write the mechanism of the reaction of diethyl ether with HI.

Correct Answer: —

Solution:

Part A – Preparation of diethyl ether.

Step 1: Diethyl ether is prepared industrially by the acid dehydration (intermolecular dehydration) of ethanol. Ethanol is heated with excess concentrated sulphuric acid at 413 K (about 140°C).

$$2\,C_2H_5OH \xrightarrow[413\,K]{\text{conc. } H_2SO_4} C_2H_5\text{-}O\text{-}C_2H_5 + H_2O$$

The acid first forms ethyl hydrogen sulphate, which is then attacked by a second ethanol molecule to give the ether. (Alternatively, Williamson's synthesis: $C_2H_5Br + C_2H_5ONa \rightarrow C_2H_5OC_2H_5 + NaBr$.) Note: temperature control matters; at a higher temperature (443 K) ethanol instead gives ethene.

Part B – Mechanism of diethyl ether with HI.

Step 2 (protonation): The oxygen of the ether has lone pairs and is basic. It is protonated by the strong acid HI to give a positively charged oxonium (protonated ether) ion, which makes one C–O bond a good leaving group.

$$C_2H_5\text{-}O\text{-}C_2H_5 + HI \rightarrow C_2H_5\overset{+}{\underset{H}{O}}\text{-}C_2H_5 + I^-$$

Step 3 (nucleophilic attack, S_N2): Since both alkyl groups are primary ethyl groups, the iodide ion $I^{\–}$ attacks the less hindered carbon from the back side, the C–O bond breaks, and ethyl iodide plus ethanol are formed.

$$I^- + C_2H_5\overset{+}{\underset{H}{O}}\text{-}C_2H_5 \rightarrow C_2H_5I + C_2H_5OH$$

Step 4 (with excess HI): The ethanol produced reacts further with more HI to give a second molecule of ethyl iodide.

$$C_2H_5OH + HI \rightarrow C_2H_5I + H_2O$$

Overall, with excess HI: $C_2H_5OC_2H_5 + 2HI \rightarrow 2C_2H_5I + H_2O$.

Quick Tip: Prepare diethyl ether by heating ethanol with conc. H_2SO_4 at 413 K (or Williamson synthesis). With HI: protonate the ether oxygen, then $I^{\–}$ does S_N2 on the less hindered carbon giving $C_2H_5I + C_2H_5OH$.

23. Complete the following reactions:

i) $C_6H_5COCl \xrightarrow{H_2/Pd\text{-}BaSO_4} ?$

ii) $CH_3\text{-}CO\text{-}CH_2\text{-}CO\text{-}OC_2H_5 \xrightarrow{(i)\ NaBH_4\ (ii)\ H^+} ?$

iii) anisole $(C_6H_5OCH_3) + CH_3COCl \xrightarrow{anhydrous\ AlCl_3} ?$

iv) acetophenone $(C_6H_5COCH_3) + NaOH + I_2 \rightarrow .....$

v) $CH_3CHO + Zn\text{-}Hg + HCl \rightarrow .....$

OR

Write short notes on the following:

i) Tollen's test

ii) Fehling test

iii) Haloform reaction of methyl ketone

iv) Reaction of phenyl methyl ketone with 2,4-dinitrophenyl hydrazine (2,4-DNP)

v) Wolff-Kishner reaction.

Correct Answer: —

Solution:

Option 1: Complete the reactions

Step 1 (i) Rosenmund reduction: Benzoyl chloride is reduced by H_2 over palladium supported on barium sulphate (a poisoned catalyst that stops reduction at the aldehyde stage). The acid chloride becomes benzaldehyde.

$C_6H_5COCl + H_2 \xrightarrow{Pd\text{-}BaSO_4} C_6H_5CHO + HCl$

Product = **Benzaldehyde**.

Step 2 (ii) $NaBH_4$ reduction: Sodium borohydride is a mild reducing agent. It reduces the ketone (C=O) group to a secondary alcohol but does NOT reduce the ester ($COOC_2H_5$) group. Ethyl acetoacetate

therefore gives ethyl 3-hydroxybutanoate.

$CH_3\text{-}CO\text{-}CH_2\text{-}COOC_2H_5 \xrightarrow{NaBH_4;\, H^+} CH_3\text{-}CH(OH)\text{-}CH_2\text{-}COOC_2H_5$

Product = **Ethyl 3-hydroxybutanoate**.

Step 3 (iii) Friedel-Crafts acylation: Anisole has an OCH_3 group which is activating and ortho/para directing. With acetyl chloride and anhydrous $AlCl_3$ (Lewis-acid catalyst) an acetyl group enters mainly at the para position (para is favoured because the ortho position is blocked by steric hindrance).

Product = **4-methoxyacetophenone** (p-methoxyacetophenone), $CH_3CO\text{-}C_6H_4\text{-}OCH_3$ $(para)$.

Step 4 (iv) Iodoform / haloform reaction: Acetophenone contains a CH_3CO- (methyl ketone) group, so it responds to the iodoform test. NaOH and I_2 convert it into a yellow precipitate of iodoform and the sodium salt of benzoic acid.

$C_6H_5COCH_3 + 3I_2 + 4NaOH \rightarrow C_6H_5COONa + CHI_3 \downarrow + 3NaI + 3H_2O$

Products = **Sodium benzoate + Iodoform (CHI_3)**.

Step 5 (v) Clemmensen reduction: Zinc amalgam (Zn-Hg) with concentrated HCl reduces the carbonyl (C=O) group of acetaldehyde all the way to a methylene/CH_2 group, giving the hydrocarbon.

$CH_3CHO + 4[H] \xrightarrow{Zn\text{-}Hg,\, HCl} CH_3CH_3 + H_2O$

Product = **Ethane**.

Option 2: Short notes

(i) Tollen's test: Tollen's reagent is ammoniacal silver nitrate, i.e. $[Ag(NH_3)_2]^+$. Aldehydes reduce it to metallic silver, which deposits as a shining silver mirror on the tube. Ketones do not respond. It

distinguishes aldehydes from ketones.

$$RCHO + 2[Ag(NH_3)_2]^+ + 3OH^- \rightarrow RCOO^- + 2Ag \downarrow + 4NH_3 + 2H_2O$$

(ii) Fehling test: Fehling's solution is a mixture of Fehling A (aqueous $CuSO_4$) and Fehling B (alkaline sodium potassium tartrate). Aliphatic aldehydes reduce the blue Cu^{2+} to a red-brown precipitate of cuprous oxide (Cu_2O). Aromatic aldehydes and ketones do not respond.

$$RCHO + 2Cu^{2+} + 5OH^- \rightarrow RCOO^- + Cu_2O \downarrow + 3H_2O$$

(iii) Haloform reaction of methyl ketone: A methyl ketone (CH_3CO-R) on treatment with excess halogen ($Cl_2/Br_2/I_2$) and NaOH gives a trihalomethane (haloform, CHX_3) plus the carboxylate salt. The three alpha-hydrogens of the methyl group are replaced by halogen, then the C-C bond is cleaved.

$$CH_3COCH_3 + 3I_2 + 4NaOH \rightarrow CHI_3 \downarrow + CH_3COONa + 3NaI + 3H_2O$$

(iv) Reaction with 2,4-DNP: Phenyl methyl ketone (acetophenone) reacts with 2,4-dinitrophenylhydrazine to form an orange-red crystalline solid, the 2,4-dinitrophenylhydrazone. This is a confirmatory test for a carbonyl (aldehyde or ketone) group.

$$C_6H_5COCH_3 + H_2N\text{-}NH\text{-}C_6H_3(NO_2)_2 \rightarrow C_6H_5C(CH_3) = N\text{-}NH\text{-}C_6H_3(NO_2)_2 + H_2O$$

(v) Wolff-Kishner reaction: The carbonyl compound first reacts with hydrazine (NH_2NH_2) to give a hydrazone. On heating this hydrazone with a strong base (KOH or sodium ethoxide) in a high-boiling solvent like ethylene glycol, nitrogen gas is lost and the C=O is reduced to a CH_2 group. It is used to convert an aldehyde/ketone into the corresponding hydrocarbon.

$$C{=}O \xrightarrow{NH_2NH_2} C{=}N\text{-}NH_2 \xrightarrow{KOH,\ glycol,\ \Delta} CH_2 + N_2$$

Quick Tip: Identify each named reaction: (i) Rosenmund, (ii) selective $NaBH_4$ ketone reduction, (iii) Friedel-Crafts acylation, (iv) iodoform, (v) Clemmensen. For the OR part, recall the reagents and colour changes of Tollen's, Fehling's, haloform, 2,4-DNP and Wolff-Kishner.

24. Discuss the nature of bonding in $[CoF_6]^{3-}$ and $[Ni(CN)_4]^{2-}$ on the basis of valence bond theory (VBT) and find the value of magnetic moment in both.

OR

Explain the stereoisomerism in coordination compounds with suitable examples.

Correct Answer: —

Solution:

Option 1: Bonding by VBT and magnetic moments

The spin-only magnetic moment is $\mu = \sqrt{n(n+2)}$ BM, where n is the number of unpaired electrons.

Step 1: Oxidation state and d-configuration in $[CoF_6]^{3-}$. Each F is -1 and the complex charge is -3, so cobalt is +3. Cobalt (Z = 27) is $[Ar]3d^7 4s^2$; removing 3 electrons gives $Co^{3+} = 3d^6$.

Step 2: Nature of ligand. F^- is a weak-field ligand, so it does NOT force pairing. The $3d^6$ electrons stay high-spin as $t_{2g}^4 e_g^2$, keeping **4 unpaired electrons**.

Step 3: Hybridisation and geometry. Since the inner 3d orbitals are occupied, cobalt uses outer orbitals: $4s, 4p, 4d$ giving $\mathbf{sp^3d^2}$ hybridisation. The complex is octahedral and outer-orbital (high-spin), hence paramagnetic.

Step 4: Magnetic moment. With n = 4, $\mu = \sqrt{4(4+2)} = \sqrt{24}$.

$$\boxed{\mu_{[CoF_6]^{3-}} = 4.90 \text{ BM}}$$

Step 5: Oxidation state and d-configuration in $[Ni(CN)_4]^{2-}$. Each CN is -1 and the charge is -2, so nickel is +2. Nickel (Z = 28) is $[Ar]3d^84s^2$; removing 2 electrons gives $Ni^{2+} = 3d^8$.

Step 6: Nature of ligand and hybridisation. CN^- is a strong-field ligand, so it pairs up the $3d^8$ electrons, freeing one 3d orbital. Nickel then uses $3d, 4s, 4p$ to give $\mathbf{dsp^2}$ hybridisation and a square-planar, inner-orbital complex. All electrons are paired, so $\mathbf{n = 0}$.

Step 7: Magnetic moment. With n = 0, $\mu = \sqrt{0(0+2)} = 0$.

$$\boxed{\mu_{[Ni(CN)_4]^{2-}} = 0 \text{ BM (diamagnetic)}}$$

Option 2: Stereoisomerism in coordination compounds

Stereoisomers have the same molecular formula and the same atom-to-atom bonds, but the atoms are arranged differently in space. Coordination compounds show two kinds:

Step 1: Geometrical (cis-trans) isomerism. It arises from different relative positions of ligands around the metal.
i) Square planar MA_2B_2: $[Pt(NH_3)_2Cl_2]$ exists as a cis form (the two Cl at 90 degrees, adjacent) and a trans form (the two Cl at 180 degrees, opposite).
ii) Octahedral MA_4B_2: $[Co(NH_3)_4Cl_2]^+$ shows cis and trans forms.
iii) Octahedral MA_3B_3: $[Co(NH_3)_3Cl_3]$ shows facial (fac, three like ligands on one face) and meridional (mer, three like ligands around a meridian) forms.

Step 2: Optical isomerism. It occurs when a complex and its mirror image are non-superimposable (chiral). The two forms, called d (dextro) and l (laevo), rotate plane-polarised light in opposite directions. Example: $[Co(en)_3]^{3+}$ (en = ethylenediamine) exists as a pair of non-superimposable mirror images. The cis-$[CoCl_2(en)_2]^+$ ion is optically active, while its trans form is optically inactive because it has a plane of symmetry.

So coordination compounds display stereoisomerism as geometrical (cis-trans, fac-mer) and optical (d-l) isomerism.

Quick Tip: Fix the metal oxidation state, then its d-count. Weak-field F^- keeps Co^{3+} (d^6) high-spin (sp^3d^2, 4 unpaired); strong-field CN^- pairs Ni^{2+} (d^8) into dsp^2 square planar (0 unpaired). Use μ = √(n(n+2)). For the OR part recall geometrical (cis-trans, fac-mer) and optical (d-l) isomerism.

25. i) Write the chemical names of water soluble vitamins and the diseases caused by their deficiency.

ii) Explain the cyclic structure of glucose. [2+3]

OR

i) Explain the primary, secondary, tertiary and quaternary structures of protein.

ii) Write a note on denaturation of protein. [4+1]

Correct Answer: —

Solution:

Option 1

i) Water soluble vitamins and deficiency diseases:

Water soluble vitamins are the B-group vitamins and vitamin C. They dissolve in water, are not stored in the body and are excreted in urine, so they must be supplied regularly in the diet.

Step 1: Vitamin B_1 (Thiamine) → deficiency causes Beri-beri.

Step 2: Vitamin B_2 (Riboflavin) → deficiency causes cheilosis (cracking at the corners of the mouth) and digestive disorders.

Step 3: Vitamin B_3 (Nicotinic acid / Niacin) → deficiency causes Pellagra (dermatitis, diarrhoea).

Step 4: Vitamin B_6 (Pyridoxine) → deficiency causes convulsions and anaemia.

Step 5: Vitamin B_{12} (Cyanocobalamin) → deficiency causes pernicious anaemia.

Step 6: Vitamin C (Ascorbic acid) → deficiency causes Scurvy (bleeding gums).

ii) Cyclic structure of glucose:

Step 1: In the open-chain form, glucose is a straight chain with an aldehyde group (–CHO) at C-1 and hydroxyl (–OH) groups at C-2 to C-6.
Step 2: The –OH group on C-5 attacks the carbonyl carbon (C-1) of the aldehyde. This intramolecular addition forms a cyclic hemiacetal, producing a six-membered ring (pyranose ring) containing one oxygen atom.
Step 3: On ring closure, C-1 becomes a new chiral (asymmetric) centre and is called the anomeric carbon. It gives two forms: α-D-glucose (the C-1 –OH is on the opposite side to the C-6 –CH_2OH in the Haworth projection, i.e. down) and β-D-glucose (C-1 –OH up). These are called anomers.
Step 4: This cyclic form explains why glucose does not give the Schiff's test and does not react with $NaHSO_3$, and why glucose shows mutarotation (a slow change in optical rotation as α and β forms interconvert in solution through the open chain).

Option 2

i) Structures of protein:
Primary structure: The exact sequence (order) in which the amino acids are linked to one another in a polypeptide chain through peptide bonds. Any change in this order changes the protein.
Secondary structure: The way the polypeptide chain folds or coils locally, stabilised by hydrogen bonds between the C=O and N–H groups of the backbone. Two common shapes are the α-helix (coil) and the β-pleated sheet.
Tertiary structure: The overall three-dimensional folding of the whole polypeptide chain, stabilised by hydrogen bonds, disulphide (–S–S–) bridges, ionic (electrostatic) attractions

and hydrophobic (van der Waals) forces. It gives fibrous (e.g. keratin) or globular (e.g. insulin) shapes.
Quaternary structure: The arrangement in which two or more polypeptide sub-units come together to form one functional protein, e.g. haemoglobin has four sub-units.

ii) Denaturation of protein:
When a protein is exposed to a physical change (heat, UV radiation) or a chemical change (strong acid or alkali, salts of heavy metals), the hydrogen bonds are broken, the globule unfolds and the helix uncoils. The secondary and tertiary structures are destroyed but the primary structure (the peptide bonds) stays intact. The protein loses its biological activity. Common examples: coagulation of egg white on boiling and curdling of milk.

Quick Tip: Water soluble vitamins are the B-complex and vitamin C (e.g. C deficiency causes scurvy). Glucose forms a six-membered pyranose ring via a C-5 OH to C-1 aldehyde hemiacetal, giving the anomeric carbon. For proteins, recall primary sequence, secondary helix/sheet, tertiary 3-D fold, quaternary sub-units, and that denaturation destroys secondary and tertiary structure but not the peptide bonds.

26. Explain mole fraction. Calculate the mole fraction of ethylene glycol if 20% of the mass of ethylene glycol is present in the solution. [1+4]
OR
i) Calculate the molarity of the solution in which 5 g NaOH is dissolved in 450 mL of solution.
ii) Calculate the molality of the solution in which 2.5 g acetic acid is dissolved in 75 g benzene. [2½+2½]

Correct Answer: —

Solution:

Option 1

Mole fraction: The mole fraction of a component in a solution is the ratio of the number of moles of that component to the total number of moles of all components present. For component A in a mixture of A and B, $x_A = \frac{n_A}{n_A + n_B}$. The sum of the mole fractions of all components is always 1.

Numerical: 20% by mass of ethylene glycol means 20 g of ethylene glycol are present in 100 g of solution, so the mass of water (solvent) = 100 − 20 = 80 g.

Step 1 (molar masses): Ethylene glycol is $C_2H_6O_2$ ($HOCH_2CH_2OH$), molar mass = (2×12) + (6×1) + (2×16) = 62 g mol$^{\−1}$; water = 18 g mol$^{\−1}$.

Step 2 (moles of glycol): $n_{glycol} = \frac{20}{62} = 0.3226$ mol.

Step 3 (moles of water): $n_{water} = \frac{80}{18} = 4.444$ mol.

Step 4 (mole fraction): $x_{glycol} = \frac{0.3226}{0.3226 + 4.444} = \frac{0.3226}{4.767}$.

$$\boxed{x_{glycol} \approx 0.068}$$

Hence the mole fraction of water = 1 − 0.068 = 0.932.

Option 2

i) Molarity of NaOH solution:

Molarity = number of moles of solute per litre of solution, $M = \frac{n}{V(L)}$.

Step 1: Molar mass of NaOH = 23 + 16 + 1 = 40 g mol$^{\−1}$.

Step 2: Moles of NaOH $= \frac{5}{40} = 0.125$ mol.

Step 3: Volume = 450 mL = 0.450 L.

Step 4: $M = \frac{0.125}{0.450}$.

$$\boxed{M \approx 0.278 \text{ mol L}^{-1}}$$

ii) Molality of acetic acid in benzene:

Molality = number of moles of solute per kilogram of solvent, $m = \frac{n}{W_{solvent}(kg)}$.

Step 1: Molar mass of acetic acid CH_3COOH = (2×12) + (4×1) + (2×16) = 60 g mol$^{\−1}$.

Step 2: Moles of acetic acid $= \frac{2.5}{60} = 0.0417$ mol.

Step 3: Mass of benzene = 75 g = 0.075 kg.

Step 4: $m = \frac{0.0417}{0.075}$.

$$\boxed{m \approx 0.556 \text{ mol kg}^{-1}}$$

Quick Tip: Mole fraction = moles of component divided by total moles (sum equals 1). For 20% glycol take 20 g glycol (M = 62) and 80 g water (M = 18). Molarity = moles of solute per litre of solution (NaOH M = 40, volume in L); molality = moles of solute per kilogram of solvent (acetic acid M = 60, benzene mass in kg).