Chemistry (Theory) – Code 043

CBSE Class 12 Board Examination 2027 – Practice Paper No. 1

Model Answer Paper

Time: 3 hours **Max. Marks: 70**

Model answers show one correct method; any other correct method gets full marks.

SECTION A Questions 1 to 16 are multiple choice questions. Only one of the choices is correct. Select and write the correct choice as well as the answer to these questions. **[16]**

1 Which of the following aqueous solutions will have the **lowest** freezing point? (Assume complete dissociation of all electrolytes.)

(A) 0.30 m glucose

(B) 0.10 m KNO_3

(C) 0.12 m $CaCl_2$

(D) 0.05 m $Al_2(SO_4)_3$

Answer (1 mark)

(C) 0.12 m $CaCl_2$

$\Delta T_f = i\,K_f\,m$, so the solution with the largest i × m freezes lowest: glucose 1 × 0.30 = 0.30; KNO_3 2 × 0.10 = 0.20; $CaCl_2$ 3 × 0.12 = 0.36; $Al_2(SO_4)_3$ 5 × 0.05 = 0.25. The largest value is 0.36 ($CaCl_2$).

2 On hot May afternoons, fish in a shallow village pond come up to the surface and gulp air. Which statement best explains this?

(A) K_H of O_2 increases with rise in temperature, so the solubility of O_2 in water decreases.

(B) K_H of O_2 decreases with rise in temperature, so the solubility of O_2 in water increases.

(C) The vapour pressure of water decreases on heating, which removes dissolved O_2.

(D) Dissolved O_2 reacts with warm water to form H_2O_2.

Answer (1 mark)

(A)

By Henry's law $p = K_H\,x$. K_H rises with temperature, so at the same partial pressure of O_2 the mole fraction (solubility) of dissolved O_2 falls in warm water.

3 How many faradays of electricity are required to reduce 0.5 mol of MnO_4^- ions to MnO_2 in neutral or faintly alkaline medium?

(A) 0.5 F

(B) 1.5 F

(C) 2.5 F

(D) 3.0 F

Answer (1 mark)

(B) 1.5 F

$MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$ (Mn: +7 → +4). 1 mol needs 3 F, so 0.5 mol needs 0.5 × 3 = 1.5 F. (2.5 F would be the answer for reduction to Mn^{2+} in acidic medium.)

4 For the reaction A + B → Products, doubling [A] (with [B] constant) makes the initial rate four times. Doubling [B] (with [A] constant) leaves the rate unchanged. The rate law is:

(A) Rate = k[A][B]

(B) Rate = $k[A]^2$

(C) Rate = $k[A]^2[B]$

(D) Rate = $k[A][B]^2$

Answer (1 mark)
(B) Rate = $k[A]^2$
$2^x = 4$ gives x = 2 for A. The rate does not depend on [B], so the order in B is zero.

5 Which of the following ions is expected to form colourless compounds? (Atomic numbers: Ti = 22, Cr = 24, Ni = 28, Cu = 29)

(A) Ni^{2+} (B) Cr^{3+}
(C) Ti^{4+} (D) Cu^{2+}

Answer (1 mark)
(C) Ti^{4+}
Ti^{4+} is $3d^0$. With no d electron, no d–d transition is possible, so it is colourless. Ni^{2+} ($3d^8$), Cr^{3+} ($3d^3$) and Cu^{2+} ($3d^9$) have partly filled d orbitals and are coloured.

6 Which of the following complexes can show geometrical (cis–trans) isomerism?

(A) $[Pd(NH_3)_2Cl_2]$ (B) $[Zn(NH_3)_2Cl_2]$
(C) $[Co(NH_3)_5Br]^{2+}$ (D) $[Ni(CO)_4]$

Answer (1 mark)
(A) $[Pd(NH_3)_2Cl_2]$
Pd(II) ($4d^8$) forms a square planar MA_2B_2 complex, which has cis and trans forms. Tetrahedral $[Zn(NH_3)_2Cl_2]$, octahedral MA_5B and homoleptic $[Ni(CO)_4]$ cannot show geometrical isomerism.

7 The number of unpaired electrons in the octahedral complex ion $[Fe(H_2O)_6]^{3+}$ is (Fe: Z = 26):

(A) 1 (B) 3
(C) 4 (D) 5

Answer (1 mark)
(D) 5
$Fe^{3+} = 3d^5$. H_2O is a weak field ligand ($\Delta_o < P$), so the configuration is $t_{2g}^3 e_g^2$ (high spin) with 5 unpaired electrons.

8 Which of the following isomers of $C_6H_{13}Br$ will undergo S_N1 reaction fastest?

(A) 1-Bromohexane (B) 3-Bromo-3-methylpentane
(C) 2-Bromohexane (D) 1-Bromo-2-methylpentane

Answer (1 mark)
(B) 3-Bromo-3-methylpentane
It is a tertiary halide, $(C_2H_5)_2C(Br)CH_3$. It ionises to the most stable (3°) carbocation, and the S_N1 rate depends on carbocation stability. 2-Bromohexane is secondary; 1-bromohexane and 1-bromo-2-methylpentane are primary.

9 Which of the following alcohols gives turbidity **immediately** with Lucas reagent at room temperature?

(A) Butan-1-ol (B) Butan-2-ol
(C) 2-Methylpropan-1-ol (D) 2-Methylpropan-2-ol

Answer (1 mark)
(D) 2-Methylpropan-2-ol
Tertiary alcohols react at once with conc. $HCl/ZnCl_2$ and form the insoluble alkyl chloride

(turbidity). Secondary alcohols react slowly and primary alcohols do not react at room temperature.

10 The correct order of **increasing** acidic strength is:

(A) ethanol < p-cresol < phenol < p-nitrophenol
(B) p-cresol < ethanol < phenol < p-nitrophenol
(C) ethanol < phenol < p-cresol < p-nitrophenol
(D) phenol < ethanol < p-cresol < p-nitrophenol

Answer (1 mark)
(A)
The phenoxide ion is resonance stabilised, so phenols are more acidic than ethanol. The electron-releasing $-CH_3$ group lowers acidity (p-cresol < phenol). The electron-withdrawing $-NO_2$ group raises acidity (p-nitrophenol is the most acidic).

11 Sugar made from sugarcane in Maharashtra's sugar factories is sucrose. In sucrose the glycosidic linkage is between:

(A) C1 of α-D-glucose and C4 of another α-D-glucose
(B) C1 of β-D-galactose and C4 of β-D-glucose
(C) C1 of α-D-glucose and C2 of β-D-fructose
(D) C1 of β-D-glucose and C4 of another β-D-glucose

Answer (1 mark)
(C)
Sucrose is formed from α-D-glucose and β-D-fructose joined through C1 (glucose) and C2 (fructose). Both reducing groups are used, so sucrose is a non-reducing sugar. Option (A) describes maltose, (B) lactose and (D) cellulose units.

12 The major product of hydroboration–oxidation of 2-methylpropene, $(CH_3)_2C{=}CH_2$, is:

(A) 2-Methylpropan-2-ol
(B) 2-Methylpropan-1-ol
(C) Butan-1-ol
(D) Butan-2-ol

Answer (1 mark)
(B) 2-Methylpropan-1-ol
In hydroboration, boron adds to the less substituted terminal carbon. Oxidation by H_2O_2/OH^- replaces B by –OH, giving $(CH_3)_2CH{-}CH_2OH$. This is the anti-Markovnikov product.

13 **Assertion (A):** A mixture of ethanol and water containing about 95% ethanol by volume cannot be separated into its pure components by fractional distillation.
Reason (R): Ethanol and water form a maximum boiling azeotrope.
Select the most appropriate answer from the options given below:

(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.

Answer (1 mark)
(C) A is true but R is false.
The 95% mixture is an azeotrope: liquid and vapour have the same composition, so fractional distillation cannot separate it. Ethanol–water shows large positive deviation and forms a **minimum** boiling azeotrope, so R is false.

14 **Assertion (A):** The half-life of a zero order reaction is independent of the initial concentration of the reactant.
Reason (R): For a first order reaction, $t_{1/2}$ = 0.693/k.
Select the most appropriate answer from the options given below:
(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.

Answer (1 mark)
(D) A is false but R is true.
For a zero order reaction $t_{1/2} = [R]_0/2k$, which is directly proportional to $[R]_0$, so A is false. R is a correct statement for first order reactions.

15 **Assertion (A):** Zinc, cadmium and mercury are not regarded as transition metals.
Reason (R): These metals have completely filled d orbitals in their ground state as well as in their common oxidation states.
Select the most appropriate answer from the options given below:
(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.

Answer (1 mark)
(A) Both A and R are true, and R is the correct explanation of A.
Zn, Cd and Hg have the configuration $(n-1)d^{10}ns^2$, and their common M^{2+} ions are d^{10}. A transition element must have an incomplete d subshell in the atom or in a common ion, so R explains A.

16 **Assertion (A):** Methanamine is a stronger base than ammonia in aqueous solution.
Reason (R): Methanamine gives a foul-smelling isocyanide when heated with chloroform and ethanolic KOH.
Select the most appropriate answer from the options given below:
(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.

Answer (1 mark)
(B) Both A and R are true, but R is not the correct explanation of A.
The +I (electron-releasing) effect of $-CH_3$ increases the electron density on N and also stabilises $CH_3NH_3^+$ by solvation, so methanamine is more basic than NH_3. R (the carbylamine reaction of 1° amines) is a true fact but does not explain basicity.

SECTION B Questions 17 to 21 are very short answer questions carrying 2 marks each. **[10]**

17 (A) (I) Complete and balance the following ionic equation:

$MnO_4^- + H_2S + H^+ \rightarrow$

(II) The spin-only magnetic moment of a divalent ion of a first-row transition metal is 4.90 BM. Which one of Mn^{2+} (Z = 25), Fe^{2+} (Z = 26) and Ni^{2+} (Z = 28) is it? Show your working.

OR

(B) (I) Actinoids show a much wider range of oxidation states than lanthanoids. Give reason.

(II) Complete and balance the following ionic equation:

$Cr_2O_7^{2-} + Sn^{2+} + H^+ \rightarrow$

Answer (2 marks)

(A) (I) $2MnO_4^- + 5H_2S + 6H^+ \rightarrow 2Mn^{2+} + 5S + 8H_2O$

(Check: charge −2 + 6 = +4 on the left and +4 on the right; H: 10 + 6 = 16 = 16; O: 8 = 8. H_2S is oxidised to sulphur.)

(II) $\mu = \sqrt{(n(n+2))}$ BM. For 4.90 BM: n(n + 2) = 24, so n = 4 unpaired electrons.

$Mn^{2+} = 3d^5$ (n = 5, μ = 5.92 BM); $Fe^{2+} = 3d^6$ (n = 4, μ = 4.90 BM); $Ni^{2+} = 3d^8$ (n = 2, μ = 2.83 BM).

Ans: the ion is Fe^{2+}.

OR

(B) (I) In actinoids the 5f, 6d and 7s subshells have comparable energies, so electrons from all of them can take part in bonding. In lanthanoids the 4f electrons are well shielded and lie deeper, so +3 is the main state.

(II) $Cr_2O_7^{2-} + 3Sn^{2+} + 14H^+ \rightarrow 2Cr^{3+} + 3Sn^{4+} + 7H_2O$

(Check: charge −2 + 6 + 14 = +18 on the left and +6 + 12 = +18 on the right.)

Marking: (A) (I) Correct products – ½ mark; correctly balanced (atoms and charge) – ½ mark · (A) (II) n = 4 from μ – ½ mark; identification of Fe^{2+} with configuration – ½ mark · (B) (I) Comparable energies of 5f, 6d, 7s – 1 mark · (B) (II) Correct products – ½ mark; balanced – ½ mark

Examiner tip: In balancing, check the charge as well as the atoms. A common slip is writing MnO_2 as the product; in acid medium permanganate goes to Mn^{2+}.

18 The active ingredient of an antibiotic syrup decomposes at 25 °C by first order kinetics. The rate constant is 4.606×10^{-3} day^{-1}.

(I) How many days will it take for the concentration of the active ingredient to fall to one-tenth of its initial value?

(II) How many days will it take for 75% of the active ingredient to decompose? (Given: log 2 = 0.301)

Answer (2 marks)

For a first order reaction: $t = (2.303/k) \log([R]_0/[R])$

$2.303/k = 2.303/(4.606 \times 10^{-3}\ day^{-1}) = 500$ days

(I) $[R] = [R]_0/10$: $t = 500 \times \log 10 = 500 \times 1 =$ **500 days**

(II) 75% decomposed means $[R] = [R]_0/4$: $t = 500 \times \log 4 = 500 \times 2 \times 0.301 =$ **301 days**

(Alternatively, 75% = two half-lives: $t_{1/2} = 0.693/k = 150.5$ days, so $t = 2 \times 150.5 = 301$ days.)

Marking: Correct integrated rate equation – ½ mark · (I) 500 days – ½ mark · (II) $[R] = [R]_0/4$ – ½ mark · 301 days – ½ mark

Examiner tip: 75% decomposed means 25% is left, so the ratio $[R]_0/[R] = 4$, not 4/3. Keep the unit (day) of k in the answer.

19 (I) When an egg is boiled, the clear liquid white becomes an opaque white solid. Name the process. Which level of protein structure remains intact in this change?
(II) Write the structure of the dipeptide alanylglycine (Ala–Gly) and mark the peptide linkage in it. (Alanine: $H_2N–CH(CH_3)–COOH$; glycine: $H_2N–CH_2–COOH$)

Answer (2 marks)

(I) The process is **denaturation** of the protein (albumin) by heat. The hydrogen bonds are broken, so the secondary and tertiary structures are lost, but the **primary structure** (sequence of amino acids joined by peptide bonds) remains intact.

(II) In Ala–Gly the –COOH of alanine combines with the $–NH_2$ of glycine:

$H_2N–CH(CH_3)–$**CO–NH**$–CH_2–COOH$

The peptide linkage is the amide bond –CO–NH– (shown in bold).

Marking: (I) Denaturation – ½ mark; primary structure retained – ½ mark · (II) Correct structure (alanine as N-terminal) – ½ mark; peptide bond marked – ½ mark

Examiner tip: In 'alanylglycine' the first-named amino acid (alanine) keeps the free $–NH_2$. Writing $H_2N–CH_2–CO–NH–CH(CH_3)–COOH$ is glycylalanine and loses the mark.

20 (I) Which of chlorobenzene and benzyl chloride ($C_6H_5CH_2Cl$) is hydrolysed more readily by aqueous NaOH? Give reason and write the equation.
(II) Optically active 3-chloro-3-methylhexane is hydrolysed in aqueous acetone. The product shows no optical rotation. Explain.

Answer (2 marks)

(I) **Benzyl chloride** is hydrolysed more readily. It ionises to the benzyl carbocation, which is stabilised by resonance with the ring (and it also reacts easily by S_N2). In chlorobenzene the C–Cl bond has partial double-bond character due to resonance and the carbon is sp^2, so it is not hydrolysed under ordinary conditions.

$C_6H_5CH_2Cl + NaOH(aq) \rightarrow C_6H_5CH_2OH + NaCl$

(II) 3-Chloro-3-methylhexane is a tertiary halide, so it reacts by the S_N1 mechanism. The intermediate carbocation is planar (sp^2), and water attacks it equally from both faces. Equal amounts of the two enantiomers of 3-methylhexan-3-ol form (a racemic mixture), so the product is optically inactive. This is **racemisation**.

Marking: (I) Benzyl chloride with reason (stable benzyl carbocation / partial double bond in chlorobenzene) – ½ mark; equation – ½ mark · (II) S_N1 with planar carbocation, attack from both sides – ½ mark; racemic mixture/racemisation – ½ mark

Examiner tip: Say why the product is inactive: equal amounts of the two enantiomers cancel each other's rotation. 'Inversion' is the S_N2 result and does not fit here.

21 (I) Give a chemical test to distinguish between the isomeric amines propan-1-amine and N,N-dimethylmethanamine. Write the chemical equation.
(II) Why is the temperature kept between 273 K and 278 K during the diazotisation of aniline?

Answer (2 marks)

(I) **Carbylamine test:** warm each amine with chloroform and ethanolic KOH. Propan-1-amine (a 1° amine) gives the foul-smelling propyl isocyanide. N,N-Dimethylmethanamine (a 3° amine) gives no such smell.

$CH_3CH_2CH_2NH_2 + CHCl_3 + 3KOH \rightarrow CH_3CH_2CH_2NC + 3KCl + 3H_2O$

(Hinsberg test is also accepted: the 1° amine gives a sulphonamide soluble in alkali; the 3° amine does not react.)

(II) Benzenediazonium chloride is stable only in cold solution. Above about 278 K it

decomposes, reacting with water to form phenol and N_2. So the reaction is carried out in an ice bath and the salt is used at once.

Marking: (I) Correct test with observation – ½ mark; balanced equation – ½ mark · (II) Diazonium salt unstable / decomposes at higher temperature – 1 mark

Examiner tip: State the observation for **both** amines. Writing only 'foul smell' without saying which amine gives it earns half credit.

SECTION C Questions 22 to 28 are short answer questions carrying 3 marks each. **[21]**

22 Consider the cell at 298 K: Fe(s) | Fe^{2+}(0.001 M) || Cu^{2+}(0.1 M) | Cu(s)

Given: $E°(Fe^{2+}/Fe) = -0.44$ V, $E°(Cu^{2+}/Cu) = +0.34$ V, F = 96500 C mol^{-1}, 2.303RT/F = 0.059 V.

(I) Write the cell reaction.

(II) Calculate the emf of the cell.

(III) Calculate Δ_rG for the cell reaction.

Answer (3 marks)

(I) Anode: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$; Cathode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Cell reaction: $Fe(s) + Cu^{2+}(aq) \rightarrow Fe^{2+}(aq) + Cu(s)$; n = 2

(II) $E°_{cell} = E°_{cathode} - E°_{anode} = 0.34 - (-0.44) = 0.78$ V

$E_{cell} = E°_{cell} - (0.059/n)\log([Fe^{2+}]/[Cu^{2+}])$

$= 0.78 - (0.059/2)\log(0.001/0.1) = 0.78 - 0.0295 \times \log 10^{-2}$

$= 0.78 - 0.0295 \times (-2) = 0.78 + 0.059 =$ **0.839 V**

(III) $\Delta_rG = -nFE_{cell} = -2 \times 96500 \times 0.839$

$= -161927$ J $mol^{-1} \approx$ **-161.9 kJ mol^{-1}**

Marking: (I) Correct cell reaction with n = 2 – ½ mark · (II) $E°_{cell} = 0.78$ V – ½ mark; Nernst equation with correct Q – ½ mark; $E_{cell} = 0.839$ V – ½ mark · (III) Formula $\Delta G = -nFE$ – ½ mark; -161.9 kJ mol^{-1} with sign and unit – ½ mark

Examiner tip: Q is [product ion]/[reactant ion] = $[Fe^{2+}]/[Cu^{2+}]$; solids are left out. Here log Q = −2 is negative, so E_{cell} comes out larger than $E°_{cell}$. Watch the sign.

23 (I) The rate constant of the first order decomposition of a pesticide residue in soil is 1.5×10^{-4} s^{-1} at 300 K and 1.5×10^{-3} s^{-1} at 330 K. Calculate the activation energy of the reaction. (R = 8.314 J K^{-1} mol^{-1})

(II) State the effect of a catalyst on (a) the activation energy and (b) the Gibbs energy change (ΔG) of a reaction.

Answer (3 marks)

(I) Arrhenius equation: $\log(k_2/k_1) = [E_a/(2.303R)] \times [(T_2 - T_1)/(T_1T_2)]$

$k_2/k_1 = (1.5 \times 10^{-3})/(1.5 \times 10^{-4}) = 10$, so log 10 = 1

$1 = [E_a/(2.303 \times 8.314)] \times [30/(300 \times 330)]$

$E_a = 2.303 \times 8.314 \times (300 \times 330)/30 = 19.147 \times 3300$

$= 63185$ J $mol^{-1} \approx$ **63.2 kJ mol^{-1}**

(II) (a) A catalyst provides an alternative path with **lower activation energy**.

(b) A catalyst does **not change ΔG** of the reaction (so it cannot make a non-spontaneous reaction spontaneous and does not change the equilibrium constant).

Marking: (I) Correct Arrhenius equation – ½ mark; substitution (ratio 10, temperatures) – ½ mark; $E_a = 63.2$ kJ mol^{-1} – 1 mark · (II) (a) lowers E_a – ½ mark; (b) no change in ΔG – ½ mark

Examiner tip: Write $(T_2 - T_1)/(T_1T_2)$ carefully: 30/99000, not 30/630. Convert J to kJ only at the end.

24 Account for the following:

(I) The atomic radii of zirconium (160 pm) and hafnium (159 pm) are almost the same.

(II) In aqueous solution Ce^{4+} is a strong oxidising agent, whereas Eu^{2+} is a strong reducing agent.

(III) The $E°(M^{2+}/M)$ values of Mn, Ni and Zn are more negative than expected from the general trend in the first transition series.

Answer (3 marks)

(I) This is due to **lanthanoid contraction**. In Hf the 14 electrons of the 4f subshell come before the 5d series. The 4f electrons shield poorly, so the size steadily decreases and cancels the expected increase in size from Zr (4d) to Hf (5d).

(II) The most stable oxidation state of lanthanoids is +3. Ce^{4+} readily gains an electron and changes to Ce^{3+} ($E°(Ce^{4+}/Ce^{3+})$ = +1.74 V), so it is an oxidant. Eu^{2+} ($4f^7$) readily loses an electron and changes to the common Eu^{3+} state, so it is a reductant.

(III) Mn^{2+} has a stable half-filled d^5 configuration and Zn^{2+} has a stable completely filled d^{10} configuration, so these ions form easily. Ni^{2+} has the highest negative enthalpy of hydration. These factors make their E° values more negative than the trend.

Marking: (I) Lanthanoid contraction with poor shielding of 4f – 1 mark · (II) $Ce^{4+} \rightarrow Ce^{3+}$ (½) and $Eu^{2+} \rightarrow Eu^{3+}$ (½) – 1 mark · (III) d^5/d^{10} stability (½) and hydration enthalpy of Ni^{2+} (½) – 1 mark

Examiner tip: In (I) the term 'lanthanoid contraction' alone gets only half credit. Add that the poor shielding by 4f electrons causes it.

25 An optically active alkyl bromide A, C_4H_9Br, reacts with aqueous NaOH by the S_N2 mechanism to give an alcohol B. When A is heated with alcoholic KOH, the major product is an alkene C. When A is heated with sodium metal in dry ether, it gives a hydrocarbon D, C_8H_{18}.

(I) Identify A and write the S_N2 mechanism for its conversion into B, showing the configuration of the product.

(II) Write the equations for the formation of C and D and give their IUPAC names.

Answer (3 marks)

(I) The only chiral isomer of C_4H_9Br is **A = 2-bromobutane**, $CH_3CH_2CH(Br)CH_3$.

S_N2 mechanism (one step): OH^- attacks C-2 from the side opposite to Br. In the transition state $[HO\cdots C\cdots Br]^{\delta-}$, C-2 is bonded partly to both OH and Br, and its other three groups (H, CH_3, C_2H_5) lie in one plane. As Br^- leaves, the three groups flip like an umbrella in the wind:

$HO^- + CH_3CH_2CH(Br)CH_3 \rightarrow [HO\cdots C(H)(CH_3)(C_2H_5)\cdots Br]^{\ddagger} \rightarrow CH_3CH_2CH(OH)CH_3 + Br^-$

B = butan-2-ol, formed with **inversion of configuration** (Walden inversion). The –OH takes the position opposite to the one Br occupied, so B has the configuration opposite to that of A and is optically active.

(II) C (Zaitsev rule – more substituted alkene is major):

$CH_3CH_2CH(Br)CH_3 + KOH(alc) \xrightarrow{-\Delta} CH_3CH{=}CHCH_3 + KBr + H_2O$; C = **but-2-ene** (but-1-ene is the minor product)

D (Wurtz reaction):

$2CH_3CH_2CH(Br)CH_3 + 2Na \xrightarrow{\text{–dry ether}} CH_3CH_2CH(CH_3)–CH(CH_3)CH_2CH_3 + 2NaBr$; D = **3,4-dimethylhexane**

Marking: (I) A = 2-bromobutane – ½ mark; S_N2 mechanism with back-side attack/transition state – ½ mark; inversion of configuration – ½ mark · (II) C: equation and name but-2-ene – ½ mark; D: Wurtz equation – ½ mark; name 3,4-dimethylhexane – ½ mark

Examiner tip: 1-Bromobutane, 1-bromo-2-methylpropane and 2-bromo-2-methylpropane are achiral, so only 2-bromobutane fits 'optically active'. Name D by the longest chain (hexane), not as 'dimethyl-sec-butyl'.

26 An organic compound X ($C_8H_{10}O$) is insoluble in aqueous NaOH and does not react with sodium metal. On heating with HI, X gives two products Y and Z. Y dissolves in aqueous NaOH but not in aqueous $NaHCO_3$, and gives a white precipitate ($C_6H_3Br_3O$) with bromine water. Z on warming with aqueous KOH gives ethanol.
Identify X, Y and Z and write the equations involved. Why does X give Y and Z, and not iodobenzene and ethanol, with HI?

Answer (3 marks)

X does not react with Na (no –OH group) and is not acidic, so it is an ether. Y is phenol (C_6H_5OH gives $C_6H_2Br_3OH$) and Z gives ethanol, so the ether has a phenyl group and an ethyl group: **X = ethoxybenzene (phenetole), $C_6H_5OC_2H_5$.**

$C_6H_5–O–C_2H_5 + HI \xrightarrow{-\Delta} C_6H_5OH + C_2H_5I$

Y = phenol (weakly acidic: dissolves in NaOH, not in $NaHCO_3$); **Z = iodoethane**.

$C_6H_5OH + 3Br_2(aq) \rightarrow$ 2,4,6-tribromophenol (white ppt, $C_6H_2Br_3OH$) + 3HBr

$C_2H_5I + KOH(aq) \rightarrow C_2H_5OH + KI$

Reason: HI first protonates the ether oxygen. I^- then attacks the ethyl carbon by S_N2 and breaks the O–C_2H_5 bond. The O–C_6H_5 bond is not broken because it has partial double-bond character (resonance), and the sp^2 carbon of the ring does not undergo nucleophilic substitution. So phenol and C_2H_5I form, not iodobenzene and ethanol.

Marking: X ethoxybenzene with reasoning – ½ mark; cleavage equation with HI – ½ mark · Y phenol + bromine water equation – ½ mark; Z + KOH equation – ½ mark · Reason (partial double bond of O–aryl / attack on ethyl carbon) – 1 mark

Examiner tip: $C_8H_{10}O$ also fits phenylethanols, ethylphenols/dimethylphenols and methyl ethers such as benzyl methyl ether. Use every clue: alcohols react with Na, phenols dissolve in NaOH, and only ethyl phenyl ether gives phenol ($C_6H_2Br_3OH$ with bromine water) and an ethyl halide.

27 (A) Identify the name reaction and write the missing product in each:
(I) $CH_3CH_2COCl + H_2 \xrightarrow{-(Pd–BaSO_4)} ?$
(II) $C_6H_5COCH_3 \xrightarrow{-(Zn–Hg,\ conc.\ HCl)} ?$
(III) $CH_3CH_2CH_2COOH \xrightarrow{-((i)\ Br_2/red\ phosphorus,\ (ii)\ H_2O)} ?$

OR

(B) (I) Propanoic acid (molar mass 74 g mol^{-1}) boils at 414 K, whereas butan-1-ol (molar mass 74 g mol^{-1}) boils at 391 K. Explain.
(II) Give a simple chemical test to distinguish between ethanal and ethanoic acid.
(III) Why does benzoic acid not undergo Friedel–Crafts reaction?

Answer (3 marks)

(A) (I) **Rosenmund reduction**: $CH_3CH_2COCl + H_2 \xrightarrow{-Pd–BaSO_4} CH_3CH_2CHO$ (propanal) + HCl

(II) **Clemmensen reduction**: $C_6H_5COCH_3 + 4[H] \xrightarrow{-Zn–Hg/conc.\ HCl} C_6H_5CH_2CH_3$ (ethylbenzene) + H_2O

(III) **Hell–Volhard–Zelinsky reaction**: $CH_3CH_2CH_2COOH \xrightarrow{-(i)\ Br_2/red\ P,\ (ii)\ H_2O} CH_3CH_2CH(Br)COOH$ (2-bromobutanoic acid)

OR

(B) (I) Carboxylic acid molecules are held by more extensive hydrogen bonding than alcohols. Two acid molecules form a hydrogen-bonded **dimer**, which persists even in the vapour phase,

so more energy is needed to boil the acid.
(II) Add $NaHCO_3$ solution: ethanoic acid gives brisk effervescence of CO_2 ($CH_3COOH + NaHCO_3 \rightarrow CH_3COONa + H_2O + CO_2\uparrow$), and ethanal does not. (Or: ethanal gives a silver mirror with Tollens' reagent; ethanoic acid does not.)
(III) The –COOH group is strongly electron-withdrawing and deactivates the benzene ring. Also, the catalyst $AlCl_3$ (a Lewis acid) gets bonded to the carboxyl group, so the reaction does not take place.

Marking: (A) Each part: name of reaction ½ + correct product ½ – 1 mark × 3 · (B) (I) Dimer / extensive H-bonding – 1 mark; (II) test with observation – 1 mark; (III) deactivation and $AlCl_3$ bonding to –COOH – 1 mark

Examiner tip: In HVZ the halogen goes to the α-carbon (next to –COOH), so the product is 2-bromobutanoic acid, not 3- or 4-bromo. Clemmensen reduces C=O to CH_2; it does not give an alcohol.

28 Write chemical equations to carry out the following conversions:
(I) Propanamide to ethanamine
(II) Aniline to iodobenzene
(III) Benzenediazonium chloride to p-hydroxyazobenzene

Answer (3 marks)
(I) Hoffmann bromamide degradation:
$CH_3CH_2CONH_2 + Br_2 + 4NaOH \rightarrow CH_3CH_2NH_2 + Na_2CO_3 + 2NaBr + 2H_2O$
(II) Diazotisation followed by reaction with potassium iodide:
$C_6H_5NH_2 + NaNO_2 + 2HCl \xrightarrow{273–278\ K} C_6H_5N_2^+Cl^- + NaCl + 2H_2O$
$C_6H_5N_2^+Cl^- + KI \rightarrow C_6H_5I + KCl + N_2$
(III) Coupling reaction with phenol in alkaline medium:
$C_6H_5N_2^+Cl^- + C_6H_5OH + NaOH \rightarrow p\text{-}HO–C_6H_4–N{=}N–C_6H_5$ (orange dye) $+ NaCl + H_2O$

Marking: (I) Correct reagents (Br_2/NaOH) – ½ mark; balanced equation – ½ mark · (II) Diazotisation step – ½ mark; reaction with KI – ½ mark · (III) Correct reagent/medium (phenol, alkaline) – ½ mark; correct product structure – ½ mark

Examiner tip: Hoffmann bromamide reaction removes one carbon: propanamide (3 C) gives ethanamine (2 C). In (II) the diazotisation temperature 273–278 K should be written.

SECTION D Questions 29 and 30 are case-based questions carrying 4 marks each. **[8]**

29 Reverse osmosis for drinking water

Many coastal villages in the Konkan region use small reverse osmosis (RO) plants to make drinking water from salty well water. Osmotic pressure (π) is a colligative property. For a dilute solution π = iCRT, where C is the molar concentration and i is the van't Hoff factor. If a pressure larger than the osmotic pressure is applied on the solution side, pure water is pushed out through the semipermeable membrane (often a film of cellulose acetate); this is reverse osmosis. The same idea matters in hospitals: a 0.9% (mass/volume) NaCl solution (normal saline) is isotonic with blood fluid, so it can be injected into veins safely.

(Take R = 0.083 L bar K^{-1} mol^{-1}; assume complete dissociation of salts.)

Answer the following questions:

(I) What will happen to red blood cells placed in a 0.5% (mass/volume) NaCl solution?

(A) They will shrink. (B) They will swell and may burst. (C) No change will occur. (D) They will first shrink and then swell.

(II) Sea water may be taken as 0.50 mol L^{-1} NaCl. The minimum pressure needed to desalinate it by reverse osmosis at 300 K is about:

(A) 12.45 bar (B) 2.49 bar (C) 24.9 bar (D) 49.8 bar

(IIIA) A well near Alibag contains 0.05 mol L^{-1} NaCl and 0.01 mol L^{-1} $MgCl_2$. Calculate the minimum pressure that the RO pump must apply at 300 K to obtain pure water from it.

OR

(IIIB) 1.0 g of an enzyme (a protein) extracted from raw papaya is dissolved in water to make 100 mL of solution. Its osmotic pressure at 300 K is 2.49×10^{-3} bar. Calculate the molar mass of the protein. Why is osmotic pressure preferred over other colligative properties for finding the molar masses of proteins?

Answer (4 marks)

(I) (B) They will swell and may burst. 0.5% NaCl is hypotonic compared with the cell fluid, so water flows into the cells by osmosis.

(II) (C) 24.9 bar. π = iCRT = 2 × 0.50 × 0.083 × 300 = 24.9 bar; the applied pressure must exceed this.

(IIIA) Total concentration of particles = i(NaCl) × C(NaCl) + i($MgCl_2$) × C($MgCl_2$)

= 2 × 0.05 + 3 × 0.01 = 0.10 + 0.03 = 0.13 mol L^{-1}

π = 0.13 × 0.083 × 300 = **3.237 bar** (≈ 3.24 bar)

So the pump must apply a pressure greater than about 3.24 bar.

OR

(IIIB) π = (w/M)RT/V, so M = wRT/(πV)

M = (1.0 g × 0.083 L bar K^{-1} mol^{-1} × 300 K)/(2.49×10^{-3} bar × 0.100 L)

= 24.9/(2.49×10^{-4}) = **1.0×10^5 g mol^{-1}**

Osmotic pressure is preferred because it is measured at room temperature (proteins are not stable at high temperatures), it uses molarity, and its value is large enough to measure even for very dilute solutions of high molar mass solutes.

Marking: (I) Correct option – 1 mark · (II) Correct option – 1 mark · (IIIA) i values 2 and 3 used – ½ mark; total 0.13 mol L^{-1} – ½ mark; formula π = iCRT – ½ mark; 3.24 bar – ½ mark · (IIIB) Formula and substitution (V in L) – ½ mark; M = 1.0×10^5 g mol^{-1} – ½ mark; any two reasons – ½ + ½ mark

Examiner tip: Always multiply by i for salts: $MgCl_2$ gives 3 ions. In (IIIB) convert 100 mL to 0.100 L, otherwise the answer is wrong by a factor of 1000.

30 **A DNA model at a school science fair**

Students in Nashik prepared a model of a short double-stranded DNA segment for their school science fair. They read that in DNA the two strands are held together by hydrogen bonds between specific pairs of bases: adenine (A) always pairs with thymine (T), and guanine (G) always pairs with cytosine (C). Each nucleotide unit contains one base, one β-D-2-deoxyribose sugar and one phosphate group. A laboratory report showed that in a sample of double-stranded DNA from a soil bacterium, cytosine makes up 18% of all the bases.

Answer the following questions:

(I) The percentage of adenine in this bacterial DNA is:

(A) 18% (B) 32% (C) 36% (D) 64%

(II) To change their DNA model into a model of RNA, the students must:

(A) replace deoxyribose by ribose and thymine by uracil

(B) replace deoxyribose by ribose and adenine by uracil

(C) replace ribose by deoxyribose and cytosine by uracil

(D) replace only thymine by uracil, keeping the same sugar

(IIIA) One strand of the model has the base sequence A–T–T–G–C–A–C. Write the base sequence of the complementary strand, base by base. How many purine bases (adenine and guanine) are present in this double-stranded segment in all?

OR

(IIIB) The complete model has 20 base pairs, of which 8 are G–C pairs. How many (a) adenine bases, (b) cytosine bases, (c) deoxyribose units and (d) phosphate groups are present in the model?

Answer (4 marks)

(I) (B) 32%. C = G = 18%, so A + T = 100 − 36 = 64% and A = T = 32%.

(II) (A). RNA contains β-D-ribose instead of β-D-2-deoxyribose, and uracil instead of thymine.

(IIIA) Given strand: A–T–T–G–C–A–C

Complementary strand (A pairs with T, G with C): **T–A–A–C–G–T–G**

Purines are adenine and guanine. Given strand: A = 2, G = 1 → 3; complementary strand: A = 2, G = 2 → 4.

Total purines = **7** (half of the 14 bases, as every base pair has one purine and one pyrimidine).

OR

(IIIB) 20 base pairs = 40 nucleotides. 8 G–C pairs, so 20 − 8 = 12 A–T pairs.

(a) Adenine = 12 (b) Cytosine = 8 (c) Deoxyribose units = 40 (d) Phosphate groups = 40 (one each per nucleotide)

Marking: (I) Correct option – 1 mark · (II) Correct option – 1 mark · (IIIA) Correct complementary sequence – 1 mark; purines = 7 with working – 1 mark · (IIIB) A = 12 – ½ mark; C = 8 – ½ mark; deoxyribose = 40 – ½ mark; phosphate = 40 – ½ mark

Examiner tip: Count the bases in both strands when the question says 'double-stranded'. Each base pair has one purine and one pyrimidine, so the purines are always half of all the bases.

SECTION E Questions 31 to 33 are long answer questions carrying 5 marks each. **[15]**

31 (A) (I) An organic compound A (C_4H_8O) forms a crystalline addition compound with sodium hydrogensulphite but gives no red precipitate when warmed with Fehling's solution. Reduction of A with sodium borohydride gives an alcohol B whose molecule has a chiral carbon atom. Identify A and B, and write the equations for the reaction of A with (a) iodine and sodium hydroxide, (b) HCN and (c) hydrazine followed by heating with KOH in ethylene glycol.

(II) Why are the α-hydrogen atoms of aldehydes acidic? Write the structure and IUPAC name of the aldol formed from propanal in the presence of dilute NaOH and of the product formed when this aldol is heated.

OR

(B) (I) Account for the following:

(a) Methanal does not undergo aldol condensation but undergoes Cannizzaro reaction.

(b) Electrophilic substitution in benzoic acid takes place at the meta position.

(c) Aldehydes are oxidised even by mild oxidising agents, whereas ketones need strong oxidising agents and drastic conditions.

(II) How will you bring about the following conversions? Write the equations.

(a) Propanenitrile to propanal (b) Benzene to acetophenone

Answer (5 marks)

(A) (I) A adds $NaHSO_3$, so it has a C=O group. It does not reduce Fehling's solution, so it is a ketone, not an aldehyde (butanal and 2-methylpropanal would reduce it). The only C_4H_8O ketone is **A = butan-2-one**, $CH_3COCH_2CH_3$.

$CH_3COCH_2CH_3$ –$NaBH_4$→ $CH_3CH(OH)CH_2CH_3$: **B = butan-2-ol** (C-2 carries H, OH, CH_3 and C_2H_5, so it is chiral).

(a) Iodoform reaction: $CH_3COCH_2CH_3 + 3I_2 + 4NaOH \rightarrow CHI_3\downarrow$ (yellow, iodoform) + $CH_3CH_2COONa + 3NaI + 3H_2O$

(b) $CH_3COCH_2CH_3 + HCN \rightarrow CH_3C(OH)(CN)CH_2CH_3$ (2-hydroxy-2-methylbutanenitrile, a cyanohydrin)

(c) Wolff–Kishner reduction: $CH_3COCH_2CH_3 + NH_2NH_2$ –(−H_2O)→ $CH_3C(=NNH_2)CH_2CH_3$ –KOH/ethylene glycol, heat→ $CH_3CH_2CH_2CH_3$ (butane) + N_2

(II) The α-hydrogen is acidic because of the strong electron-withdrawing effect of the C=O group, and because the carbanion (enolate) formed is stabilised by resonance.

$2CH_3CH_2CHO$ –dil. NaOH→ $CH_3CH_2CH(OH)–CH(CH_3)–CHO$: **3-hydroxy-2-methylpentanal** (aldol)

On heating: $CH_3CH_2CH(OH)CH(CH_3)CHO$ –Δ, −H_2O→ $CH_3CH_2CH=C(CH_3)CHO$: **2-methylpent-2-enal**

OR

(B) (I) (a) Aldol condensation needs at least one α-hydrogen; HCHO has no α-carbon/α-hydrogen. Without α-H, it undergoes Cannizzaro reaction (self oxidation–reduction) with conc. alkali:

$2HCHO + \text{conc. } KOH \rightarrow CH_3OH + HCOOK$

(b) –COOH is an electron-withdrawing group. It lowers electron density most at the ortho and para positions (seen in its resonance structures), so the meta position is relatively richer in electrons and is attacked by the electrophile.

(c) Aldehydes have an H atom on the carbonyl carbon, which is easily converted to –OH (C–H to C–OH) without breaking a C–C bond. Ketones have no such H, so a C–C bond must be broken. This needs strong oxidants and drastic conditions and gives a mixture of acids with fewer

carbon atoms.

(II) (a) Stephen reaction: $CH_3CH_2CN + SnCl_2 + HCl \rightarrow CH_3CH_2CH{=}NH$ (imine) $\xrightarrow{-H_3O^+} CH_3CH_2CHO + NH_3$

(b) Friedel–Crafts acylation: $C_6H_6 + CH_3COCl \xrightarrow{\text{–anhyd. } AlCl_3} C_6H_5COCH_3 + HCl$

Marking: (A) (I) A = butan-2-one and B = butan-2-ol with reasoning – ½ mark; iodoform equation – 1 mark; cyanohydrin equation – ½ mark; Wolff–Kishner equation – 1 mark · (A) (II) Reason for acidity of α-H – ½ mark; aldol structure and name – 1 mark; dehydration product – ½ mark · (B) (I) Each reason – 1 mark × 3 · (B) (II) Each conversion with reagents and equation – 1 mark × 2

Examiner tip: In the aldol of propanal, the new C–C bond forms between the α-carbon of one molecule and the C=O carbon of the other. So the methyl branch is on C-2, giving 3-hydroxy-2-methylpentanal, not 3-hydroxyhexanal.

32 (A) Answer the following:

(I) Write the IUPAC name of $[Co(en)_2(H_2O)Cl]SO_4$.

(II) Write the formula of pentaamminethiocyanato-S-chromium(III) chloride.

(III) Using valence bond theory, predict the hybridisation, shape and magnetic behaviour (number of unpaired electrons and spin-only magnetic moment) of the tetrahedral complex ion $[CoCl_4]^{2-}$. (Co: Z = 27)

(IV) Write the formula and IUPAC name of the linkage isomer of the compound in (II).

OR

(B) Answer the following:

(I) Using crystal field theory, explain why $[Co(en)_3]^{3+}$ is diamagnetic whereas $[CoF_6]^{3-}$ is paramagnetic. Draw the d-orbital splitting diagrams. (Co: Z = 27)

(II) How many geometrical isomers are possible for the octahedral complex ion $[Cr(H_2O)_4Cl_2]^+$? Name them.

(III) $[Ni(en)_3]^{2+}$ is more stable than $[Ni(NH_3)_6]^{2+}$. Give reason.

(IV) Write the oxidation number and coordination number of the central metal in $K_2[Ni(C_2O_4)_2]$.

Answer (5 marks)

(A) (I) Aquachloridobis(ethane-1,2-diamine)cobalt(III) sulphate

(Ligands in alphabetical order: aqua, chlorido, ethane-1,2-diamine; Co: x + 0 + 0 − 1 = +2, so x = +3.)

(II) $[Cr(NH_3)_5(SCN)]Cl_2$

(III) $Co^{2+} = [Ar]\ 3d^7$: 3d orbitals hold ↑↓ ↑↓ ↑ ↑ ↑, i.e. three unpaired electrons. Cl^- is a weak field ligand and no extra pairing is needed for tetrahedral bonding. The empty 4s and three 4p orbitals hybridise (**sp^3**) and accept four electron pairs from four Cl^- ions.

Shape: **tetrahedral**. Unpaired electrons = 3, so it is **paramagnetic**.

$\mu = \sqrt{(n(n+2))} = \sqrt{(3 \times 5)} = \sqrt{15} =$ **3.87 BM**

(IV) Linkage isomer: $[Cr(NH_3)_5(NCS)]Cl_2$, pentaamminethiocyanato-N-chromium(III) chloride.

(The ambidentate thiocyanate ion binds through N instead of S.)

OR

(B) (I) $Co^{3+} = 3d^6$.

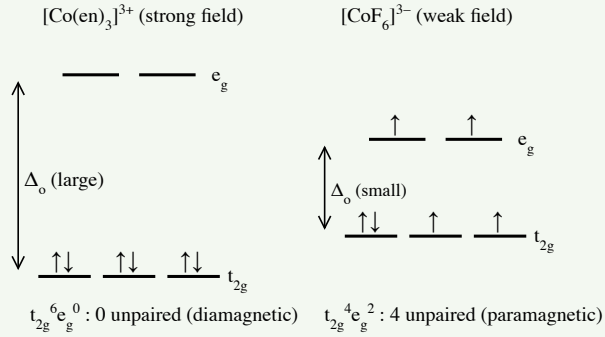
In $[Co(en)_3]^{3+}$, en is a strong field ligand: $\Delta_o > P$, so all six electrons pair up in the t_{2g} set: $t_{2g}^6 e_g^0$. No unpaired electron, so it is **diamagnetic**.

In $[CoF_6]^{3-}$, F^- is a weak field ligand: $\Delta_o < P$, so electrons enter e_g before pairing: $t_{2g}^4 e_g^2$. There are 4 unpaired electrons, so it is **paramagnetic** ($\mu = \sqrt{24} = 4.90$ BM). (Diagrams below.)

(II) Two geometrical isomers: **cis**, with the two Cl^- ligands on adjacent positions (90° apart), and **trans**, with the two Cl^- ligands opposite each other (180° apart).

(III) en is a didentate (chelating) ligand. It forms stable five-membered rings with Ni^{2+} (chelate effect), so $[Ni(en)_3]^{2+}$ is more stable than the complex with the unidentate NH_3.

(IV) Oxidation number of Ni: 2(+1) + x + 2(−2) = 0, so x = **+2**. Coordination number = **4** (two didentate oxalate ions, each giving two donor O atoms).



Marking: (A) (I) Correct name – 1 mark; (II) correct formula – 1 mark · (A) (III) sp^3 and tetrahedral – 1 mark; 3 unpaired, paramagnetic, 3.87 BM – 1 mark · (A) (IV) Linkage isomer formula with name – 1 mark · (B) (I) Configurations $t_{2g}^6e_g^0$ and $t_{2g}^4e_g^2$ with field strength – 1 mark; splitting diagrams – 1 mark · (B) (II) cis and trans – 1 mark; (III) chelate effect – 1 mark; (IV) +2 and 4 – ½ + ½ mark

Examiner tip: Coordination number counts donor atoms, not ligands: two oxalate ions give 4, not 2. In IUPAC names ignore the prefixes 'bis' and 'tri' when putting ligands in alphabetical order.

33 (A) (I) The conductivity of a 0.010 mol L^{-1} solution of propanoic acid at 298 K is 1.40×10^{-4} S cm^{-1}. Calculate (a) its molar conductivity, (b) its degree of dissociation and (c) its dissociation constant. Given: $\lambda°(H^+) = 349.6$ S cm^2 mol^{-1}, $\lambda°(CH_3CH_2COO^-) = 35.8$ S cm^2 mol^{-1}.

(II) Write the reactions taking place at the anode and the cathode of the mercury cell used in hearing aids and watches. Why does its cell potential stay nearly constant (about 1.35 V) during its life?

OR

(B) (I) A steel spoon is to be silver-plated in a small workshop in Pune. A current of 0.50 A is passed through $AgNO_3$ solution for 32 minutes 10 seconds. Calculate the mass of silver deposited on the spoon. (Ag = 108 g mol^{-1}, F = 96500 C mol^{-1})

(II) Write the anode and cathode reactions in the rusting of iron. How does coating iron with zinc (galvanisation) protect it even when the coating is scratched?

(III) The molar conductivity of a strong electrolyte increases slightly on dilution. Why?

Answer (5 marks)

(A) (I) (a) $\Lambda_m = \kappa \times 1000/C = (1.40 \times 10^{-4}\ S\ cm^{-1} \times 1000\ cm^3\ L^{-1})/(0.010\ mol\ L^{-1})$ = **14.0 S cm^2 mol^{-1}**

(b) By Kohlrausch's law: $\Lambda°_m(CH_3CH_2COOH) = \lambda°(H^+) + \lambda°(CH_3CH_2COO^-) = 349.6 + 35.8 = 385.4$ S cm^2 mol^{-1}

$\alpha = \Lambda_m/\Lambda°_m = 14.0/385.4$ = **0.0363**

(c) $K_a = C\alpha^2/(1 - \alpha) = 0.010 \times (0.0363)^2/(1 - 0.0363)$ = **1.37×10^{-5} mol L^{-1}**

(Using $K_a \approx C\alpha^2$ gives 1.32×10^{-5}; also accepted.)

(II) Mercury cell (anode: zinc–mercury amalgam; cathode: paste of HgO and carbon; electrolyte: paste of KOH and ZnO):

Anode: $Zn(Hg) + 2OH^- \rightarrow ZnO(s) + H_2O + 2e^-$

Cathode: $HgO(s) + H_2O + 2e^- \rightarrow Hg(l) + 2OH^-$

Overall: $Zn(Hg) + HgO(s) \rightarrow ZnO(s) + Hg(l)$

The overall reaction does not involve any ion in solution whose concentration changes during the life of the cell (OH^- used at the anode is given back at the cathode), so the cell potential stays nearly constant.

OR

(B) (I) t = 32 min 10 s = 1930 s; Q = It = 0.50 A × 1930 s = 965 C

$Ag^+ + e^- \rightarrow Ag$: 96500 C deposit 108 g of Ag

Mass of Ag = (108 × 965)/96500 = **1.08 g**

(II) Anode (oxidation): $2Fe(s) \rightarrow 2Fe^{2+} + 4e^-$

Cathode (reduction): $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

(Overall: $2Fe + O_2 + 4H^+ \rightarrow 2Fe^{2+} + 2H_2O$; Fe^{2+} is further oxidised to rust, $Fe_2O_3 \cdot xH_2O$.)

Zinc is more reactive than iron (lower E°). Even if the coating is scratched, zinc is oxidised in preference to iron and acts as the anode. Iron becomes the cathode and is protected (sacrificial protection).

(III) In a strong electrolyte, the interionic attractions decrease on dilution, because the ions move further apart. So ionic mobility increases and Λ_m increases slightly ($\Lambda_m = \Lambda^\circ_m - A\sqrt{C}$).

Marking: (A) (I) Λ_m = 14.0 – 1 mark; Λ°_m by Kohlrausch law and α = 0.0363 – 1 mark; $K_a = 1.37 \times 10^{-5}$ – 1 mark · (A) (II) Anode reaction – ½ mark; cathode reaction – ½ mark; reason for constant potential (no ion whose concentration changes in the overall reaction) – 1 mark · (B) (I) Q = 965 C – 1 mark; mass 1.08 g – 1 mark · (B) (II) Anode and cathode reactions – 1 mark; sacrificial protection by Zn – 1 mark · (B) (III) Decrease in interionic attraction – 1 mark

Examiner tip: Use the factor 1000 when C is in mol L^{-1} and κ is in S cm^{-1}. In (B)(I) change minutes to seconds first: 32 min 10 s = 1930 s.

All the best for your exam!