Roll No. ☐☐☐☐☐☐☐☐

Q.P. Code 56/1/1

CHEMISTRY (THEORY)

CBSE Class XII Board Examination 2023 — with answers

Time allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. The paper has 35 questions in five sections (A to E); all of them must be answered.
2. Section A: Q1–18, multiple choice and Assertion-Reason, 1 mark each.
3. Section B: Q19–25, very short answer, 2 marks each.
4. Section C: Q26–30, short answer, 3 marks each.
5. Section D: Q31–32, case-based, 4 marks each.
6. Section E: Q33–35, long answer, 5 marks each.
7. There is no overall choice, but two questions each in Sections B, C, D and E offer an internal choice (OR). Calculators are not allowed.

SECTION A

Q1–18 carry 1 mark each (MCQ; Q15–18 are Assertion-Reason).

1. Which colligative property is preferred for finding the molar mass of polymers and proteins? **1**

(A) Osmotic pressure

(B) Depression in freezing point

(C) Relative lowering of vapour pressure

(D) Elevation in boiling point

ANSWER

(a) Osmotic pressure

Polymers and proteins have very large molar masses, so a normal solution gives tiny ΔTb, ΔTf or vapour-pressure changes that are hard to measure.
Osmotic pressure is measurable even for very dilute solutions, is measured at room temperature (proteins are not denatured by heating) and uses molarity instead of molality.
Hence osmotic pressure is the method of choice.

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2. People who live at high altitudes have a low concentration of oxygen in their blood and tissues. This is because of: **1**

(A) high atmospheric pressure

(B) low temperature

(C) low atmospheric pressure

(D) both low temperature and high atmospheric pressure

ANSWER

(c) low atmospheric pressure

By Henry's law, the solubility of a gas in a liquid is proportional to its partial pressure above the liquid ($p = K_H \cdot x$).
At high altitude the atmospheric pressure, and so the partial pressure of O_2, is low.
Therefore less O_2 dissolves in blood → anoxia (weakness, inability to think clearly).

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3. Which cell notation correctly represents the reaction $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$? **1**

(A) $2Ag \mid Ag^+ \parallel Zn \mid Zn^{2+}$

(B) $Ag^+ \mid Ag \parallel Zn^{2+} \mid Zn$

(C) $Ag \mid Ag^+ \parallel Zn \mid Zn^{2+}$

(D) $\mathbf{Zn \mid Zn^{2+} \parallel Ag^+ \mid Ag}$

ANSWER

(d) $Zn \mid Zn^{2+} \parallel Ag^+ \mid Ag$

Zn is oxidised ($Zn \rightarrow Zn^{2+}$), so the zinc electrode is the anode and is written on the left as $Zn \mid Zn^{2+}$.
Ag^+ is reduced ($Ag^+ \rightarrow Ag$), so the silver electrode is the cathode, written on the right as $Ag^+ \mid Ag$.
The salt bridge is shown by ||: $Zn \mid Zn^{2+} \parallel Ag^+ \mid Ag$.
Stoichiometric coefficients are never written in cell notation.

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4. For a reaction that occurs spontaneously, the signs of ΔG and E°cell are respectively: **1**

(A) positive, negative
(B) negative, negative
(C) negative, positive
(D) positive, positive

ANSWER
(c) negative, positive

ΔG = −nFE_cell.
A spontaneous reaction has ΔG < 0; since n and F are positive, E_cell must be > 0.
So ΔG is negative and E_cell is positive.

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5. Which one of the following quantities is changed by a catalyst? **1**

(A) ΔH
(B) ΔG
(C) Ea
(D) ΔS

ANSWER
(c) Ea

A catalyst provides an alternative pathway with a lower activation energy (Ea).
ΔH, ΔG and ΔS are state functions that depend only on the initial and final states, so a catalyst does not change them (nor the equilibrium constant).

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6. What is the order of the photochemical reaction $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ carried out in the presence of light (hν)? **1**

(A) 2
(B) 1
(C) 0
(D) 3

ANSWER
(c) Zero order

The photochemical combination of H_2 and Cl_2 (over water) is the standard textbook example of a zero-order reaction.
Its rate depends on the intensity of light absorbed, not on the concentrations of H_2 and Cl_2: rate = k.
(Note: the official key accepted any option for this question, but the textbook answer is zero order.)

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7. Which oxidation state is the most common and most stable for lanthanoids? **1**

(A) +2
(B) +3
(C) +4
(D) +6

ANSWER
(b) +3

Lanthanoids lose the two 6s electrons and one 4f/5d electron easily, so +3 is their characteristic oxidation state.
+2 (e.g. Eu^{2+}, Yb^{2+}) and +4 (e.g. Ce^{4+}) appear only where they give empty, half-filled or full f subshells.

8. $[Co(SO_4)(NH_3)_5]Br$ and $[Co(Br)(NH_3)_5]SO_4$ are examples of which type of isomerism? **1**

(A) optical isomerism **(B)** linkage isomerism

(C) ionisation isomerism **(D)** coordination isomerism

ANSWER

(c) ionisation isomerism

Both compounds have the same formula; the ligand inside the sphere and the counter-ion outside it are exchanged ($SO_4^{2-} \leftrightarrow Br^-$).

So in water one gives Br^- ions and the other gives SO_4^{2-} ions → ionisation isomers.

9. Alkyl fluorides are best prepared by: **1**

(A) Free radicals **(B) Swarts reaction**

(C) Sandmeyer reaction **(D)** Finkelstein reaction

ANSWER

(b) Swarts reaction

In the Swarts reaction an alkyl chloride/bromide is heated with a metallic fluoride such as AgF, Hg_2F_2, CoF_2 or SbF_3: $CH_3Br + AgF \rightarrow CH_3F + AgBr$.

Finkelstein gives alkyl iodides (NaI/acetone); Sandmeyer gives aryl halides from diazonium salts.

10. In the reaction R–OH + HCl (anhydrous $ZnCl_2$) → R–Cl + H_2O, what is the correct order of reactivity of alcohols? **1**

(A) 1° < 2° < 3° **(B)** 1° > 3° > 2°

(C) 1° > 2° > 3° **(D)** 3° > 1° > 2°

ANSWER

(a) 1° < 2° < 3°

HCl/$ZnCl_2$ (Lucas reagent) reacts through a carbocation (SN1).

Carbocation stability: 3° > 2° > 1°, so tertiary alcohols react fastest (turbidity at once), secondary in about 5 minutes, primary only on heating.

Reactivity: 1° < 2° < 3°.

11. When CH_3CONH_2 is treated with Br_2 and NaOH (alcoholic medium), the product is: **1**

(A) CH_3COONa **(B)** CH_3NH_2

(C) CH_3CH_2Br **(D)** $CH_3CH_2NH_2$

ANSWER

(b) CH_3NH_2

This is the Hoffmann bromamide degradation: $RCONH_2 + Br_2 + 4NaOH \rightarrow RNH_2 + Na_2CO_3 + 2NaBr + 2H_2O$.

The amine formed has one carbon less than the amide, so acetamide (2 C) gives methanamine CH_3NH_2 (1 C).

12. Which of these is the weakest base? **1**

(A) $(CH_3)_2NH$ **(B)** NH_3

(C) $C_6H_5NH_2$ (aniline) **(D)** $(CH_3)_3N$

ANSWER

(c) Aniline

In aniline the lone pair on N is delocalised into the benzene ring by resonance, so it is less available to accept a proton.

Alkylamines are stronger than NH_3 because the +I effect of alkyl groups increases electron density on N.

So aniline (pKb ≈ 9.4) is the least basic.

13. Which glycosidic linkage joins the glucose units in the amylose part of starch? **1**

(A) C1–C6 α linkage **(B)** C1–C6 β linkage

(C) C1–C4 α linkage **(D)** C1–C4 β linkage

ANSWER

(c) C1–C4 α linkage

Amylose is an unbranched chain of α-D-glucose units joined by C1–C4 α-glycosidic bonds.

Amylopectin has the same C1–C4 α chain plus C1–C6 α links at the branch points.

Cellulose uses C1–C4 β links.

(Because of the printing error the official key gave full marks for any attempt.)

14. The α-helix is a structural feature found in: **1**

(A) Sucrose **(B)** Starch

(C) Polypeptides **(D)** Nucleotides

ANSWER

(c) Polypeptides

The α-helix is a secondary structure of proteins: the polypeptide chain coils into a right-handed helix held by hydrogen bonds between –NH and C=O groups of the peptide links (every 4th residue).

15. Assertion (A): In electrophilic substitution, the $–NH_2$ group directs incoming groups to ortho and para positions. **1**

Reason (R): Aniline does not undergo the Friedel–Crafts reaction.

(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

(b) Both true, R is not the explanation of A

A is true: the lone pair of $–NH_2$ is donated into the ring (+R effect), raising electron density at o- and p-positions.

R is true: aniline (a Lewis base) forms a salt with the Lewis acid $AlCl_3$, and the N then carries a positive charge, deactivating the ring.

But R does not explain why $–NH_2$ is o/p-directing.

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16. Assertion (A): Acetylating aniline (and then brominating) gives a monosubstituted product. **1**

Reason (R): The $–NHCOCH_3$ group is a stronger activating group than the $–NH_2$ group.

(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

(c) A true, R false

In acetanilide the N lone pair is also shared with the C=O group (resonance), so it is less available to the ring.

Hence $–NHCOCH_3$ is a weaker activator than $–NH_2$, and substitution can be controlled to give a single (para) product.

So A is true and R is false (the activating effect is LESS, not more).

17. Assertion (A): The molecularity of the reaction $H_2 + Br_2 \rightarrow 2HBr$ appears to be 2. **1**
Reason (R): Two molecules of reactants take part in this given elementary reaction.

(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

(a) Both true, R explains A

Molecularity = number of reacting species that collide simultaneously in an elementary step.
As written, one H_2 and one Br_2 molecule collide, so the molecularity appears to be 2, and this is exactly what R states.
So the official answer is (a). (Remember: the experimental rate law of this reaction is complex, which is why A only says 'appears'.)

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18. Assertion (A): Tetrahedral complexes that are low spin are seldom seen. **1**
Reason (R): For tetrahedral complexes, the crystal field splitting energy is smaller than the pairing energy.

(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

(a) Both true, R explains A

$\Delta t \approx (4/9)\Delta o$, so the tetrahedral splitting is small and nearly always less than the pairing energy P.
Electrons therefore prefer to occupy the higher orbitals singly rather than pair up → high-spin complexes.
So low-spin tetrahedral complexes are rare, and R is the correct reason.

SECTION B

Q19–25 carry 2 marks each.

19. State Henry's law and give one of its applications. **2**

ANSWER

$p = K_H \cdot x$; e.g. soda bottles are sealed under high CO_2 pressure.

Henry's law: at constant temperature, the partial pressure of a gas in vapour phase is directly proportional to its mole fraction in the solution: $p = K_H \cdot x$ (K_H = Henry's law constant). Equivalently, solubility of a gas $\propto$ its pressure.

Applications (any one):

- Soft drinks/soda water are bottled under high pressure to increase CO_2 solubility.
- Scuba divers use air diluted with helium to reduce the 'bends' caused by N_2 dissolving in blood at high pressure.
- At high altitude, low O_2 partial pressure $\rightarrow$ less O_2 in blood (anoxia).

20. Two electrolytes A and B are diluted. On dilution, the molar conductivity Λm of A increases 25 times, while that of B increases only 1.5 times. Which electrolyte is strong? Support your answer with a graph. **2**

ANSWER

B is the strong electrolyte.

For a strong electrolyte, it is already almost fully ionised, so Λm rises only slightly on dilution ($\Lambda m = \Lambda^\circ m - A\sqrt{C}$, interionic attraction decreases). $\rightarrow$ B (1.5 times).

For a weak electrolyte, the degree of dissociation increases sharply on dilution, so Λm rises very steeply $\rightarrow$ A (25 times).

Graph: plot Λm (y-axis) against $\sqrt{C}$ (x-axis). B gives a nearly straight line with small negative slope, which can be extrapolated to $\Lambda^\circ m$ at $\sqrt{C} = 0$. A gives a curve that stays low at higher $\sqrt{C}$ and shoots up steeply as $\sqrt{C} \rightarrow 0$ (cannot be extrapolated).

OR

A column of 0.05 mol L^{-1} NaOH solution has diameter 1 cm and length 50 cm, and its resistance is $5.55 \times 10^3\ \Omega$. Find its conductivity.

ANSWER

$\kappa \approx 1.15 \times 10^{-2}$ S cm^{-1}

Area $A = \pi r^2 = 3.14 \times (0.5\ cm)^2 = 0.785\ cm^2$; $l = 50$ cm.

$\kappa = l / (R \times A) = 50 / (5.55 \times 10^3 \times 0.785)$ S cm^{-1}

$= 50 / 4356.75 = 1.147 \times 10^{-2}$ S cm^{-1} ($\approx 11.47 \times 10^{-3}$ S cm^{-1}).

Common mistake: using diameter instead of radius in πr^2.

21. Complete these ionic equations: **2**

(a) $2MnO_4^- + 5NO_2^- + 6H^+ \rightarrow$

(b) $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow$

ANSWER

(a) $2Mn^{2+} + 5NO_3^- + 3H_2O$; (b) $2Cr^{3+} + 7H_2O$

(a) In acid, MnO_4^- (Mn +7) is reduced to Mn^{2+}, gaining $5e^-$ each; NO_2^- (N +3) is oxidised to NO_3^- (N +5), losing $2e^-$ each. $2 \times 5 = 5 \times 2$ electrons balance.

$2MnO_4^- + 5NO_2^- + 6H^+ \rightarrow 2Mn^{2+} + 5NO_3^- + 3H_2O$

(b) Dichromate (Cr +6) gains $3e^-$ per Cr in acid:

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

Check: O 7 = 7, H 14 = 14, charge $(-2 + 14 - 6 = +6) = 2 \times (+3)$.

22. Identify A and B: **2**

(a) $CH_3–CH(OH)–CH_3 \xrightarrow{PCl_5} A \xrightarrow{AgCN} B$

(b) $CH_3CH_2CH_2Cl + KOH\ (ethanol) \rightarrow A \xrightarrow{HBr} B$

ANSWER

(a) A = 2-chloropropane, B = 2-propyl isocyanide $(CH_3)_2CH–NC$; (b) A = propene, B = 2-bromopropane

(a) PCl_5 replaces –OH by –Cl: A = $CH_3CHClCH_3$ (2-chloropropane).

AgCN is mainly covalent, so attack occurs through N: B = $(CH_3)_2CH–N{\equiv}C$ (isopropyl isocyanide).

(b) Alcoholic KOH causes dehydrohalogenation (β-elimination): A = $CH_3–CH{=}CH_2$ (propene).

HBr adds by Markovnikov's rule (Br to the carbon with fewer H): B = $CH_3–CHBr–CH_3$ (2-bromopropane).

23. Give reasons: **2**

(i) Phenol is more acidic than an alcohol.

(ii) Among isomeric alcohols, the boiling point falls as the alkyl chain becomes more branched.

ANSWER

(i) Phenoxide ion is resonance-stabilised; (ii) branching lowers surface area and van der Waals forces.

(i) On losing H^+, phenol forms phenoxide ion, whose negative charge is delocalised over the benzene ring (resonance) → stable ion → phenol ionises more readily. The alkoxide ion has no such delocalisation; the +I effect of the alkyl group even intensifies its charge.
(ii) Branching makes the molecule more compact (nearly spherical), so its surface area decreases. Van der Waals attractions decrease, so less energy is needed to boil it → lower boiling point.

OR

(i) Give the mechanism of: $CH_3CH_2OH \xrightarrow{H^+,\ 443\ K} CH_2{=}CH_2 + H_2O$.

(ii) Write the equation for the Reimer–Tiemann reaction.

ANSWER

(i) Protonation → loss of H_2O (carbocation) → loss of H^+; (ii) phenol + $CHCl_3$ + aq NaOH → salicylaldehyde

(i) Step 1 – protonation of alcohol: $CH_3CH_2{-}OH + H^+ \rightleftharpoons CH_3CH_2{-}OH_2^+$ (fast).
Step 2 – loss of water forms carbocation (slow, rate-determining): $CH_3CH_2{-}OH_2^+ \rightarrow CH_3CH_2^+ + H_2O$.
Step 3 – loss of a β-proton: $CH_3CH_2^+ \rightarrow CH_2{=}CH_2 + H^+$.
(ii) $C_6H_5OH + CHCl_3 + aq\ NaOH \rightarrow$ (intermediate o-substituted benzal chloride) → sodium salicylaldehyde; acidification (H^+) gives salicylaldehyde, o-$HO{-}C_6H_4{-}CHO$.

24. Explain briefly, writing the chemical equation in each case: **2**

(a) Carbylamine reaction

(b) Gabriel phthalimide synthesis

ANSWER

(a) $R{-}NH_2 + CHCl_3 + 3KOH \rightarrow R{-}NC + 3KCl + 3H_2O$; (b) phthalimide → K-salt → N-alkylphthalimide → 1° amine

(a) A primary amine (aliphatic or aromatic) heated with chloroform and alcoholic KOH gives a foul-smelling isocyanide (carbylamine). It is a test for 1° amines; 2° and 3° amines do not respond.
$R{-}NH_2 + CHCl_3 + 3KOH\ (alc.) \rightarrow R{-}N{\equiv}C + 3KCl + 3H_2O$
(b) Phthalimide + ethanolic KOH → potassium phthalimide; heated with an alkyl halide R–X → N-alkylphthalimide; alkaline hydrolysis (aq NaOH) → primary amine $R{-}NH_2$ + sodium phthalate.
It gives pure 1° aliphatic amines; aromatic amines cannot be made this way because aryl halides do not undergo nucleophilic substitution with the phthalimide anion.

25. (a) Give a chemical reaction showing that the open-chain form of D-glucose has a straight (unbranched) chain of carbon atoms. **2**

(b) Which type of linkage holds amino acids together in a protein?

ANSWER

(a) Glucose + HI (heat) → n-hexane; (b) peptide linkage (–CO–NH–)

(a) On prolonged heating with HI, glucose is reduced to n-hexane: $C_6H_{12}O_6$ —HI, $\Delta\rightarrow$ $CH_3–CH_2–CH_2–CH_2–CH_2–CH_3$. Since the product is a straight-chain alkane, all six carbons of glucose are in a straight chain.

(b) Peptide linkage – the amide bond –CO–NH– formed between –COOH of one amino acid and $–NH_2$ of the next, with loss of water.

SECTION C

Q26–30 carry 3 marks each.

26. (a) Distinguish between an ideal solution and a non-ideal solution. **3**

(b) 30 g urea (M = 60 g mol^{-1}) is dissolved in 846 g water. If pure water has vapour pressure 23.8 mm Hg at 298 K, find the vapour pressure of water over this solution.

ANSWER

(b) p ≈ 23.5 mm Hg

(a) Ideal: obeys Raoult's law at all concentrations; ΔmixH = 0 and ΔmixV = 0; A–B interactions equal to A–A and B–B.
Non-ideal: does not obey Raoult's law (positive or negative deviation); ΔmixH ≠ 0, ΔmixV ≠ 0.
(b) n(urea) = 30/60 = 0.5 mol; n(water) = 846/18 = 47 mol.
x(water) = 47 / (47 + 0.5) = 47/47.5.
p = x(water) × p° = (47/47.5) × 23.8 = 23.55 ≈ 23.5 mm Hg.
(Relative lowering = 0.5/47.5 = 0.0105.)

27. Give the main product in each case: **3**

(a) Methyl chloride is treated with NaI in acetone.

(b) 2,4,6-Trinitrochlorobenzene is hydrolysed.

(c) n-Butyl chloride is heated with alcoholic KOH.

ANSWER

(a) CH_3I; (b) 2,4,6-trinitrophenol (picric acid); (c) but-1-ene

(a) Finkelstein reaction: $CH_3Cl + NaI \rightarrow CH_3I + NaCl$; NaCl is insoluble in acetone, which drives the reaction forward.
(b) Three $-NO_2$ groups at o/p positions strongly withdraw electrons, so the Cl is replaced by –OH just with warm water: product 2,4,6-trinitrophenol (picric acid).
(c) Dehydrohalogenation: $CH_3CH_2CH_2CH_2Cl + KOH\ (alc.) \rightarrow CH_3CH_2CH{=}CH_2 + KCl + H_2O$ (only one kind of β-H, so but-1-ene).

28. How will you carry out any three of these conversions? **3**

(a) Phenol → picric acid

(b) Propanone → 2-methylpropan-2-ol

(c) Phenol → anisole

(d) Propene → propan-1-ol

ANSWER

(a) conc. HNO_3/conc. H_2SO_4; (b) CH_3MgBr then H_3O^+; (c) NaOH then CH_3I; (d) B_2H_6 then H_2O_2/OH^-

(a) Phenol + conc. HNO_3 (with conc. H_2SO_4) → 2,4,6-trinitrophenol (picric acid). (Industrially phenol is first sulphonated, then nitrated.)

(b) CH_3COCH_3 + CH_3MgBr (dry ether) → $(CH_3)_3C–OMgBr$ —H_3O^+→ $(CH_3)_3C–OH$ (2-methylpropan-2-ol).

(c) C_6H_5OH + NaOH → C_6H_5ONa; C_6H_5ONa + CH_3I → $C_6H_5OCH_3$ (anisole) + NaI (Williamson synthesis).

(d) Hydroboration–oxidation: $CH_3CH=CH_2$ + $(BH_3)_2$ → $(CH_3CH_2CH_2)_3B$ —H_2O_2/OH^-→ $CH_3CH_2CH_2OH$ (anti-Markovnikov product).

Mistake to avoid: acid-catalysed hydration of propene gives propan-2-ol, not propan-1-ol.

29. Explain why: **3**

(i) The –COOH group of benzoic acid directs incoming electrophiles to the meta position.

(ii) Sodium bisulphite is used to purify aldehydes and ketones.

(iii) Carboxylic acids do not show the typical reactions of the carbonyl group.

ANSWER

(i) –COOH is electron-withdrawing/deactivating; (ii) forms crystalline bisulphite adducts that are reversible; (iii) resonance makes the C=O carbon less electrophilic.

(i) –COOH withdraws electrons from the ring (−I and −R). The o- and p-positions become more electron-poor than the meta position, so electrophilic substitution occurs at meta.
(ii) Aldehydes/methyl ketones add $NaHSO_3$ to form crystalline addition products that can be separated from impurities; the adduct is then decomposed with dilute acid or alkali to regenerate the pure carbonyl compound.
(iii) In –COOH, the lone pair of the –OH oxygen is in resonance with C=O, so the carbonyl carbon is much less electrophilic; nucleophilic additions (e.g. with HCN, NH_2OH) typical of aldehydes/ketones do not occur.

OR

Compound A (C_3H_8O) is heated with Cu at 573 K to give B. B does not reduce Fehling's solution but forms a yellow precipitate C with I_2/NaOH. Find the structures of A, B and C.

ANSWER

A = propan-2-ol, B = propanone, C = iodoform (CHI_3)

Cu at 573 K dehydrogenates alcohols: 1° → aldehyde, 2° → ketone.
B does not reduce Fehling's → B is a ketone, so A is a 2° alcohol.
The only 2° alcohol C_3H_8O is $CH_3CH(OH)CH_3$ (A, propan-2-ol).
$CH_3CH(OH)CH_3 \xrightarrow{Cu,\ 573\ K} CH_3COCH_3$ (B, acetone) + H_2.
$CH_3COCH_3 + 3I_2 + 4NaOH \rightarrow CHI_3$ (C, yellow ppt of iodoform) + CH_3COONa + 3NaI + $3H_2O$.

30. (a) Name the products obtained on hydrolysis of (i) lactose and (ii) maltose. **3**

(b) What is the basic structural difference between starch and cellulose?

ANSWER

(a)(i) β-D-galactose + β-D-glucose; (ii) two α-D-glucose; (b) starch = α-glucose polymer, cellulose = β-glucose polymer

(a) (i) Lactose (milk sugar) → β-D-galactose + β-D-glucose.
(ii) Maltose → 2 molecules of α-D-glucose.
(b) Starch is a polymer of α-D-glucose (amylose: C1–C4 α links; amylopectin: also C1–C6 α branches), whereas cellulose is a straight-chain polymer of β-D-glucose joined by C1–C4 β-glycosidic links.

SECTION D

Q31–32 are case-based, 4 marks each (choice in part (iii)).

31. *The rate of a reaction is the change in concentration of a reactant or product per unit time. It may be reported as an instantaneous rate at a given moment or an average rate over an interval; a rate law expresses it mathematically, and the rate constant and order can be found from the rate law or its integrated form.* **4**

(i) What is meant by the average rate of a reaction? (1)

(ii) State two factors that affect reaction rate. (1)

(iii) (1) How does the rate of a zero-order reaction change as the reaction proceeds? (2) Give the unit of k for a zero-order reaction. (2)

ANSWER

(i) Δ[concentration]/Δt over an interval; (ii) concentration, temperature (or catalyst, surface area); (iii) rate stays constant (rate = k); unit mol L^{-1} s^{-1}

(i) Average rate = change in concentration of a reactant or product divided by the time interval: r_av = $-\Delta[R]/\Delta t = +\Delta[P]/\Delta t$.

(ii) Any two: concentration of reactants, temperature, presence of a catalyst, surface area (and light for photochemical reactions).

(iii) (1) For a zero-order reaction rate = $k[R]^0 = k$, so the rate is independent of concentration and remains constant until the reactant is used up.

(2) Units of k = units of rate = mol L^{-1} s^{-1}.

OR

(iii) (1) For P + 2Q → products, the rate law is rate = k[P]^(1/2)[Q]¹. What is the overall order?

(2) Define a pseudo-first-order reaction and give one example.

ANSWER

(1) Order = 3/2; (2) higher-order reaction that behaves as first order, e.g. acid hydrolysis of an ester

(1) Order = sum of powers in the rate law = 1/2 + 1 = 3/2 (1.5). Note: the coefficient 2 of Q in the equation does not matter; only the experimental rate law counts.

(2) A reaction that is actually of higher order but behaves like first order because one reactant is in large excess (its concentration stays practically constant).

Example: $CH_3COOC_2H_5 + H_2O \xrightarrow{H^+} CH_3COOH + C_2H_5OH$; water is in large excess, so rate = k′[ester]. (Inversion of cane sugar is another example.)

32. *In coordination compounds a metal shows two kinds of valency (Werner). Primary valencies are ionisable, non-directional and satisfied by anions; secondary valencies are non-ionisable, satisfied by neutral molecules or anions with lone pairs, and they decide the shape of the complex.* **4**

(i) $PtCl_2 \cdot 2NH_3$ gives no precipitate with $AgNO_3$. Write its formula. (1)

(ii) What is the secondary valency of the metal in $[Co(en)_3]^{3+}$? (1)

(iii) (1) Write the formula of iron(III) hexacyanidoferrate(II). (2) Give the IUPAC name of $[Co(NH_3)_5Cl]Cl_2$. (2)

ANSWER

(i) $[Pt(NH_3)_2Cl_2]$; (ii) 6; (iii) $Fe_4[Fe(CN)_6]_3$; pentaamminechloridocobalt(III) chloride

(i) No AgCl precipitate means no ionisable Cl^-; both Cl are inside the coordination sphere: $[Pt(NH_3)_2Cl_2]$ (a neutral square-planar complex).

(ii) en (ethane-1,2-diamine) is bidentate; 3 en × 2 donor atoms = 6. Secondary valency (coordination number) = 6.

(iii) (1) Cation Fe^{3+}, anion $[Fe(CN)_6]^{4-}$; balance charges $4 \times (+3) = 3 \times (-4) \rightarrow Fe_4[Fe(CN)_6]_3$ (Prussian blue).

(2) $[Co(NH_3)_5Cl]Cl_2$: ligands alphabetically (ammine before chlorido), Co oxidation state $x + 0 - 1 = +2 \rightarrow x = +3$. Name: pentaamminechloridocobalt(III) chloride.

OR

(iii) State the hybridisation and magnetic nature of $[Ni(CN)_4]^{2-}$. (Atomic number of Ni = 28)

ANSWER

dsp^2, square planar, diamagnetic

Ni: $[Ar]3d^8 4s^2$; Ni^{2+}: $3d^8$.

CN^- is a strong-field ligand, so the 8 d electrons pair up in four 3d orbitals, leaving one 3d orbital empty.

One 3d + one 4s + two 4p orbitals hybridise → dsp^2 (square planar); four CN^- donate lone pairs into them.

No unpaired electrons → diamagnetic.

SECTION E

Q33–35 carry 5 marks each.

33. (i) State Kohlrausch's law of independent migration of ions and use it to write an expression for the limiting molar conductivity of acetic acid. **5**

(ii) For the reaction $Ni(s) + 2Ag^+(aq) \rightleftharpoons Ni^{2+}(aq) + 2Ag(s)$ at 298 K, find the maximum work obtainable and log Kc.

Given: $E°(Ni^{2+}/Ni) = -0.25$ V, $E°(Ag^+/Ag) = +0.80$ V, 1 F = 96500 C mol^{-1}.

ANSWER

(i) $\Lambda°m(CH_3COOH) = \lambda°(CH_3COO^-) + \lambda°(H^+)$; (ii) max work = 202.65 kJ mol^{-1}, log Kc ≈ 35.6

(i) Kohlrausch's law: the limiting molar conductivity of an electrolyte is the sum of the limiting molar conductivities of its cation and anion, each ion contributing independently.

$\Lambda°m(CH_3COOH) = \lambda°(H^+) + \lambda°(CH_3COO^-)$.

(In practice: $\Lambda°m(CH_3COOH) = \Lambda°m(CH_3COONa) + \Lambda°m(HCl) - \Lambda°m(NaCl)$.)

(ii) $E°cell = E°cathode - E°anode = 0.80 - (-0.25) = 1.05$ V; n = 2.

$\Delta G° = -nFE° = -2 \times 96500 \times 1.05 = -202650$ J mol^{-1}.

Maximum work $= -\Delta G° = 202650$ J $mol^{-1} = 202.65$ kJ mol^{-1}.

$\log Kc = nE°/0.059 = (2 \times 1.05)/0.059 = 2.10/0.059 \approx 35.6$.

OR

(i) State Faraday's first law of electrolysis. How many faradays of charge are needed to reduce 1 mol of Cu^{2+} to Cu?

(ii) Find the emf at 298 K of the cell $Mg(s) \mid Mg^{2+}(0.1\ M) \parallel Cu^{2+}(0.01\ M) \mid Cu(s)$.

Given: $E°cell = +2.71$ V, 1 F = 96500 C mol^{-1}, log 10 = 1.

ANSWER

(i) $m \propto Q$; 2 F; (ii) $E_{cell} \approx 2.68$ V

(i) Faraday's first law: the mass of a substance deposited or liberated at an electrode is directly proportional to the quantity of electricity passed: $m = Z \cdot Q = Z \cdot I \cdot t$.

$Cu^{2+} + 2e^- \rightarrow Cu$, so 1 mol Cu^{2+} needs 2 mol electrons = 2 F (= 193000 C).

(ii) Cell reaction: $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$; n = 2.

$E = E° - (0.059/2) \log([Mg^{2+}]/[Cu^{2+}])$

$= 2.71 - 0.0295 \times \log(0.1/0.01)$

$= 2.71 - 0.0295 \times \log 10 = 2.71 - 0.0295$

= 2.68 V.

Mistake to avoid: putting $[Cu^{2+}]$ in the numerator – products go on top.

34. Give a reason for each: **5**

(i) Among 3d transition elements, manganese shows the highest oxidation state, +7.

(ii) Transition metals and their compounds are usually good catalysts.

(iii) Cr^{2+} acts as a reducing agent, but Mn^{3+}, which has the same d^4 configuration, acts as an oxidising agent.

(iv) Zinc has the lowest enthalpy of atomisation in the series.

(v) Cu^+ is not stable in aqueous solution.

ANSWER

(i) all $3d^5 4s^2$ electrons can be used; (ii) variable oxidation states/complex formation/surface; (iii) $Cr^{2+} \rightarrow Cr^{3+}$ (t_2g^3), $Mn^{3+} \rightarrow Mn^{2+}$ (d^5); (iv) no unpaired d electrons, weak metallic bonding; (v) disproportionates

(i) Mn is $3d^5 4s^2$; it can use all seven (3d + 4s) electrons in bonding (e.g. MnO_4^-, Mn_2O_7), the largest number available in the series.

(ii) They show variable oxidation states (can form unstable intermediates), provide a large surface for adsorption, and form complexes; e.g. V_2O_5 in contact process, Fe in Haber process.

(iii) Cr^{2+} (d^4) is oxidised to Cr^{3+} (d^3 = half-filled t_2g^3), which is stable → reducing agent. Mn^{3+} (d^4) is reduced to Mn^{2+} (d^5, half-filled), which is extra stable → oxidising agent.

(iv) Zn ($3d^{10} 4s^2$) has no unpaired d electrons, so metallic bonding (interatomic attraction) is weakest → lowest enthalpy of atomisation.

(v) In water Cu^+ disproportionates: $2Cu^+(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$, because the very high hydration enthalpy of Cu^{2+} more than compensates for the second ionisation enthalpy.

35. (i) Carry out these conversions: **5**

(1) Ethanal → but-2-en-1-al

(2) Propanoic acid → 2-chloropropanoic acid

(ii) An alkene A (C_5H_{10}) on ozonolysis gives two compounds B and C. B gives a positive Fehling's test and also reacts with I_2/NaOH. C does not respond to Fehling's solution but gives iodoform. Identify A, B and C.

ANSWER

(i)(1) aldol condensation; (2) HVZ (Cl_2/red P); (ii) A = 2-methylbut-2-ene, B = ethanal, C = propanone

(i)(1) $2CH_3CHO$ —dil. NaOH→ $CH_3–CH(OH)–CH_2–CHO$ (aldol) —heat, $-H_2O$→ $CH_3–CH=CH–CHO$ (but-2-enal).

(2) Hell–Volhard–Zelinsky: CH_3CH_2COOH —(i) Cl_2/red P, (ii) H_2O→ $CH_3CH(Cl)COOH$ (Cl enters at the α-carbon).

(ii) B gives Fehling's (an aldehyde) and iodoform (has $CH_3CO–$ group) → B = CH_3CHO (ethanal, 2 C).

C is a ketone that gives iodoform; it must have 5 − 2 = 3 C → C = CH_3COCH_3 (propanone).

Joining the two carbonyl carbons with a C=C: A = $(CH_3)_2C=CH–CH_3$ (2-methylbut-2-ene).

Check: $(CH_3)_2C=CHCH_3$ —O_3, Zn/H_2O→ $(CH_3)_2C=O + CH_3CHO$.

OR

(i) Give one chemical test to distinguish:

(1) $CH_3COCH_2CH_3$ and $CH_3CH_2CH_2CHO$

(2) Ethanal and ethanoic acid

(ii) Draw the structure of the oxime of acetone.

(iii) Identify A, B, C and D: CH_3COOH —PCl_5→ A —$H_2/Pd–BaSO_4$→ B; B —(i) CH_3MgBr, (ii) H_3O^+→ C; B —$LiAlH_4$→ D.

ANSWER

(i) iodoform test; $NaHCO_3$ test; (ii) $(CH_3)_2C=N–OH$; (iii) A = CH_3COCl, B = CH_3CHO, C = $(CH_3)_2CHOH$, D = CH_3CH_2OH

(i)(1) Iodoform test: warm with I_2/NaOH. Butanone (has $CH_3CO–$) gives a yellow precipitate of CHI_3; butanal does not. (Tollens' test also works: butanal gives a silver mirror.)

(2) Add $NaHCO_3$ solution: ethanoic acid gives brisk effervescence of CO_2; ethanal does not. (Or Tollens'/Fehling's: only ethanal responds.)

(ii) Acetone oxime: $(CH_3)_2C=N–OH$, formed from $(CH_3)_2C=O + NH_2OH$ with loss of H_2O.

(iii) A: $CH_3COOH + PCl_5$ → CH_3COCl (acetyl chloride).

B: Rosenmund reduction, $CH_3COCl + H_2$ ($Pd/BaSO_4$) → CH_3CHO (ethanal).

C: $CH_3CHO + CH_3MgBr$ then H_3O^+ → $CH_3CH(OH)CH_3$ (propan-2-ol).

D: CH_3CHO —$LiAlH_4$→ CH_3CH_2OH (ethanol).

— END —

Questions restated from the CBSE Class XII Board Examination 2023 (set 56/1/1) for practice. Reading passages and map items are described, not reproduced.