Roll No. ☐☐☐☐☐☐☐☐

**Q.P. Code 56/1/1**

# CHEMISTRY (THEORY)

CBSE Class XII Board Examination 2026 — with answers

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

**General Instructions:**

1. The paper has 33 questions in five sections (A to E); all of them must be answered.
2. Section A: Q1–16, multiple choice (Q13–16 Assertion-Reason), 1 mark each.
3. Section B: Q17–21, very short answer, 2 marks each.
4. Section C: Q22–28, short answer, 3 marks each.
5. Section D: Q29–30, case-based, 4 marks each.
6. Section E: Q31–33, long answer, 5 marks each.
7. There is no overall choice, but some questions in Sections B to E offer an internal choice (OR). Calculators are not allowed.

## SECTION A

*Q1–16 are multiple choice questions of 1 mark each (Q13–16 are Assertion-Reason).*

**1.** Four graphs are shown. Which one is characteristic of a first order reaction? **1**

(A) $t_{½}$ plotted against initial concentration $[R]_0$ is a straight line rising from the origin.

(B) $t_{½}$ plotted against $[R]_0$ is a horizontal straight line.

(C) Rate plotted against concentration is a horizontal straight line.

(D) Rate plotted against concentration is a curve that falls steeply and then levels off.

**(A)** $t_{½}$ vs $[R]_0$: straight line rising from origin

**(B) $t_{½}$ vs $[R]_0$: horizontal line**

**(C)** Rate vs concentration: horizontal line

**(D)** Rate vs concentration: falling curve

**ANSWER**

(B) $t_{½}$ independent of $[R]_0$

For a first order reaction $t_{½} = 0.693/k$, which contains no concentration term.
So $t_{½}$ stays the same whatever the starting concentration → a horizontal line on a $t_{½}$ vs $[R]_0$ graph.
(A) ($t_{½} \propto [R]_0$) is zero order; (C) (rate independent of concentration) is also zero order. For first order, rate = k[R] would give a straight rising line, not a horizontal one.

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**2.** Among the following aqueous solutions, which one freezes at the lowest temperature? **1**

**(A)** 0.1 M glucose

**(B) 0.1 M $CaCl_2$**

**(C)** 0.1 M KCl

**(D)** 0.1 M urea

**ANSWER**

(B) 0.1 M $CaCl_2$

Depression in freezing point $\Delta Tf = i \cdot Kf \cdot m$, so the solution with the most particles (largest i) freezes lowest.
Glucose, urea: i = 1; $KCl \rightarrow K^+ + Cl^-$: i = 2; $CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$: i = 3.
$CaCl_2$ gives the largest $\Delta Tf$, hence the lowest freezing point.

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**3.** Identify the element that is NOT regarded as a transition metal. **1**

**(A)** Sc

**(B)** Ag

**(C) Hg**

**(D)** Cu

**ANSWER**

(C) Hg

A transition element has an incompletely filled d subshell in the atom or in one of its common oxidation states.
Hg (like Zn, Cd) is $5d^{10}6s^2$ and $Hg^{2+}$ is $5d^{10}$ – d subshell always full, so it is not a true transition metal.
Sc ($3d^1$), $Cu^{2+}$ ($3d^9$) and $Ag^{2+}$ ($4d^9$) have partly filled d orbitals.

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**4.** Which expression gives the fraction of molecules that have energy equal to or greater than the activation energy Ea? **1**

**(A)** $+\frac{E_a}{RT}$

**(B)** $e^{-E_a/RT}$

**(C)** $-\frac{E_a}{RT}$

**(D)** $e^{+E_a/RT}$

**ANSWER**

(B) $e^{-E_a/RT}$

In the Arrhenius equation k = A·e^(−Ea/RT), the factor e^(−Ea/RT) is the Boltzmann factor: the fraction of molecules having kinetic energy ≥ Ea.
It is always less than 1 and increases with temperature, which is why rate increases with T.
e^(+Ea/RT) would be greater than 1, which is impossible for a fraction.

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**5.** An aqueous solution of $CuCl_2$ is electrolysed using platinum electrodes. What is observed? **1**

**(A)** Copper deposits at the anode

**(B)** $H_2$ gas is evolved at the cathode

**(C)** $O_2$ gas is evolved at the anode

**(D) $Cl_2$ gas is evolved at the anode**

**ANSWER**

(D) $Cl_2$ at anode

Cathode: $Cu^{2+}$ ($E° = +0.34$ V) is reduced more easily than water, so $Cu^{2+} + 2e^- \rightarrow Cu$ deposits on the cathode (not the anode, and no $H_2$).
Anode: in a reasonably concentrated chloride solution, $Cl^-$ is oxidised because of the overpotential of $O_2$: $2Cl^- \rightarrow Cl_2 + 2e^-$.
So chlorine gas is liberated at the anode.

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**6.** Aspirin is prepared by acetylating which compound? **1**

**(A)** Phenol

**(B)** Salicylaldehyde

**(C) 2-Hydroxybenzoic acid**

**(D)** Benzoic acid

**ANSWER**

(C) 2-Hydroxybenzoic acid (salicylic acid)

Aspirin is acetylsalicylic acid (2-acetoxybenzoic acid).
It is made by treating salicylic acid (2-hydroxybenzoic acid) with acetic anhydride (or acetyl chloride) in the presence of an acid: the phenolic –OH becomes $–OCOCH_3$.

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**7.** What is the secondary valency of cobalt in the complex ion $[Co(NH_3)_5(NO_2)]^{2+}$? **1**

**(A)** 5 **(B)** 1

**(C)** 4 **(D) 6**

**ANSWER**

(D) 6

Secondary valency (Werner) = coordination number = number of donor atoms bonded to the metal.
Five $NH_3$ + one $NO_2^-$ (both monodentate) → 6 donor atoms.
So secondary valency = 6. (Primary valency = oxidation state = +3.)

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**8.** When phenol is treated with dilute nitric acid at low temperature (about 298 K), the product is: **1**

**(A)** 2,4,6-trinitrophenol **(B)** o-nitrophenol only

**(C)** p-nitrophenol only **(D) a mixture of o- and p-nitrophenol**

**ANSWER**

(D) o- and p-nitrophenol

–OH strongly activates the ring and is ortho/para directing, so even dilute $HNO_3$ nitrates phenol at room temperature.
A mixture of o-nitrophenol and p-nitrophenol is formed (separated by steam distillation).
Picric acid (2,4,6-trinitrophenol) needs concentrated $HNO_3$.

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**9.** Pick the statement that is NOT correct for a pair of enantiomers. **1**

**(A)** Their chemical reactivity (towards achiral reagents) is the same.

**(B) Their specific rotation is the same.**

**(C)** Their melting/boiling points are the same.

**(D)** Their refractive index is the same.

**ANSWER**

(B) – they do not have the same specific rotation

Enantiomers are non-superimposable mirror images. They have identical physical properties (m.p., b.p., refractive index, solubility) and identical reactivity towards achiral reagents.
They differ only in the direction of rotation of plane polarised light: equal magnitude, opposite sign (+ and −).
So 'same specific rotation' is false.

**10.** Direct nitration of aniline (with nitrating mixture) gives which product distribution? **1**

**(A)** 51% ortho, 47% para, 2% meta

**(B)** 51% meta, 47% ortho, 2% para

**(C) 51% para, 47% meta, 2% ortho**

**(D)** 51% ortho, 47% meta, 2% para

**ANSWER**

(C) 51% para, 47% meta, 2% ortho

In strongly acidic nitrating mixture much of aniline is protonated to the anilinium ion $C_6H_5NH_3^+$, which is meta directing.

The free aniline that remains gives mainly para product.

Result: about 51% p-nitroaniline, 47% m-nitroaniline and 2% o-nitroaniline. Oxidation products also form – that is why $–NH_2$ is protected by acetylation first.

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**11.** Which of these amines has the lowest pKb (i.e. is the strongest base)? **1**

**(A) $C_6H_5–N(CH_3)_2$**

**(B)** $C_6H_5–NH(CH_3)$

**(C)** $C_6H_5–NH_2$

**(D)** $p\text{-}O_2N–C_6H_4–NH_2$ (4-nitroaniline)

**ANSWER**

(A) N,N-dimethylaniline

Lower pKb = stronger base.

In aryl amines, methyl groups on nitrogen push electron density (+I) onto N, increasing basicity: $C_6H_5N(CH_3)_2$ (pKb ≈ 8.92) > $C_6H_5NHCH_3$ (≈ 9.30) > $C_6H_5NH_2$ (≈ 9.38).

$–NO_2$ at para position withdraws electrons (−R, −I), making 4-nitroaniline a very weak base (highest pKb).

So N,N-dimethylaniline has the lowest pKb.

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**12.** Lack of which vitamin leads to increased fragility of red blood cells and weakness of muscles? **1**

**(A)** Vitamin A

**(B)** Vitamin K

**(C) Vitamin E**

**(D)** Vitamin D

**ANSWER**

(C) Vitamin E

Vitamin E (tocopherol) deficiency → increased fragility of RBCs and muscular weakness.

Others: A → night blindness/xerophthalmia; K → delayed blood clotting; D → rickets/osteomalacia.

**13.** Assertion (A): The two components of an azeotropic mixture cannot be separated by fractional distillation. **1**

Reason (R): An azeotrope boils at a constant temperature, and its liquid and vapour have the same composition.

**(A) Both A and R are true, and R correctly explains A.**

**(B)** Both A and R are true, but R does not explain A.

**(C)** A is true, but R is false.

**(D)** A is false, but R is true.

**ANSWER**

(A) Both true, R explains A

Fractional distillation works only because the vapour is richer in the more volatile component.
At the azeotropic composition the vapour has exactly the same composition as the liquid, and it boils at a fixed temperature, so no enrichment is possible.
Thus R is the correct explanation of A.

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**14.** Assertion (A): In phenols the –OH group sends the incoming electrophile to the meta position. **1**

Reason (R): The –OH group of phenol activates the benzene ring for electrophilic substitution.

**(A)** Both A and R are true, and R correctly explains A.

**(B)** Both A and R are true, but R does not explain A.

**(C)** A is true, but R is false.

**(D) A is false, but R is true.**

**ANSWER**

(D) A false, R true

By resonance (+R effect) the –OH group increases electron density at ortho and para positions, so it is ortho/para directing – the assertion (meta) is false.
The same resonance makes the ring more reactive than benzene, so the reason is true.

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**15.** Assertion (A): Actinoids exhibit a wide range of oxidation states. **1**
Reason (R): Actinoids are radioactive.

**(A)** Both A and R are true, and R correctly explains A.

**(B) Both A and R are true, but R does not explain A.**

**(C)** A is true, but R is false.

**(D)** A is false, but R is true.

**ANSWER**
(B) Both true, R not the explanation

A is true: actinoids show many oxidation states (+3 to +7) because the 5f, 6d and 7s levels are of comparable energy, so variable numbers of electrons can be used.
R is true: all actinoids are radioactive.
But radioactivity has nothing to do with the range of oxidation states, so R does not explain A.

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**16.** Assertion (A): Glucose pentaacetate does not react with hydroxylamine ($H_2N–OH$). **1**
Reason (R): This shows that glucose has a free –CHO group.

**(A)** Both A and R are true, and R correctly explains A.

**(B)** Both A and R are true, but R does not explain A.

**(C) A is true, but R is false.**

**(D)** A is false, but R is true.

**ANSWER**
(C) A true, R false

A is true: the pentaacetate gives no oxime.
This behaviour shows that in glucose (and its pentaacetate) the –CHO group is NOT free – it is tied up in the cyclic hemiacetal structure. So R, which says it indicates a free –CHO group, is false.

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## SECTION B

*Q17–21 are very short answer questions of 2 marks each.*

**17.** A mixture of phenol and aniline deviates from Raoult's law. State the type of deviation with reason. How does the boiling point of the mixture compare with that expected? **2**

**ANSWER**

Negative deviation; boiling point increases

Type: negative deviation from Raoult's law.
Reason: the phenolic O–H forms a strong intermolecular hydrogen bond with the lone pair on the nitrogen of aniline (O–H···N). These A–B attractions are stronger than the phenol–phenol and aniline–aniline attractions, so fewer molecules escape → vapour pressure is lower than predicted.
Effect: lower vapour pressure means the boiling point of the solution rises (such mixtures can form maximum-boiling azeotropes).

**18.** Give two reasons why aryl halides (haloarenes) are much less reactive than alkyl halides towards nucleophilic substitution. **2**

**ANSWER**

Partial double-bond character of C–X (resonance) and $sp^2$ carbon (any two reasons)

Any two:
1. Resonance: a lone pair on the halogen is delocalised into the ring, giving the C–X bond partial double-bond character; it is harder to break.
2. The carbon of C–X is $sp^2$ hybridised (more s character, more electronegative), so the bond is shorter and stronger than the $sp^3$ C–X bond of haloalkanes.
3. The phenyl cation that SN1 would need is unstable (not resonance stabilised).
4. The electron-rich π cloud of the ring repels the incoming nucleophile; backside attack (SN2) is also blocked by the ring.

**19.** Give the IUPAC names of: **2**

(i) $[Ag(NH_3)_2][Ag(CN)_2]$

(ii) $K_3[Fe(C_2O_4)_3]$

**ANSWER**

(i) Diamminesilver(I) dicyanidoargentate(I); (ii) Potassium trioxalatoferrate(III)

(i) Both ions are complex: cation $[Ag(NH_3)_2]^+$ (Ag +1) is named first, then anion $[Ag(CN)_2]^-$ (Ag +1, anion suffix -ate, Latin 'argent'):
Diamminesilver(I) dicyanidoargentate(I).
(ii) Oxalate $C_2O_4^{2-} \times 3 = -6$, $3K^+ = +3$, so Fe = +3; anionic complex of iron → ferrate:
Potassium trioxalatoferrate(III).

**OR**

(i) Suggest a chemical test to show that $[Co(NH_3)_5SO_4]Cl$ and $[Co(NH_3)_5Cl]SO_4$ are ionisation isomers.

(ii) What is the chelate effect? Give one example.

**ANSWER**

(i) $AgNO_3$ (or $BaCl_2$) test; (ii) extra stability of complexes with polydentate ligands, e.g. $[Co(en)_3]^{3+}$

(i) Add $AgNO_3$ solution to each: $[Co(NH_3)_5SO_4]Cl$ releases $Cl^-$ ions and gives a white precipitate of AgCl; $[Co(NH_3)_5Cl]SO_4$ does not (its Cl is inside the coordination sphere).
Alternatively $BaCl_2$ gives white $BaSO_4$ only with $[Co(NH_3)_5Cl]SO_4$.
(ii) Chelate effect: a di- or polydentate ligand that binds one metal ion through two or more donor atoms forms a ring (chelate); such complexes are more stable than similar complexes with monodentate ligands.
Example: $[Co(en)_3]^{3+}$ is more stable than $[Co(NH_3)_6]^{3+}$; also metal–EDTA complexes.

**20.** Distinguish between: **2**

(i) a peptide linkage and a glycosidic linkage

(ii) essential and non-essential amino acids

**ANSWER**

(i) –CO–NH– between amino acids vs –O– between monosaccharides; (ii) from diet vs made in body

(i) Peptide linkage: amide bond –CO–NH– formed between the –COOH of one amino acid and the $–NH_2$ of another (with loss of water); found in proteins.
Glycosidic linkage: oxygen bridge (C–O–C) joining two monosaccharide units; found in di- and polysaccharides.
(ii) Essential amino acids cannot be synthesised by the body and must be supplied in the diet (e.g. valine, leucine, lysine).
Non-essential amino acids can be made in the body (e.g. glycine, alanine).

**21.** The reaction $2A + B \rightarrow 2C$ occurs in a single (elementary) step. If the volume of the reaction vessel is reduced to one-third of its original value, how does the rate change? Does the order of the reaction change? **2**

**ANSWER**

Rate becomes 27 times; order unchanged (3)

Elementary step → rate law from stoichiometry: rate = $k[A]^2[B]$ (order 3).
Reducing volume to 1/3 makes every concentration 3 times larger.
New rate = $k(3[A])^2(3[B]) = 27k[A]^2[B]$ → 27 times the original rate.
Order depends on the rate law, not on volume, so the order stays 3.

## SECTION C

*Q22–28 are short answer questions of 3 marks each.*

**22.** The gas-phase decomposition $C_2H_5Cl(g) \rightarrow C_2H_4(g) + HCl(g)$ is first order. The total pressure was 0.30 atm at t = 0 s and 0.50 atm at t = 30 s. Find the rate constant. (log 3 = 0.48) **3**

**ANSWER**

$k \approx 3.7 \times 10^{-2}\ s^{-1}$

Let initial pressure $P_0 = 0.30$ atm and let x atm decompose.

At time t: $C_2H_5Cl = P_0 - x$, $C_2H_4 = x$, $HCl = x \rightarrow Pt = P_0 + x$, so $x = Pt - P_0 = 0.20$ atm.

Pressure of reactant left $= P_0 - x = 2P_0 - Pt = 0.60 - 0.50 = 0.10$ atm.

$k = (2.303/t) \log[P_0/(2P_0 - Pt)] = (2.303/30) \log(0.30/0.10) = (2.303/30) \times 0.48$

$k = 0.0368\ s^{-1} \approx 3.7 \times 10^{-2}\ s^{-1}$.

Common mistake: using Pt directly in place of the reactant pressure.

**23.** Answer: **3**

(i) Why is the equilibrium constant Kc linked to E°cell and not to Ecell?

(ii) Metals A and B have standard electrode potentials −0.24 V and +0.80 V respectively. Which of them can displace hydrogen from dilute $H_2SO_4$?

(iii) Write the reaction taking place in a lead storage battery while it is being charged.

**ANSWER**

(i) Ecell = 0 at equilibrium; (ii) A; (iii) $2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2H_2SO_4$

(i) Nernst: $Ecell = E°cell - (0.059/n) \log Q$. At equilibrium Ecell = 0 and Q = Kc, so $E°cell = (0.059/n) \log Kc$. Since Ecell is always zero at equilibrium, Kc can only be related to the constant E°cell.

(ii) A metal with negative E° (below hydrogen, E° = 0) is a better reducing agent than $H_2$ and reduces $H^+$ to $H_2$. So metal A (−0.24 V) liberates $H_2$; B (+0.80 V) cannot.

(iii) Charging reverses the discharge reaction (electrolysis):

$2PbSO_4(s) + 2H_2O(l) \rightarrow Pb(s) + PbO_2(s) + 2H_2SO_4(aq)$.

**OR**

What kind of battery is the mercury cell? Why is it better than a dry cell? Write the overall cell reaction of the mercury cell.

**ANSWER**

Primary cell; constant voltage (~1.35 V); $Zn(Hg) + HgO \rightarrow ZnO + Hg$

Type: primary cell (cannot be recharged).

Advantage: it gives a constant potential (about 1.35 V) throughout its life, because the overall reaction contains no ions whose concentration changes; a dry cell's voltage falls as it is used.

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

(anode: $Zn(Hg) + 2OH^- \rightarrow ZnO + H_2O + 2e^-$; cathode: $HgO + H_2O + 2e^- \rightarrow Hg + 2OH^-$).

**24.** 0.61 g of benzoic acid (M = 122 g $mol^{-1}$) is dissolved in 5 g of $CS_2$, in which it dimerises to the extent of 88%. Find the boiling point of the solution. (Boiling point of $CS_2$ = 46.2 °C, Kb = 2.3 K kg $mol^{-1}$) **3**

**ANSWER**

Tb ≈ 47.49 °C (ΔTb = 1.288 K)

Association 2 $C_6H_5COOH \rightleftharpoons (C_6H_5COOH)_2$ with α = 0.88.
i = 1 − α + α/2 = 1 − α/2 = 1 − 0.44 = 0.56.
Molality m = (0.61/122) × (1000/5) = 0.005 × 200 = 1.0 mol $kg^{-1}$.
ΔTb = i·Kb·m = 0.56 × 2.3 × 1.0 = 1.288 K.
Tb = 46.2 + 1.288 = 47.488 °C ≈ 47.49 °C.
Common mistake: taking i > 1 – association lowers the number of particles, so i < 1.

**25.** Write the reactions of D-glucose with: **3**

(a) HI (on prolonged heating)

(b) bromine water

(c) concentrated $HNO_3$

**ANSWER**

(a) n-hexane; (b) gluconic acid; (c) saccharic (glucaric) acid

(a) $CHO–(CHOH)_4–CH_2OH$ + HI, heat → $CH_3–CH_2–CH_2–CH_2–CH_2–CH_3$ (n-hexane); shows six carbons in a straight chain.
(b) $CHO–(CHOH)_4–CH_2OH$ + [O] ($Br_2$ water, mild oxidant) → $HOOC–(CHOH)_4–CH_2OH$ (gluconic acid); only –CHO is oxidised, showing an aldehyde group.
(c) $CHO–(CHOH)_4–CH_2OH$ + conc. $HNO_3$ → $HOOC–(CHOH)_4–COOH$ (saccharic acid); both the –CHO and the primary $–CH_2OH$ are oxidised.

**26.** Explain: **3**

(a) Carboxylic acids boil at higher temperatures than alcohols of similar molar mass.

(b) The α-hydrogens of aldehydes and ketones are acidic.

(c) Ammonia and its derivatives do not add to the carbonyl group in a strongly acidic medium.

**ANSWER**

(a) H-bonded dimers; (b) –I of C=O and resonance-stabilised enolate; (c) nucleophile gets protonated

(a) Carboxylic acid molecules are held by stronger and more extensive hydrogen bonding; they exist as cyclic dimers even in the vapour, so more energy is needed to boil them.
(b) The C=O group withdraws electrons, weakening the α C–H bond, and the carbanion (enolate) formed after loss of $H^+$ is stabilised by resonance with the carbonyl group.
(c) In strong acid the nitrogen lone pair of $NH_3/NH_2–Z$ is protonated ($NH_4^+$, $^+NH_3–Z$), so it is no longer a nucleophile and cannot attack the carbonyl carbon. Hence a weakly acidic medium (pH ≈ 3.5) is used.

**27.** Write the chemical reaction for each: **3**

(a) Reimer–Tiemann reaction

(b) Kolbe's reaction

(c) Friedel–Crafts acylation of anisole

**ANSWER**

(a) phenol → salicylaldehyde; (b) phenol → salicylic acid; (c) anisole → 2- and 4-methoxyacetophenone

(a) Phenol + $CHCl_3$ + aq. NaOH (≈ 340 K) → intermediate dichloromethyl compound → on acidification ($H^+$) gives salicylaldehyde (2-hydroxybenzaldehyde), $C_6H_4(OH)CHO$.

(b) Phenol + NaOH → sodium phenoxide; heated with $CO_2$ (4–7 atm, ≈ 400 K) then $H^+$ → salicylic acid (2-hydroxybenzoic acid), $C_6H_4(OH)COOH$.

(c) $C_6H_5OCH_3$ + $CH_3COCl$, anhydrous $AlCl_3$ → 2-methoxyacetophenone (minor) + 4-methoxyacetophenone (major) + HCl. $–OCH_3$ is o/p directing.

**28.** A compound X ($C_4H_9Br$) gives an alcohol with aqueous KOH, and the rate depends only on [X]. An optically active isomer Y of X reacts with aqueous KOH at a rate that depends on both [Y] and [KOH]. **3**

(a) Give the structures of X and Y.

(b) Which of X and Y would undergo racemisation, and why?

(c) Which one gives a product with inversion of configuration, and why?

**ANSWER**

X = $(CH_3)_3CBr$; Y = $CH_3CH(Br)CH_2CH_3$; (b) X (SN1); (c) Y (SN2)

(a) Rate depends only on [X] → SN1 → X must give a stable 3° carbocation: X = $(CH_3)_3C–Br$ (2-bromo-2-methylpropane).

Rate depends on [Y][$OH^-$] → SN2; Y is optically active, so it has a chiral carbon: Y = $CH_3–CH(Br)–CH_2–CH_3$ (2-bromobutane).

(b) X – it reacts by SN1 through a planar carbocation that can be attacked from either face, so an optically active substrate would give a racemic mixture. (X itself is achiral, so its product is not optically active.)

(c) Y – SN2 occurs by backside attack of $OH^-$ in one step (Walden inversion), so the product alcohol has the inverted configuration.

## SECTION D

*Q29–30 are case-based questions of 4 (2 + 1 + 1) marks each, with an internal choice.*

**29.** *Amines are basic and form salts with acids; aliphatic amines are stronger bases than $NH_3$ while aryl amines are weaker. 1° and 2° amines are acylated by acid chlorides; aryl amines are very reactive towards electrophiles (o/p substitution). Hinsberg's reagent distinguishes 1°, 2° and 3° amines, and arenediazonium salts are used to make aryl halides, nitriles, phenols and arenes.* **4**

(a) (i) In water, why is $CH_3NH_2$ a stronger base than $(CH_3)_3N$?

(ii) Give structures of A and B: $CH_3CONH_2$ —(NaOBr)→ A —($C_6H_5COCl$, base)→ B.

(b) A compound X ($C_3H_9N$) gives with Hinsberg's reagent a product that is insoluble in alkali. Identify X.

(c) Why is the $–NH_2$ group of aniline acetylated before nitration?

**ANSWER**

(a)(ii) A = $CH_3NH_2$, B = $CH_3NHCOC_6H_5$; (b) X = $CH_3CH_2NHCH_3$; (c) to control nitration and get p-product

(a)(i) In water basicity depends on +I effect, solvation of the conjugate acid by H-bonding, and steric factors together. $CH_3NH_3^+$ has three N–H for H-bonding with water and is well stabilised; $(CH_3)_3NH^+$ has only one N–H and the three methyl groups also hinder solvation and approach of $H^+$. So $CH_3NH_2$ is the stronger base in water.

(ii) Hoffmann bromamide degradation: $CH_3CONH_2 + NaOBr \rightarrow A = CH_3NH_2$ (one carbon less). Benzoylation: $CH_3NH_2 + C_6H_5COCl$ (base) → B = $CH_3NHCOC_6H_5$ (N-methylbenzamide) + HCl.

(b) A 2° amine gives an N,N-dialkylsulphonamide with no acidic H on N, so it is alkali-insoluble. The only 2° amine of formula $C_3H_9N$ is N-methylethanamine, $CH_3CH_2NHCH_3$.

(c) $–NH_2$ makes the ring too reactive (over-nitration, oxidation) and in acid it becomes meta-directing $–NH_3^+$. Acetylation ($–NHCOCH_3$) moderates the activation, prevents anilinium ion formation, and gives mainly p-nitroaniline after hydrolysis.

**OR**

(b) How would you convert aniline into benzonitrile?

**ANSWER**

Diazotise ($NaNO_2$ + HCl, 0–5 °C), then CuCN

Step 1: $C_6H_5NH_2 + NaNO_2 + 2HCl$ (0–5 °C) → $C_6H_5N_2^+Cl^-$ (benzenediazonium chloride) + $NaCl + 2H_2O$.

Step 2 (Sandmeyer): $C_6H_5N_2^+Cl^- + CuCN/KCN \rightarrow C_6H_5CN + N_2$.

**30.** *Valence bond theory explains the formation, magnetism and shape of complexes. Crystal field theory treats ligands as point charges that remove the degeneracy of the metal d orbitals; different electron arrangements result in strong and weak fields.* **4**

(a) In an octahedral field, which d orbitals are raised in energy as the ligands approach? Give the reason.

(b) Using CFT, write the d-electron configuration of the central ion in (i) $[CoF_6]^{3-}$ (ii) $[Co(NH_3)_6]^{3+}$. (Co = 27)

(c) Both $[NiCl_4]^{2-}$ and $[Ni(CO)_4]$ are tetrahedral, but the first is paramagnetic and the second diamagnetic. Why? (Ni = 28)

**ANSWER**

(a) e_g ($dx^2-y^2$, $dz^2$); (b) $t_2g^4e_g^2$, $t_2g^6e_g^0$; (c) $Cl^-$ weak field vs CO strong field

(a) $dx^2-y^2$ and $dz^2$ (the e_g set). In an octahedral complex the six ligands approach along the x, y, z axes; these two orbitals point directly along the axes, so they suffer greater repulsion and rise in energy (by $0.6\Delta o$), while $t_2g$ (dxy, dyz, dxz) lie between the axes and are lowered.

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

(i) $F^-$ is a weak-field ligand ($\Delta o < P$): $t_2g^4\ e_g^2$ (high spin, 4 unpaired).

(ii) $NH_3$ is a stronger field ligand for $Co^{3+}$ ($\Delta o > P$): $t_2g^6\ e_g^0$ (low spin, diamagnetic).

(c) $[NiCl_4]^{2-}$: $Ni^{2+}$ is $3d^8$; $Cl^-$ is weak field and cannot pair electrons, so two unpaired electrons remain ($sp^3$) → paramagnetic.

$[Ni(CO)_4]$: Ni(0) is $3d^84s^2$; strong-field CO pushes the 4s electrons into 3d giving $3d^{10}$ with all electrons paired ($sp^3$) → diamagnetic.

**OR**

(c) State the hybridisation and magnetic nature of $[Fe(CN)_6]^{3-}$. (Fe = 26)

**ANSWER**

$d^2sp^3$; paramagnetic (1 unpaired electron)

$Fe^{3+} = 3d^5$. $CN^-$ is a strong-field ligand, so electrons pair up in $t_2g$: $t_2g^5$ (one unpaired electron). Two empty 3d orbitals + 4s + three 4p → $d^2sp^3$ (inner orbital, octahedral).

One unpaired electron → paramagnetic ($\mu \approx 1.73$ BM).

## SECTION E

*Q31–33 are long answer questions of 5 marks each.*

**31.** (i) An organic compound X has molecular formula $C_5H_{10}O$. Draw X if it: **5**

(I) gives a negative Tollens' test but a positive iodoform test;

(II) gives neither Tollens' nor iodoform test but undergoes aldol condensation;

(III) undergoes Cannizzaro reaction.

(ii) How can each of these be converted into benzoic acid? (I) Acetophenone (II) Ethylbenzene

**ANSWER**

(I) $CH_3COCH_2CH_2CH_3$; (II) $CH_3CH_2COCH_2CH_3$; (III) $(CH_3)_3CCHO$; acetophenone/ethylbenzene → $KMnO_4$–KOH, heat, then $H_3O^+$

(i) (I) No Tollens' → ketone; positive iodoform → $CH_3CO–$ group: pentan-2-one, $CH_3COCH_2CH_2CH_3$ (3-methylbutan-2-one also fits).
(II) Ketone without $CH_3CO–$ but with α-H: pentan-3-one, $CH_3CH_2COCH_2CH_3$.
(III) Cannizzaro needs an aldehyde with no α-H: 2,2-dimethylpropanal, $(CH_3)_3C–CHO$.
(ii) (I) $C_6H_5COCH_3$ + NaOI ($I_2$/NaOH) → $C_6H_5COONa$ + $CHI_3$; then $H^+$ → $C_6H_5COOH$. (Or $KMnO_4$–KOH, heat, then $H_3O^+$.)
(II) $C_6H_5CH_2CH_3$ + alkaline $KMnO_4$, heat → $C_6H_5COOK$ (whole side chain oxidised to –COOH); then $H_3O^+$ → $C_6H_5COOH$.

**OR**

Answer briefly:

(i) Draw the 2,4-dinitrophenylhydrazone of benzaldehyde.

(ii) Arrange in increasing order of reactivity towards HCN: di-tert-butyl ketone, acetaldehyde, acetone.

(iii) Give a simple chemical test to tell benzoic acid from ethyl benzoate.

(iv) Name the reagent that converts ethanenitrile into ethanal.

(v) Give the structure of X: cyclohexanol —($CrO_3$)→ X.

**ANSWER**

(ii) di-tert-butyl ketone < acetone < acetaldehyde; (iii) $NaHCO_3$; (iv) DIBAL-H then $H_2O$ (or $SnCl_2$/HCl, Stephen); (v) cyclohexanone

(i) $C_6H_5–CH=N–NH–C_6H_3(NO_2)_2$, the $NO_2$ groups at positions 2 and 4 of the second ring (formed from $C_6H_5CHO$ + $H_2N–NH–C_6H_3(NO_2)_2$ with loss of $H_2O$).
(ii) Reactivity in nucleophilic addition falls with more alkyl groups (+I, steric hindrance): $(t\text{-}Bu)_2C=O$ < $CH_3COCH_3$ < $CH_3CHO$.
(iii) Add $NaHCO_3$ solution: benzoic acid gives brisk effervescence of $CO_2$; ethyl benzoate (an ester) does not.
(iv) (a) DIBAL-H, then $H_2O$; or (b) $SnCl_2$ + HCl, then $H_3O^+$ (Stephen reduction): $CH_3CN$ → $CH_3CHO$.
(v) $CrO_3$ oxidises the 2° alcohol to a ketone: X = cyclohexanone ($C_6H_{10}O$, ring with C=O).

**32.** (i) Standard electrode potentials $E°(M^{2+}/M)$ in volts are: V −1.18, Cr −0.91, Mn −1.18, Fe −0.44, Co −0.28, Ni −0.25, Cu +0.34. Using these: **5**

(I) Why do the values show an irregular trend?

(II) Why is $E°(Cu^{2+}/Cu)$ unusually positive?

(III) Why is $E°(Mn^{2+}/Mn)$ highly negative?

(ii) Write ionic equations for the oxidation of $I^-$ by $KMnO_4$ in (a) acidic and (b) neutral/faintly alkaline solution.

**ANSWER**

(I) irregular IE and sublimation enthalpies; (II) high ΔaH, low ΔhydH of Cu; (III) stable $3d^5$ $Mn^{2+}$

(i)(I) $E°(M^{2+}/M)$ depends on sublimation enthalpy + ($IE_1$ + $IE_2$) − hydration enthalpy. Ionisation and sublimation enthalpies vary irregularly across the series, so E° values are irregular.

(II) Cu has a high enthalpy of atomisation and high $IE_2$ which are not compensated by its hydration enthalpy; so converting Cu(s) to $Cu^{2+}$(aq) is unfavourable → positive E°.

(III) $Mn^{2+}$ is $3d^5$ (half-filled, extra stable), so Mn is readily oxidised to $Mn^{2+}$ → highly negative E°.

(ii) Acidic: $2MnO_4^- + 10I^- + 16H^+ \rightarrow 2Mn^{2+} + 5I_2 + 8H_2O$

Neutral/alkaline: $2MnO_4^- + I^- + H_2O \rightarrow 2MnO_2 + IO_3^- + 2OH^-$

**OR**

Answer:

(i) Name a lanthanoid that shows (I) the +4 oxidation state (II) the +2 oxidation state.

(ii) Why are transition metals good catalysts?

(iii) Why does Cr have a higher melting point than Mn?

(iv) What happens when an acidic solution of $KMnO_4$ is kept for some time? Write the equation and name the type of reaction.

**ANSWER**

(i) Ce (+4), Eu or Yb (+2); (iv) $4MnO_4^- + 4H^+ \rightarrow 4MnO_2 + 3O_2 + 2H_2O$ (slow redox decomposition)

(i) (I) Cerium, $Ce^{4+}$ ($4f^0$). (II) Europium, $Eu^{2+}$ ($4f^7$) or ytterbium, $Yb^{2+}$ ($4f^{14}$).

(ii) They show variable oxidation states (form unstable intermediates easily), can form complexes, and provide a large surface for adsorption of reactants.

(iii) Cr ($3d^5 4s^1$) can use more unpaired (n−1)d and ns electrons in metallic bonding than Mn, whose stable half-filled $3d^5 4s^2$ configuration holds its electrons more tightly; stronger metallic bonding → higher m.p.

(iv) Acidified permanganate slowly decomposes, depositing brown $MnO_2$ and releasing oxygen:

$4MnO_4^- + 4H^+ \rightarrow 4MnO_2 + 3O_2 + 2H_2O$

Mn(+7) is reduced and O(−2) is oxidised to $O_2$ – it is a redox (decomposition) reaction, catalysed by the $MnO_2$ formed (autocatalysis).

**33.** Find the emf and $\Delta G$ of this cell at 298 K: **5**

$Mg(s) \mid Mg^{2+}(0.01\ M) \parallel Ag^{+}(0.001\ M) \mid Ag(s)$

Given $E^\circ(Mg^{2+}/Mg) = -2.37$ V, $E^\circ(Ag^{+}/Ag) = +0.80$ V, 1 F = 96500 C $mol^{-1}$, log 10 = 1.

**ANSWER**

$E_{cell} = 3.052$ V; $\Delta G \approx -589$ kJ $mol^{-1}$

Cell reaction: $Mg + 2Ag^{+} \rightarrow Mg^{2+} + 2Ag$, n = 2.

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode} = 0.80 - (-2.37) = 3.17$ V.

Nernst: $E_{cell} = E^\circ_{cell} - (0.059/2) \log([Mg^{2+}]/[Ag^{+}]^2)$

$= 3.17 - 0.0295 \log(0.01/(0.001)^2) = 3.17 - 0.0295 \log 10^4 = 3.17 - 0.0295 \times 4$

$= 3.17 - 0.118 = 3.052$ V.

$\Delta G = -nFE_{cell} = -2 \times 96500 \times 3.052 = -589\,036$ J $mol^{-1} \approx -589$ kJ $mol^{-1}$.

Common mistake: forgetting to square $[Ag^{+}]$.

**OR**

For the cell reaction $2AgCl(s) + H_2(g, 0.4\ atm) \rightarrow 2Ag(s) + 2H^{+}(0.1\ M) + 2Cl^{-}(0.2\ M)$, $\Delta G^\circ = -43500$ J $mol^{-1}$. Find the emf of the cell at 25 °C. (log 10 = 1, 1 F = 96500 C $mol^{-1}$)

**ANSWER**

$E_{cell} \approx 0.314$ V

n = 2.

$E^\circ_{cell} = -\Delta G^\circ/(nF) = 43500/(2 \times 96500) = 0.225$ V.

$Q = [H^{+}]^2[Cl^{-}]^2/p(H_2) = (0.1)^2(0.2)^2/0.4 = (0.01 \times 0.04)/0.4 = 10^{-3}$ (solids omitted).

$E_{cell} = E^\circ_{cell} - (0.059/2) \log Q = 0.225 - 0.0295 \times (-3) = 0.225 + 0.0885$

$E_{cell} = 0.3135$ V $\approx 0.314$ V.

**— END —**

Questions restated from the CBSE Class XII Board Examination 2026 (set 56/1/1) for practice. Reading passages and map items are described, not reproduced.