Roll No. ☐☐☐☐☐☐☐☐

Q.P. Code 56/2/1

CHEMISTRY (THEORY)

CBSE Class XII Board Examination 2022 (Term 2) — with answers

Time allowed: 2 hours **Maximum Marks: 35**

General Instructions:

1. The paper has 12 questions in three sections (A, B and C); all of them must be answered.
2. Section A: Q1–3, very short answer, 2 marks each.
3. Section B: Q4–11, short answer, 3 marks each.
4. Section C: Q12, a case-based question worth 5 marks.
5. Some questions offer an internal choice (OR). Log tables and calculators are not allowed.

SECTION A

Q1–3 are very short answer questions of 2 marks each.

1. Show how each of the following changes can be brought about (attempt any two): **2**

(i) Propanal → Propane

(ii) Ethanal → But-2-enal

(iii) Ethanoic acid → Ethanamide

ANSWER

(i) Clemmensen reduction (Zn-Hg/conc. HCl); (ii) aldol condensation with dil. NaOH, then heat ($-H_2O$); (iii) NH_3 to form ammonium salt, then heat ($-H_2O$).

(i) Propanal to propane: reduce the C=O group to CH_2 by Clemmensen reduction.

$CH_3CH_2CHO + 4[H] \xrightarrow{Zn\text{-}Hg\ /\ conc.\ HCl} CH_3CH_2CH_3 + H_2O$

(Wolff–Kishner reduction with NH_2NH_2 then KOH/ethylene glycol, heat, is also accepted.)

(ii) Ethanal to but-2-enal: ethanal has α-hydrogens, so it undergoes aldol condensation.

$2\ CH_3CHO \xrightarrow{dil.\ NaOH} CH_3CH(OH)CH_2CHO$ (3-hydroxybutanal, the aldol)

$CH_3CH(OH)CH_2CHO \xrightarrow{heat,\ -H_2O} CH_3CH{=}CHCHO$ (but-2-enal)

(iii) Ethanoic acid to ethanamide:

$CH_3COOH + NH_3 \rightarrow CH_3COO^-NH_4^+$ (ammonium ethanoate)

$CH_3COO^-NH_4^+ \xrightarrow{heat} CH_3CONH_2 + H_2O$

(Alternative: $CH_3COOH \xrightarrow{SOCl_2} CH_3COCl \xrightarrow{NH_3} CH_3CONH_2$.)

Common mistake: in (ii) stopping at the aldol – the question asks for the unsaturated aldehyde, so dehydration on heating must be shown.

2. For the reaction $N_2\,(g) + 3\,H_2\,(g) \longrightarrow 2\,NH_3\,(g)$, ammonia is being formed at a rate of 3.6×10^{-4} mol L^{-1} s^{-1}. Find: **2**

(i) the rate of the reaction

(ii) the rate at which $H_2(g)$ is used up.

ANSWER

(i) Rate = 1.8×10^{-4} mol L^{-1} s^{-1}; (ii) $-\Delta[H_2]/\Delta t = 5.4 \times 10^{-4}$ mol L^{-1} s^{-1}

Rate of reaction = $-\Delta[N_2]/\Delta t = -(1/3)\ \Delta[H_2]/\Delta t = +(1/2)\ \Delta[NH_3]/\Delta t$

(i) Rate = $(1/2) \times 3.6 \times 10^{-4} = 1.8 \times 10^{-4}$ mol L^{-1} s^{-1}

(ii) $-\Delta[H_2]/\Delta t = 3 \times$ rate $= 3 \times 1.8 \times 10^{-4} = 5.4 \times 10^{-4}$ mol L^{-1} s^{-1}

Common mistake: forgetting to divide by the stoichiometric coefficient (2 for NH_3) when writing the rate of reaction.

3. (i) State Kohlrausch's law of independent migration of ions. **2**

(ii) For CH_3COOH, the molar conductivity $\Lambda m = 48$ S cm² mol⁻¹ and the limiting molar conductivity $\Lambda^\circ m = 400$ S cm² mol⁻¹. Find its degree of dissociation (α).

ANSWER

(i) $\Lambda^\circ m$ of an electrolyte = sum of the limiting molar conductivities of its cation and anion; (ii) $\alpha = 0.12$

(i) Kohlrausch's law: at infinite dilution, every ion migrates independently, so the limiting molar conductivity of an electrolyte equals the sum of the individual contributions of its cation and anion: $\Lambda^\circ m = \nu_+\lambda^\circ_+ + \nu_-\lambda^\circ_-$.

(ii) Degree of dissociation $\alpha = \Lambda m / \Lambda^\circ m$

$\alpha = 48 / 400 = 0.12$ (i.e. 12% dissociated)

SECTION B

Q4–11 are short answer questions of 3 marks each.

4. Give the hybridisation and the magnetic nature of each complex: **3**

(i) $[NiCl_4]^{2-}$

(ii) $[Co(NH_3)_6]^{3+}$

(iii) $[FeF_6]^{3-}$

(Atomic numbers: Ni = 28, Co = 27, Fe = 26)

ANSWER

(i) sp^3, paramagnetic; (ii) d^2sp^3, diamagnetic; (iii) sp^3d^2, paramagnetic

(i) $[NiCl_4]^{2-}$: $Ni^{2+} = 3d^8$. Cl^- is a weak-field ligand, so the 3d electrons are not paired; two unpaired electrons remain. The four Cl^- use 4s + three 4p orbitals → sp^3 (tetrahedral), paramagnetic.
(ii) $[Co(NH_3)_6]^{3+}$: $Co^{3+} = 3d^6$. NH_3 is strong-field here, so all six d electrons pair up in three 3d orbitals, leaving two 3d orbitals empty → d^2sp^3 (inner-orbital, octahedral); no unpaired electrons → diamagnetic.
(iii) $[FeF_6]^{3-}$: $Fe^{3+} = 3d^5$. F^- is weak-field, the five electrons stay unpaired; 4s, 4p and two 4d orbitals are used → sp^3d^2 (outer-orbital, octahedral), paramagnetic (5 unpaired electrons).

OR

(i) Give the IUPAC name of $[Co(NH_3)_4(H_2O)Cl]Cl_2$.

(ii) How does an ambidentate ligand differ from a bidentate ligand?

(iii) Which is more stable, $[Fe(NH_3)_6]^{3+}$ or $[Fe(C_2O_4)_3]^{3-}$? Give the reason.

ANSWER

(i) Tetraammineaquachloridocobalt(III) chloride; (ii) ambidentate: two different donor atoms but binds through only one at a time; bidentate: binds through two donor atoms simultaneously; (iii) $[Fe(C_2O_4)_3]^{3-}$ – chelate effect

(i) Ligands in alphabetical order: ammine (×4 → tetraammine), aqua, chlorido. Charge on Co: x + 0 + 0 − 1 = +2 → x = +3.
Name: tetraammineaquachloridocobalt(III) chloride.
(ii) Ambidentate ligand: has two different donor atoms but attaches to the metal through only one of them at a time, e.g. NO_2^- (through N or O), SCN^- (through S or N).
Bidentate ligand: attaches to the metal through two donor atoms at the same time, e.g. ethane-1,2-diamine, $C_2O_4^{2-}$.
(iii) $[Fe(C_2O_4)_3]^{3-}$ is more stable. Oxalate is a bidentate (chelating) ligand that forms five-membered rings with Fe^{3+}; chelate complexes are much more stable than complexes of comparable monodentate ligands (chelate effect). NH_3 is monodentate.

5. Find the emf of the cell **3**

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

Given: $E°(Zn^{2+}/Zn) = -0.76$ V, $E°(Ag^{+}/Ag) = +0.80$ V. (log 2 = 0.3010, log 3 = 0.4771, log 10 = 1)

ANSWER

E(cell) = 1.442 V

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

$E°cell = E°cathode - E°anode = 0.80 - (-0.76) = 1.56$ V

Nernst equation: $Ecell = E°cell - (0.059/n) \log ([Zn^{2+}]/[Ag^{+}]^2)$

$[Zn^{2+}]/[Ag^{+}]^2 = 0.01 / (0.001)^2 = 10^{-2} / 10^{-6} = 10^4$

$Ecell = 1.56 - (0.059/2) \times \log 10^4 = 1.56 - 0.0295 \times 4 = 1.56 - 0.118$

Ecell = 1.442 V

Common mistake: not squaring $[Ag^{+}]$ (coefficient 2 in the balanced equation) or using n = 1.

6. Give the main product of each reaction: **3**

(i) Benzaldehyde treated with $HNO_3 + H_2SO_4$ at 273–283 K

(ii) Sodium cyclohexanecarboxylate ($C_6H_{11}COONa$) heated with NaOH and CaO (soda lime)

(iii) Ethanal (CH_3CHO) treated with hydroxylamine (NH_2OH)

ANSWER

(i) m-Nitrobenzaldehyde; (ii) Cyclohexane; (iii) Ethanal oxime, $CH_3CH{=}N{-}OH$

(i) –CHO is an electron-withdrawing, meta-directing group, so nitration gives m-nitrobenzaldehyde (3-nitrobenzaldehyde).

(ii) Heating a sodium carboxylate with soda lime removes CO_2 (decarboxylation): $C_6H_{11}COONa + NaOH \xrightarrow{CaO,\ \Delta} C_6H_{12}$ (cyclohexane) + Na_2CO_3.

(iii) Aldehydes react with NH_2OH (addition–elimination, loss of H_2O): $CH_3CHO + NH_2OH \rightarrow CH_3CH{=}N{-}OH + H_2O$; product is ethanal oxime (acetaldoxime).

OR

(i) Explain why propanal is oxidised more easily than propanone.

(ii) Suggest a test to tell acetophenone and benzophenone apart.

(iii) Draw the structure of the 2,4-dinitrophenylhydrazone of propanone.

ANSWER

(i) Oxidising an aldehyde breaks a weak C–H bond, a ketone needs C–C bond cleavage; (ii) iodoform test – acetophenone gives yellow CHI_3, benzophenone does not; (iii) $(CH_3)_2C{=}N{-}NH{-}C_6H_3(NO_2)_2$ (NO_2 at 2 and 4 positions)

(i) Propanal has an H atom on the carbonyl carbon; on oxidation only this C–H bond breaks to give propanoic acid. Propanone has no such H; oxidation requires breaking a stronger C–C bond, so it needs vigorous conditions.

(ii) Iodoform test: warm each with NaOH + I_2. Acetophenone ($C_6H_5COCH_3$, has a $CH_3CO–$ group) gives a yellow precipitate of iodoform (CHI_3). Benzophenone ($C_6H_5COC_6H_5$) gives no precipitate.

(iii) Propanone + 2,4-dinitrophenylhydrazine → $(CH_3)_2C{=}N{-}NH{-}C_6H_3(NO_2)_2 + H_2O$, i.e. the C=O oxygen is replaced by =N–NH– attached to a benzene ring carrying NO_2 groups at positions 2 (ortho) and 4 (para) to the NH.

7. A first-order reaction is 75% complete in 30 minutes. Find its half-life $t_{1/2}$. **3**

(log 2 = 0.3, log 3 = 0.48, log 4 = 0.6, log 5 = 0.7)

ANSWER

$t_{1/2}$ = 15 min

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

75% complete → [R] = 25% of $[R]_0$, so $[R]_0/[R] = 100/25 = 4$

$k = (2.303/30) \times \log 4 = (2.303/30) \times 0.6 = 0.046\ min^{-1}$

$t_{1/2} = 0.693/k = 0.693/0.046 \approx 15$ min

Shortcut check: 75% completion = two half-lives (100 → 50 → 25), so $t_{1/2} = 30/2 = 15$ min.

Common mistake: taking [R] = 75 instead of the amount left (25).

8. Give three points of difference between a lyophobic sol and a lyophilic sol. **3**

ANSWER

Lyophobic: solvent-repelling, irreversible, unstable, easily coagulated; lyophilic: solvent-loving, reversible, stable, hard to coagulate.

Any three of these differences earn the marks (1 mark each):
1. Affinity: in a lyophobic sol the dispersed particles have little attraction for the medium (solvent-hating); in a lyophilic sol they attract the medium strongly (solvent-loving).
2. Reversibility: a lyophobic sol, once precipitated, cannot be re-formed simply by adding the medium (irreversible); a lyophilic sol re-forms on adding the medium (reversible).
3. Stability: lyophobic sols are unstable and need stabilising ions; lyophilic sols are stable because the particles are solvated.
4. Coagulation: lyophobic sols coagulate easily with a small amount of electrolyte; lyophilic sols are difficult to coagulate.

OR

(i) Name the dispersed phase and the dispersion medium in milk.
(ii) What causes the Brownian movement of colloidal particles?
(iii) Why does physisorption decrease as the temperature rises?

ANSWER

(i) Both are liquids (liquid fat dispersed in water); (ii) uneven bombardment of the particles by molecules of the dispersion medium; (iii) physisorption is exothermic and depends on weak van der Waals forces that are overcome at higher temperature.

(i) Milk is an emulsion: liquid fat droplets (dispersed phase = liquid) spread through water (dispersion medium = liquid).
(ii) Molecules of the dispersion medium keep striking a colloidal particle from all sides; the hits are not balanced at every instant, so the particle is pushed along a random zig-zag path – this is Brownian movement.
(iii) Physical adsorption is an exothermic process. By Le Chatelier's principle, raising the temperature shifts the equilibrium towards desorption; also the weak van der Waals attraction between adsorbate and adsorbent is easily broken by the extra thermal energy.

9. Standard electrode potentials $E°(M^{2+}/M)$ of some first-row transition metals are: Cr −0.91 V, Mn −1.18 V, Fe −0.44 V, Co −0.28 V, Ni −0.25 V, Cu +0.34 V, Zn −0.76 V. Using these values, answer: **3**

(i) Why is $E°(Mn^{2+}/Mn)$ much more negative than for the other metals?

(ii) What causes the irregular trend in these values?

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

ANSWER

(i) Mn^{2+} has a stable half-filled $3d^5$ configuration; (ii) irregular variation of ionisation enthalpies ($IE_1 + IE_2$) and sublimation enthalpies; (iii) high enthalpy of atomisation of Cu and low hydration enthalpy of Cu^{2+}

(i) Mn^{2+} is $3d^5$ – a stable half-filled configuration – so Mn readily forms Mn^{2+}; in addition Mn has a low enthalpy of atomisation. Hence E° is highly negative.

(ii) $E°(M^{2+}/M)$ depends on enthalpy of atomisation + ($IE_1 + IE_2$) − hydration enthalpy. The sum of the first and second ionisation enthalpies and the sublimation enthalpies do not change regularly along the series (e.g. Mn and V have relatively low sublimation enthalpies), so E° values are irregular.

(iii) Converting Cu(s) to Cu^{2+}(aq) needs a high enthalpy of atomisation plus a high IE_2; the hydration enthalpy of Cu^{2+} is not large enough to compensate. So Cu has a positive E° and does not liberate H_2 from acids.

10. Write one chemical equation for each named reaction: **3**

(i) Rosenmund reduction

(ii) Etard reaction

(iii) Stephen reaction

ANSWER

(i) $RCOCl + H_2 \xrightarrow{Pd/BaSO_4} RCHO + HCl$; (ii) $C_6H_5CH_3 \xrightarrow{CrO_2Cl_2,\ CS_2;\ then\ H_3O^+} C_6H_5CHO$; (iii) $RCN \xrightarrow{SnCl_2/HCl} RCH{=}NH \xrightarrow{H_3O^+} RCHO$

(i) Rosenmund reduction: an acyl chloride is hydrogenated over palladium poisoned with $BaSO_4$ to give an aldehyde.

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

(ii) Etard reaction: toluene is oxidised by chromyl chloride (in CS_2) to a chromium complex, which on hydrolysis gives benzaldehyde.

$C_6H_5CH_3 + CrO_2Cl_2\ (CS_2) \rightarrow C_6H_5CH(OCrOHCl_2)_2 \xrightarrow{H_3O^+} C_6H_5CHO$

(iii) Stephen reaction: a nitrile is reduced by $SnCl_2 + HCl$ to an imine (as its salt), which is hydrolysed to an aldehyde.

$CH_3CN + SnCl_2 + HCl \rightarrow CH_3CH{=}NH \xrightarrow{H_3O^+} CH_3CHO$

Tip: full marks need the equation with reagents/conditions, not just a description.

OR

(i) In each pair, pick the stronger acid and explain:

(I) CH_3COOH or FCH_2COOH

(II) Phenol (C_6H_5OH) or CH_3COOH

(ii) Give a test to distinguish pentan-2-one from pentan-3-one.

ANSWER

(i) (I) FCH_2COOH (–I effect of F); (II) CH_3COOH (acetate ion more resonance-stabilised than phenoxide); (ii) iodoform test – pentan-2-one gives yellow CHI_3, pentan-3-one does not

(i)(I) FCH_2COOH is stronger. Fluorine pulls electron density (–I effect), dispersing the negative charge of the carboxylate ion FCH_2COO^- and stabilising it.

(II) CH_3COOH is stronger. In the acetate ion the negative charge is shared equally by two electronegative O atoms (equivalent resonance structures); in phenoxide the charge is spread onto less electronegative ring carbons, so it is less stabilised.

(ii) Warm each with NaOH + I_2 (iodoform test). Pentan-2-one ($CH_3COCH_2CH_2CH_3$, has a $CH_3CO–$ group) gives a yellow precipitate of iodoform; pentan-3-one ($CH_3CH_2COCH_2CH_3$) does not.

11. Give reasons: **3**

(i) Transition metals and their compounds act as good catalysts.

(ii) Zn, Cd and Hg are not regarded as transition elements.

(iii) Zr and Hf have nearly the same atomic radii.

ANSWER

(i) Variable oxidation states, ability to form complexes and large surface area; (ii) completely filled d^{10} orbitals in atom and in common ions; (iii) lanthanoid contraction

(i) Transition metals can show several oxidation states and form unstable intermediate compounds/complexes with reactants; they also provide a large surface area for adsorption, using (n−1)d and ns electrons for bonding. This lowers the activation energy (e.g. Fe in Haber process, V_2O_5 in contact process).

(ii) Zn, Cd, Hg have a completely filled $(n-1)d^{10}$ configuration both in the ground state and in their common +2 ions, so they do not have partly filled d orbitals – they do not fit the definition of a transition element.

(iii) Hf (5d series) comes after the 14 lanthanoids. The 4f electrons shield the outer electrons poorly, so the size shrinks steadily (lanthanoid contraction); this cancels the expected increase in size from Zr to Hf, making their radii almost identical (≈160 and 159 pm).

SECTION C

Q12 is a case-based question of 5 marks.

12. Read the passage (summarised here) and answer the questions. **5**

Amines are obtained when one or more H atoms of NH_3 are replaced by alkyl or aryl groups. They are prepared from nitro compounds, halides, amides etc., show hydrogen bonding, and their reactions depend on the lone pair on nitrogen; the number of H atoms on N lets us tell 1°, 2° and 3° amines apart. The reactivity of aromatic amines can be controlled by acylation.

(i) Why does aniline not undergo the Friedel–Crafts reaction? (1)

(ii) Arrange in increasing order of pKb: $C_6H_5NH_2$, NH_3, $C_2H_5NH_2$, $(CH_3)_3N$. (1)

(iii) How would the Hinsberg test distinguish $CH_3CH_2NH_2$ from $(CH_3CH_2)_2NH$? (1)

(iv)(a) Identify A and B: (2)

(I) Nitrobenzene —Sn + HCl→ A —Br_2 water→ B

(II) $CH_3CH_2CONH_2$ —Br_2 / alc. KOH→ A —CH_3COCl, pyridine→ B

ANSWER

(i) Aniline (Lewis base) forms a salt with $AlCl_3$, the $–NH_2$ becomes positively charged and deactivates the ring; (ii) $C_2H_5NH_2 < (CH_3)_3N < NH_3 < C_6H_5NH_2$ (aqueous); (iii) 1° amine's sulphonamide dissolves in alkali, 2° amine's does not; (iv)(I) A = aniline, B = 2,4,6-tribromoaniline; (II) A = $CH_3CH_2NH_2$, B = $CH_3CH_2NHCOCH_3$

(i) The catalyst $AlCl_3$ is a Lewis acid; aniline, a Lewis base, gives a salt with it. Nitrogen then carries a positive charge, which strongly deactivates the ring, so no Friedel–Crafts reaction occurs.
(ii) Lower pKb = stronger base. In water: $C_2H_5NH_2$ (pKb ≈ 3.29) > $(CH_3)_3N$ (≈ 4.22) > NH_3 (4.75) > $C_6H_5NH_2$ (9.38) in basic strength. Increasing pKb: $C_2H_5NH_2 < (CH_3)_3N < NH_3 < C_6H_5NH_2$. (Gas-phase order $(CH_3)_3N < C_2H_5NH_2 < NH_3 < C_6H_5NH_2$ was also accepted since no medium was given.)
(iii) Treat both with benzenesulphonyl chloride (Hinsberg reagent). Ethylamine (1°) forms N-ethylbenzenesulphonamide, which still has an acidic H on N and dissolves in alkali. Diethylamine (2°) forms N,N-diethylbenzenesulphonamide with no H on N – it is insoluble in alkali.
(iv)(I) Sn/HCl reduces $–NO_2$ to $–NH_2$: A = aniline ($C_6H_5NH_2$). Bromine water brominates all o- and p-positions of the strongly activated ring: B = 2,4,6-tribromoaniline (white ppt).
(II) Hoffmann bromamide degradation removes one carbon: $CH_3CH_2CONH_2$ → A = ethanamine $CH_3CH_2NH_2$. Acetylation with CH_3COCl/pyridine gives B = N-ethylethanamide, $CH_3CH_2NHCOCH_3$.

OR

(iv) How will you convert:

(b) (I) Benzoic acid → aniline

(II) Aniline → p-bromoaniline

ANSWER

(I) C_6H_5COOH —NH_3, Δ→ $C_6H_5CONH_2$ —Br_2/NaOH→ $C_6H_5NH_2$; (II) acetylate (CH_3COCl/pyridine), brominate (Br_2/$FeBr_3$ or Br_2/CH_3COOH) to para product, then hydrolyse

(I) $C_6H_5COOH + NH_3 \rightarrow C_6H_5COO^-NH_4^+$ —heat→ $C_6H_5CONH_2$ (benzamide)
$C_6H_5CONH_2 + Br_2 + 4NaOH \rightarrow C_6H_5NH_2 + Na_2CO_3 + 2NaBr + 2H_2O$ (Hoffmann bromamide degradation)
(II) Direct bromination of aniline gives 2,4,6-tribromoaniline, so first reduce the activating effect by acetylation:
$C_6H_5NH_2$ —CH_3COCl, pyridine→ $C_6H_5NHCOCH_3$ (acetanilide)

$C_6H_5NHCOCH_3$ —Br_2 / $FeBr_3$→ p-$BrC_6H_4NHCOCH_3$ (bulky group favours para)
p-$BrC_6H_4NHCOCH_3$ —H_2O (H^+ or OH^-), heat→ p-$BrC_6H_4NH_2$ (p-bromoaniline)
Common mistake: brominating aniline directly with bromine water – that gives the tribromo product.

— END —

Questions restated from the CBSE Class XII Board Examination 2022 (set 56/2/1) for practice. Reading passages and map items are described, not reproduced.