CBSE Class 10 2025 Chemistry Compartment Question Paper

Time Allowed :3 hours	**Maximum Marks :**80	**Total questions :**38

General Instructions

Read the following instructions very carefully and strictly follow them:

1. This question paper contains 38 questions. All questions are compulsory.
2. This question paper is divided into five Sections – A, B, C, D and E.
3. In Section A, Questions no. 1 to 18 are multiple choice questions (MCQs) andquestions number 19 and 20 are Assertion-Reason based questions of 1 markeach.
4. In Section B, Questions no. 21 to 25 are very short answer (VSA) type questions, carrying 2 marks each.
5. In Section C, Questions no. 26 to 31 are short answer (SA) type questions,carrying 3 marks each.
6. In Section D, Questions no. 32 to 35 are long answer (LA) type questions carrying 5 marks each.
7. In Section E, Questions no. 36 to 38 are case study based questions carrying 4 marks each.
8. There is no overall choice. However, an internal choice has been provided in 2 questions in Section B, 3 questions in Section C, 2 questions in Section D and 2 questions in Section E.
9. Use of calculators is not allowed.

SECTION-A

1. The standard electrode potential for Sn^{4+}/Sn^{2+} couple is $+0.15$ V and for Cu^{2+}/Cu couple is $+0.73$ V. These two couples are connected to make an electrochemical cell. The redox reaction is spontaneous. The cell potential will be:

(A) $+0.58$ V

(B) 0.85 V

(C) -0.58 V

(D) -0.85 V

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2. The most stable complex among the following is:

(A) $[Ni(NH_3)_6]Cl_2$

(B) $[Ag(NH_3)_2]Cl$

(C) $[Fe(en)_2Cl_2]^+$

(D) $K_4[Fe(CN)_6]$

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3. The geometry of diamagnetic nickel complex $[Ni(CN)_4]^{2-}$ is:

(A) Tetrahedral

(B) Octahedral

(C) Square planar

(D) Distorted octahedral

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4. Out of Fe^{2+}, Co^{2+}, Cr^{3+}, Ni^{2+}, the one which shows highest magnetic moment is:

(A) Fe^{2+}

(B) Co^{2+}

(C) Cr^{3+}

(D) Ni^{2+}

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5. If amines are arranged in increasing order of their basic strength in gaseous phase, the correct order will be:

(A) $NH_3 < CH_3NH_2 < (CH_3)_2NH < (CH_3)_3N$

(B) $NH_3 < (CH_3)_2NH < (CH_3)_3N < CH_3NH_2$

(C) $(CH_3)_3N < (CH_3)_2NH < CH_3NH_2 < NH_3$

(D) $NH_3 < CH_3NH_2 < (CH_3)_2NH < (CH_3)_3N$

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6. Which of the following does **not** undergo aldol condensation?

(A) CH_3CHO

(B) CH_3COCH_3

(C) C_6H_5CHO

(D) C_2H_5CHO

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7. The correct IUPAC name of $(CH_3)_3C–CH_2Br$ is:

(A) 2,2-Dimethyl-2-bromopropane

(B) 1-Bromo-2,2,2-trimethylethane

(C) 2-Bromo-1,1,1-trimethylethane

(D) 1-Bromo-2,2-dimethylpropane

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8. Considering the strength of the ligand, the highest excitation energy will be observed in:

(A) $[Co(H_2O)_6]^{3+}$

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

(C) $[Co(CN)_6]^{3-}$

(D) $[CoCl_6]^{3-}$

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9. For a chemical reaction A → B, it was observed that the rate of reaction doubles when the concentration of A is increased four times. The order of the reaction is:

(A) 2

(B) 1

(C) $\frac{1}{2}$

(D) Zero

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10. The IUPAC name of the complex $[Co(NH_3)_5(NO_2)]Cl_2$ is:

(A) Pentaamminenitrito-O-cobalt(III) chloride

(B) Pentaamminenitrito-N-cobalt(III) chloride

(C) Pentaamminenitro-cobalt(III) chloride

(D) Pentaamminenitroso-cobalt(II) chloride

11. Williamson's synthesis of preparing dimethyl ether is a/an:

(A) Electrophilic substitution

(B) S_N1 reaction

(C) Electrophilic addition

(D) S_N2 reaction

12. The chemical test which can be used to distinguish between ethanamine and aniline is:

(A) Haloform test

(B) Tollen's test

(C) Azo dye test

(D) Hinsberg test

13. Assertion (A): Maltose is a reducing sugar.

Reason (R): Maltose is composed of two glucose units in which C-1 of one glucose unit is linked to C-4 of another glucose unit.

(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

14. Assertion (A): Acetamide (structure: $C_6H_5NHCOCH_3$) is less basic than aniline.

Reason (R): Acetylation of aniline results in decrease of electron density on nitrogen.

(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

15. Assertion (A): Rate constant increases with increase in temperature.

Reason (R): Increasing the temperature of the substance increases the fraction of molecules which collide with energies greater than activation 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

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16. Assertion (A): Cu^{2+} iodide is not known.

Reason (R): Cu^{2+} has strong tendency to oxidise I^- to iodine.

(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

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17. Write the reactions involved in the following:

(a) Reimer–Tiemann reaction

(b) Kolbe's reaction

Solution:

(a) Reimer–Tiemann reaction:

This is used to convert phenol to salicylaldehyde using chloroform and NaOH.

$$C_6H_5OH + CHCl_3 + 3NaOH \xrightarrow{\Delta} OH\text{–}C_6H_4\text{–}CHO + 3NaCl + 2H_2O$$

(b) Kolbe's reaction:

Sodium phenoxide reacts with CO_2 under pressure to form salicylic acid.

$$C_6H_5ONa + CO_2 \xrightarrow{473\,K,\,6\,atm} OH\text{–}C_6H_4\text{–}COONa \xrightarrow{H^+} OH\text{–}C_6H_4\text{–}COOH$$

Quick Tip

Reimer–Tiemann adds –CHO at ortho; Kolbe adds –COOH to ortho position of phenol under heat and pressure.

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18. Draw the structures of major monohalogenation products in the following reactions:

(a)

$$NO_2–C_6H_4–CH_2CH_3 \xrightarrow{\text{Br}_2,\text{ heat or UV}}$$

(b)

$$C_6H_5–CH_3 \xrightarrow{\text{Cl}_2,\ h\nu}$$

Solution:

(a) The reaction is a free radical halogenation at the benzylic position:

$$\text{NO}_2–C_6H_4–CH_2CH_3 \xrightarrow{\text{Br}_2,h\nu} \text{NO}_2–C_6H_4–CHBrCH_3$$

(b) Toluene undergoes benzylic chlorination:

$$\text{C}_6\text{H}_5–CH_3 \xrightarrow{\text{Cl}_2,h\nu} \text{C}_6\text{H}_5–CH_2Cl$$

Only one hydrogen is replaced at the benzylic position in monohalogenation.

Quick Tip

Free radical halogenation under UV/light occurs preferentially at benzylic positions due to resonance stabilization.

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19. The thermal decomposition of an acid is a first-order reaction with a rate constant of $2.3 \times 10^{-5}\ \text{s}^{-1}$ at a certain temperature. Calculate how long it will take for three-fourths of the initial quantity of acid to decompose. $(\log 4 = 0.6021, \log 2 = 0.3010)$

Solution:

For a first-order reaction:

$$k = \frac{2.303}{t}\log\left(\frac{[A]_0}{[A]}\right)$$

Let the initial amount be $[A]_0$, and three-fourths decomposed means $[A] = \frac{1}{4}[A]_0$

So:

$$k = \frac{2.303}{t}\log\left(\frac{[A]_0}{[A]_0/4}\right) = \frac{2.303}{t}\log 4 \Rightarrow k = \frac{2.303 \times 0.6021}{t}$$

Given $k = 2.3 \times 10^{-5}\ \text{s}^{-1}$, so:

$$2.3 \times 10^{-5} = \frac{2.303 \times 0.6021}{t} \Rightarrow t = \frac{2.303 \times 0.6021}{2.3 \times 10^{-5}} \approx \frac{1.387}{2.3 \times 10^{-5}} \approx 60217.4 \text{ seconds}$$

$$\boxed{t \approx 6.02 \times 10^4 \text{ seconds}}$$

Quick Tip

Use the first-order rate law formula: $t = \frac{2.303}{k} \log \frac{[A]_0}{[A]}$ when amount decomposed is given.

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20. Account for the following:

(i) CH_3CHO is more reactive than CH_3COCH_3 towards reaction with HCN.

(i) Solution:

Aldehydes (like CH_3CHO) are more reactive than ketones (like CH_3COCH_3) due to two reasons: - **Steric hindrance**: Ketones have two bulky alkyl groups, whereas aldehydes have one H, making them less hindered. - **+I effect**: Alkyl groups in ketones donate electrons, reducing electrophilicity of carbonyl C.

Thus, CH_3CHO is more reactive than acetone towards nucleophiles like HCN.

$$\boxed{\text{CH}_3\text{CHO} > \text{CH}_3\text{COCH}_3 \text{ in reactivity toward HCN}}$$

(ii) Carboxylic acids are higher boiling liquids than aldehydes and ketones.

(ii) Solution:

Carboxylic acids form **extensive hydrogen bonds** (dimers) in liquid state due to the presence of –OH and =O groups. - This results in stronger intermolecular forces. - Aldehydes and ketones only have dipole–dipole interactions (no strong H-bonding). Hence, carboxylic acids have significantly higher boiling points.

$$\boxed{\text{Boiling point: Carboxylic acids} > \text{Aldehydes/Ketones}}$$

Quick Tip

Hydrogen bonding raises boiling points. Carboxylic acids dimerize strongly via H-bonds unlike aldehydes and ketones.

OR

20 (b). Give chemical tests to distinguish between the following pairs:

(i) Propanal and Propanone

(i) Solution:

Test: Tollen's Test or Fehling's Test

- Propanal (aldehyde) gives positive test → forms silver mirror (Tollen's) or red ppt (Fehling's). - Propanone (ketone) gives negative test.

$$\boxed{\text{Tollen's/Fehling's test distinguishes aldehydes from ketones}}$$

(ii) Benzaldehyde and Benzoic acid

(ii) Solution:

Test: Sodium bicarbonate ($NaHCO_3$) test

- Benzoic acid reacts with $NaHCO_3$ → brisk effervescence (CO_2)

- Benzaldehyde shows no reaction

$$\boxed{\text{NaHCO}_3\text{ test distinguishes acids from aldehydes}}$$

Quick Tip

Aldehydes respond to Tollen's/Fehling's; acids react with $NaHCO_3$. Use simple visible tests for easy differentiation.

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21. Write the reaction of glucose with:

(a) HI

(a) Solution:

When glucose is heated with excess HI, it is fully reduced to form n-hexane. This proves that glucose has a straight-chain structure.

$$C_6H_{12}O_6 + HI \xrightarrow{\Delta} \text{n-}C_6H_{14}$$

$$\boxed{\text{Glucose} + \text{HI} \rightarrow \text{n-hexane}}$$

(b) Br_2 water

(b) Solution:

Br_2 water is a mild oxidising agent. It oxidizes the aldehyde group (–CHO) in glucose to carboxylic acid (–COOH), forming gluconic acid.

$$C_6H_{12}O_6 + Br_2 \rightarrow C_6H_{12}O_7 + 2HBr$$

$$\boxed{\text{Glucose} + Br_2 \rightarrow \text{Gluconic acid}}$$

Quick Tip

Glucose reduces Br_2 water → gluconic acid, and reacts with HI → straight chain alkane (n-hexane). Used for structural proof.

22.

(a) Draw the geometrical isomers of the complex $[Pt(NH_3)_2Cl_2]$.

(a) Solution:

This is a square planar complex of type MA_2B_2. Two geometrical isomers are possible:

- **Cis-isomer:** both Cl ligands adjacent - **Trans-isomer:** Cl ligands opposite

$$\boxed{\text{Cis-}[Pt(NH3)2Cl2] \quad \text{and} \quad \text{Trans-}[Pt(NH3)2Cl2]}$$

(b) Give the electronic configuration of d^4 ion when $\Delta_0 > P$.

(b) Solution:

When $\Delta_0 > P$, the ligand field is strong → **low-spin configuration**

$$d^4 \Rightarrow \text{All electrons pair in } t_{2g} \text{ first: } t_{2g}^4 e_g^0$$

$$\boxed{\text{Low-spin: } t_{2g}^4 e_g^0}$$

(c) Solution of $[Ni(H_2O)_6]^{2+}$ is green in colour, whereas $[Ni(CN)_4]^{2-}$ is colourless. Give reason.

(Ni = 28)

(c) Solution:

- In $[\mathrm{Ni(H_2O)_6}]^{2+}$: Weak field ligand → octahedral, d^8 → partially filled d-orbitals → d-d transition allowed → green color.

- In $[\mathrm{Ni(CN)_4}]^{2-}$: Strong field ligand ($\mathrm{CN^-}$) → low-spin, square planar → all electrons paired → d-d transition not allowed → colourless.

$$\boxed{\text{Colour arises due to d-d transition. Strong field ligand prevents it.}}$$

Quick Tip

Presence of unpaired electrons and allowed d-d transitions cause colour in complexes. $\mathrm{CN^-}$ induces strong pairing.

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23. The electrical resistance of a column of 0.05 M NaOH solution of cell constant $50\ \mathrm{cm^{-1}}$ is $4.5 \times 10^3\ \Omega$. Calculate its resistivity, conductivity and molar conductivity.

Solution:

Given:

$$R = 4.5 \times 10^3\ \Omega, \quad l/A = \text{cell constant} = 50\ \mathrm{cm^{-1}}$$

(i) Conductivity:

$$\kappa = \text{cell constant} \times \frac{1}{R} = 50 \times \frac{1}{4.5 \times 10^3} = 1.11 \times 10^{-2}\ \mathrm{S\ cm^{-1}}$$

(ii) Resistivity:

$$\rho = \frac{1}{\kappa} = \frac{1}{1.11 \times 10^{-2}} = 90.09\ \Omega\ \mathrm{cm}$$

(iii) Molar Conductivity:

$$\Lambda_m = \frac{1000 \times \kappa}{C} = \frac{1000 \times 1.11 \times 10^{-2}}{0.05} = 222\ \mathrm{S\ cm^2\ mol^{-1}}$$

$$\boxed{\Lambda_m = 222, \quad \kappa = 1.11 \times 10^{-2}, \quad \rho = 90.09}$$

Quick Tip

Use $\kappa = \frac{1}{R} \times$ cell constant, and $\Lambda_m = \frac{1000\kappa}{C}$ to find molar conductivity.

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24. Calculate elevation of boiling point when 4 g of $MgSO_4$ is dissolved in 100 g water. (Molar mass = 120 g/mol), $K_b = 0.52$ K kg mol^{-1}, assume complete ionisation.

Solution:

Step 1: Molality

$$\text{Molality (m)} = \frac{\text{moles of solute}}{\text{mass of solvent in kg}} = \frac{4/120}{0.1} = \frac{1}{3}$$

Step 2: van't Hoff factor (i) $MgSO_4$ dissociates completely $\rightarrow Mg^{2+} + SO_4^{2-} \Rightarrow i = 2$

Step 3: Boiling point elevation

$$\Delta T_b = i \cdot K_b \cdot m = 2 \cdot 0.52 \cdot \frac{1}{3} = 0.346 \text{ K}$$

$$\boxed{\Delta T_b = 0.35 \text{ K (approx)}}$$

Quick Tip

Always multiply molality with van't Hoff factor when electrolyte dissociates.

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25. Account for the following:

(a) The dipole moment of chlorobenzene is lower than that of cyclohexylchloride.

(a) Explanation:

In chlorobenzene, the lone pair on Cl is delocalised via resonance into the benzene ring, reducing electron density on Cl and lowering the dipole moment.

Cyclohexylchloride lacks resonance → greater dipole.

$$\boxed{\text{Resonance reduces dipole in chlorobenzene.}}$$

(b) Alkyl halides are immiscible in water.

(b) Explanation:

Alkyl halides are non-polar or weakly polar and cannot form hydrogen bonds with water → immiscible.

$$\boxed{\text{Lack of H-bonding} \rightarrow \text{immiscibility in water}}$$

(c) t-butyl bromide has lower boiling point than n-butyl bromide.

(c) Explanation:

n-butyl bromide is linear → greater surface area → stronger van der Waals forces.

t-butyl bromide is branched → lower boiling point.

$$\boxed{\text{Boiling point: straight ¿ branched isomer}}$$

Quick Tip

Boiling point increases with surface area and polarity. Resonance reduces dipole moment.

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26. What happens when (any three):

(a) Phenyl magnesium bromide is treated with CH_3CHO followed by hydrolysis.

(a) Grignard reagent reacts with aldehyde:

$$C_6H_5MgBr + CH_3CHO \xrightarrow{H_2O} C_6H_5CH(OH)CH_3$$

Product: Secondary alcohol (1-phenylethanol)

(b) Phenol treated with conc. HNO_3 + H_2SO_4.

$$\text{Phenol} \xrightarrow{\text{HNO}_3/H_2SO_4} 2,4,6\text{-trinitrophenol (picric acid)}$$

(c) Anisole with CH_3COCl and anhydrous $AlCl_3$.

Friedel–Crafts acylation occurs at para position:

$$\text{Anisole} \xrightarrow{CH_3COCl/AlCl_3} \text{p-methoxyacetophenone}$$

(d) Propan-2-ol is heated with Cu at 573 K.

Dehydrogenation to form propanone:

$$CH_3CH(OH)CH_3 \xrightarrow{Cu,573K} CH_3COCH_3$$

Quick Tip

Grignard reagents give alcohols, phenol undergoes electrophilic substitution, and Cu dehydrogenates alcohols to carbonyls.

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27. Give plausible explanation for the following:

(a) Diazonium salts of aromatic amines are stable.

(b) Aniline does not undergo Friedel–Crafts reaction.

(c) Aniline on nitration gives a substantial amount of meta product.

(a) Stability due to resonance and delocalization of N_2^+ over benzene ring.

(b) Aniline forms a Lewis acid–base complex with $AlCl_3$ → deactivates ring.

(c) In acidic medium, aniline gets protonated to $Ph\text{–}NH3^+$, a meta-directing group.

$$\boxed{\text{Acidic conditions lead to meta product due to protonation}}$$

Quick Tip

Amine group becomes protonated under acid, changing its directive influence and reactivity.

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28. Hydrolysis of sucrose:

$$C_{12}H_{22}O_{11} + H2O \xrightarrow{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$

(a) Rate law equation

(b) Molecularity and order of reaction

(c) What do you call such reactions?

(a) Rate law:

$$\text{Rate} = k[\text{Sucrose}]$$

(b) - Molecularity = 2 (Sucrose + H_2O) - Order = 1 (depends only on sucrose concentration)

(c) These are called **pseudo-first-order reactions** because one reactant (water) is in large excess and treated as constant.

$$\boxed{\text{Pseudo-first-order reaction}}$$

Quick Tip

If one reactant is in large excess (e.g. water), the reaction appears first-order even if two species are involved.

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29. Passage: The particles in the nucleus of the cell, responsible for heredity, are called chromosomes which are made up of proteins and another type of biomolecules called nucleic acids. These are mainly of two types, DNA and RNA. Nucleic acids on hydrolysis yield a pentose sugar, phosphoric acid and nitrogen containing heterocyclic compound. Nucleic acids have a very diverse set of functions, such as cell creation, the storage and processing of genetic information, protein synthesis and the generation of energy cells. Although their functions may differ, the structure of DNA and RNA are very similar, with only a few fundamental differences in their molecular make-up.
Based on the above information, answer the following questions:

(a) Write two functions of DNA.

(a) Solution:

Two important functions of DNA are: 1. **Genetic Information Storage:** DNA stores the hereditary material and transfers it from one generation to the next.
2. **Regulation of Cellular Processes:** DNA controls cell division, growth and protein synthesis by coding for enzymes and structural proteins.

$$\boxed{\text{DNA stores genetic information and regulates protein synthesis.}}$$

(b) What products would be formed when a nucleotide from DNA containing Adenine is hydrolyzed?

(b) Solution:

A DNA nucleotide consists of three parts: - A nitrogenous base (in this case, Adenine) - A pentose sugar (2-deoxyribose) - A phosphate group

On hydrolysis, it gives:

$$\boxed{\text{Adenine} + \text{2-deoxyribose} + \text{Phosphoric acid}}$$

(c)(i) What are nucleic acids? What is the difference between nucleotide and nucleoside?

(c)(i) Solution:

Nucleic acids are biological macromolecules made up of nucleotides joined by phosphodiester bonds. They carry genetic information and are of two main types: DNA and RNA.

Difference between nucleotide and nucleoside:

Nucleoside	**Nucleotide**
Base + Sugar	Base + Sugar + Phosphate
No phosphoric acid group	Contains phosphoric acid group

$$\boxed{\begin{array}{l}\text{Nucleoside} = \text{Nitrogen base + Sugar} \\ \text{Nucleotide} = \text{Nitrogen base + Sugar + Phosphate group}\end{array}}$$

OR

(c)(ii) Give one similarity and one difference between DNA and RNA.

(c)(ii) Solution:

Similarity: Both DNA and RNA are nucleic acids made up of nucleotides containing nitrogenous bases, a sugar, and a phosphate group.

Difference: - DNA contains deoxyribose sugar and the base thymine. - RNA contains ribose sugar and uracil instead of thymine.

$$\boxed{\begin{array}{c}\text{Similarity: Both are made of nucleotides.} \\ \text{Difference: DNA has thymine, RNA has uracil.}\end{array}}$$

Quick Tip

DNA is the genetic material in most organisms. Nucleotides differ from nucleosides by the presence of a phosphate group. RNA contains ribose and uracil, while DNA has deoxyribose and thymine.

30. Passage: The cause for deviation from Raoult's law in the colligative properties of non-ideal solutions lies in the nature of interactions at the molecular level. These properties show deviations from Raoult's law due to difference in interactions between solute–solvent, solute–solute and solvent–solvent. Some liquids on mixing form azeotropes which are binary mixtures having the same composition in liquid and vapour phase and boil at a constant temperature. In such cases, it is not possible to separate the components by fractional distillation. There are two types of azeotropes called minimum boiling azeotrope and maximum boiling azeotrope.

(a) Pure ethanol cannot be prepared by fractional distillation of ethanol–water mixture. Comment.

(a) Solution:

Ethanol and water form a **minimum boiling azeotrope** at about 95.6- This azeotropic mixture boils at a constant temperature. - Since both liquid and vapour have the same composition at this point, further separation by fractional distillation is not possible.

$$\boxed{\text{Ethanol–water forms an azeotrope that cannot be separated by distillation.}}$$

(b) Why does a mixture of chloroform and acetone show deviation from ideal behaviour?

(b) Solution:

Chloroform and acetone exhibit strong **intermolecular hydrogen bonding** between them: - Acetone has a polar carbonyl group (C=O) - Chloroform has acidic hydrogen ($\text{C–H}\cdots\text{O}$ hydrogen bonding)

These new solute–solvent interactions are **stronger** than the individual ones. Hence, the mixture shows **negative deviation** from Raoult's law.

$$\boxed{\text{Strong intermolecular attraction} \rightarrow \text{negative deviation from ideality.}}$$

(c)(i) The vapour pressure of pure benzene at a certain temperature is 1.25 atm. When 1.2 g of non-volatile, non-electrolyte solute is added to 60 g of benzene (M = 78 g/mol), the vapour pressure of the solution becomes 1.237 atm. Calculate the molar mass of the non-volatile solute.

(c)(i) Solution:

$$\text{Relative lowering of vapour pressure: } \frac{P^0 - P_s}{P^0} = \frac{n_{\text{solute}}}{n_{\text{solvent}}}$$

Given: - $P^0 = 1.25$ atm, $P_s = 1.237$ atm - $w_1 = 1.2$ g (solute), $w_2 = 60$ g (solvent) - $M_2 = 78$ g/mol (benzene), $M_1 = ?$

$$\frac{1.25 - 1.237}{1.25} = \frac{1.2/M_1}{60/78} \Rightarrow \frac{0.013}{1.25} = \frac{1.2 \times 78}{M_1 \times 60} \Rightarrow 0.0104 = \frac{93.6}{60M_1} \Rightarrow M_1 = \frac{93.6}{60 \times 0.0104} \Rightarrow M_1 \approx \boxed{150\text{ g/mo}}$$

OR

(c)(ii) The boiling point of benzene is 353.23 K. When 1.80 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point is raised to 354.11 K. Calculate the molar mass of the solute. $K_b = 2.53$ K kg mol^{-1}

(c)(ii) Solution:

Boiling point elevation:

$$\Delta T_b = T_{\text{solution}} - T_{\text{pure}} = 354.11 - 353.23 = 0.88\text{ K}$$

Molality:

$$\Delta T_b = K_b{\cdot}m = \frac{K_b \cdot w_1 \cdot 1000}{M_1 \cdot w_2} \Rightarrow 0.88 = \frac{2.53 \cdot 1.8 \cdot 1000}{M_1 \cdot 90} \Rightarrow M_1 = \frac{2.53 \cdot 1.8 \cdot 1000}{0.88 \cdot 90} \Rightarrow M_1 = \frac{4554}{79.2} \approx \boxed{57.5\text{ g}}$$

Quick Tip

Deviations from Raoult's law arise due to unequal solute–solvent interactions. Azeotropes boil at constant composition, limiting distillation.

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31. Attempt any five of the following:

(a) Cu$^+$ is not stable in aqueous solution. Comment.

(a) Solution:

Cu$^+$ is unstable in aqueous solution because it undergoes disproportionation:

$$2\text{Cu}^+ \rightarrow \text{Cu}^{2+} + \text{Cu}$$

This is thermodynamically favored as Cu^{+} has a tendency to be both oxidised to Cu^{2+} and reduced to Cu.
This instability arises due to the positive value of the standard electrode potential for the disproportionation reaction.

$$\boxed{\text{Cu}^{+} \text{ is unstable and disproportionates in aqueous solution.}}$$

(b) Out of Cr^{2+} and Fe^{2+}, which is a stronger reducing agent and why?

(b) Solution:

Cr^{2+} is a stronger reducing agent than Fe^{2+} because:

- Cr^{2+} readily loses an electron to form the more stable Cr^{3+} (having half-filled t_{2g}^{3} configuration).
- Fe^{2+} does not gain as much stability on oxidation.

$$\boxed{\text{Cr}^{2+} \text{ is stronger reducing agent due to stability of Cr}^{3+}}$$

(c) Actinoid contraction is greater from element to element than lanthanoid contraction. Why?

(c) Solution:

Actinoid contraction is more pronounced because:

- Poor shielding of 5f electrons compared to 4f electrons in lanthanoids.
- Greater increase in effective nuclear charge across the series.

$$\boxed{\text{5f electrons shield poorly} \rightarrow \text{stronger contraction across actinoids}}$$

(d) $KMnO_4$ acts as an oxidising agent in acidic medium. Write the ionic equation to support this.

(d) Solution:

In acidic medium, $KMnO_4$ gets reduced from Mn^{7+} to Mn^{2+}. The ionic redox equation is:

$$\text{MnO}_4^- + 8\text{H}^+ + 5e^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$$

$$\boxed{\text{KMnO}_4 \text{ acts as a strong oxidising agent in acidic medium.}}$$

(e) Name the metal in the first transition series which exhibits $+1$ oxidation state most frequently.

(e) Solution:

The metal is **Copper (Cu)**. Cu shows +1 oxidation state frequently due to configuration:

$$\text{Cu: [Ar]}\,3d^{10}\,4s^1 \Rightarrow \text{Cu}^+ = \text{[Ar]}\,3d^{10}$$

A completely filled d-orbital provides extra stability.

$$\boxed{\text{Cu exhibits } +1 \text{ oxidation state most frequently.}}$$

(f) Transition metals and their compounds are good catalysts. Justify.

(f) Solution:

Transition metals act as good catalysts due to:

- Variable oxidation states $\rightarrow$ allow redox cycling
- Ability to form complexes with reactants $\rightarrow$ intermediate formation
- Provide surface area for adsorption

$$\boxed{\text{Transition metals facilitate alternate paths with lower activation energy.}}$$

(g) Scandium forms no coloured ions, yet it is regarded as a transition element. Why?

(g) Solution:

Scandium forms Sc^{3+} with 3d^0 configuration $\rightarrow$ no unpaired electrons $\rightarrow$ no d-d transitions $\rightarrow$ hence, no colour.

However, it is a transition element because:

- It has an incompletely filled d-subshell in its ground state (Sc: $3\text{d}^1 4\text{s}^2$)

$$\boxed{\text{Transition elements are defined by ground or ionic d-orbital incompleteness.}}$$

Quick Tip

Transition metals show catalytic activity, variable oxidation states, and colored ions due to partially filled d-orbitals. Scandium qualifies despite forming colorless Sc^{3+}.

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32. (a)(i) What type of battery is the lead storage battery? Write the anode and the cathode reactions and the overall reaction occurring in a lead storage battery when current is drawn from it.

(a)(i) Solution:

The lead storage battery is a **secondary battery** (rechargeable). It is commonly used in automobiles.

Anode reaction:

$$\text{Pb}(s) + \text{SO}_4^{2-}(aq) \rightarrow \text{PbSO}_4(s) + 2e^-$$

Cathode reaction:

$$\text{PbO}_2(s) + 4\text{H}^+(aq) + \text{SO}_4^{2-}(aq) + 2e^- \rightarrow \text{PbSO}_4(s) + 2\text{H}_2\text{O}(l)$$

Overall cell reaction:

$$\text{Pb}(s) + \text{PbO}_2(s) + 2\text{H}_2\text{SO}_4(aq) \rightarrow 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l)$$

$$\boxed{\text{Lead storage battery involves Pb and PbO}_2 \text{ electrodes in H}_2\text{SO}_4 \text{ electrolyte.}}$$

(a)(ii) Calculate the time to deposit 1.5 g of silver at the cathode when a current of 1.5 A was passed through the solution of $AgNO_3$. (Molar mass of Ag = 108 g mol^{-1}, $F = 96500$ C mol^{-1})

(a)(ii) Solution:

Use Faraday's second law:

$$\text{mass} = \frac{M \cdot I \cdot t}{nF} \Rightarrow t = \frac{m \cdot n \cdot F}{M \cdot I}$$

Given:

$$m = 1.5 \text{ g}, \; M = 108, \; I = 1.5 \text{ A}, \; n = 1, \; F = 96500$$

$$t = \frac{1.5 \cdot 1 \cdot 96500}{108 \cdot 1.5} = \frac{144750}{162} \approx 893.5 \text{ seconds}$$

$$\boxed{t \approx 894 \text{ seconds}}$$

Quick Tip

Faraday's laws relate the quantity of deposited substance with time, current, and equivalent weight.

OR

(b)(i) State Kohlrausch's law of independent migration of ions. Molar conductivity at infinite dilution for NH_4Cl, NaOH and NaCl solution at 298 K are 149.8, 217.4 and 126.4 S cm^2 mol^{-1}, respectively. Calculate the molar conductivity of NH_4OH solution.

(b)(i) Solution:

Kohlrausch's law: At infinite dilution, the molar conductivity of an electrolyte is the sum of the individual contributions of its ions:

$$\Lambda_m^\circ(\text{electrolyte}) = \lambda_+^\circ + \lambda_-^\circ$$

To calculate:

$$\Lambda_m^\circ(\text{NH}_4\text{OH}) = \Lambda_m^\circ(\text{NaOH}) + \Lambda_m^\circ(\text{NH}_4\text{Cl}) - \Lambda_m^\circ(\text{NaCl})$$

$$= 217.4 + 149.8 - 126.4 = 240.8 \text{ S cm}^2 \text{ mol}^{-1}$$

$$\boxed{\Lambda_m^\circ(\text{NH}_4\text{OH}) = 240.8 \text{ S cm}^2 \text{ mol}^{-1}}$$

(b)(ii) Calculate ΔG° of the following cell at 25°C: Zn(s) — Zn^{2+}(aq) —— Cu^{2+}(aq) — Cu(s) Given:

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = 0.34 - (-0.76) = 1.10 \text{ V}$$

Use:

$$\Delta G^\circ = -nFE^\circ_{\text{cell}} = -2 \cdot 96500 \cdot 1.10 = -212300 \text{ J mol}^{-1}$$

$$\boxed{\Delta G^\circ = -212.3 \text{ kJ mol}^{-1}}$$

Quick Tip

Kohlrausch's law helps calculate unknown molar conductivities. Gibbs free energy relates to cell potential as $\Delta G^\circ = -nFE^\circ$.

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33. (a)(i) Explain with the help of chemical reactions:

(I) Acetone is treated with semicarbazide.

(I) Solution:

Acetone reacts with semicarbazide (H_2N–NH–$CONH_2$) to form a semicarbazone derivative via nucleophilic addition followed by elimination of water:

$$CH_3COCH_3 + H_2N\text{–}NH\text{–}CONH_2 \rightarrow CH_3C\text{=}NNHCONH_2 + H_2O$$

$$\boxed{\text{Acetone} + \text{Semicarbazide} \rightarrow \text{Semicarbazone}}$$

(II) Two molecules of benzaldehyde are treated with conc. NaOH.

(II) Solution:

This is the **Cannizzaro reaction** (disproportionation of aldehydes with no α-hydrogen):

$$2C_6H_5CHO \xrightarrow{\text{NaOH}} C_6H_5COO^- + C_6H_5CH_2OH$$

$$\boxed{\text{One aldehyde is oxidised, other is reduced}}$$

(III) Butan-2-one is treated with Zn–Hg and conc. HCl.

(III) Solution:

This is the **Clemmensen reduction**, converting ketones to alkanes:

$$CH_3COCH_2CH_3 \xrightarrow{\text{Zn–Hg/HCl}} CH_3CH_2CH_2CH_3$$

$$\boxed{\text{Butan-2-one} \rightarrow \text{Butane}}$$

(a)(ii) Arrange the following in increasing order of acidic strength:

(I) $CH_3CH_2CH_2COOH$, $BrCH_2CH_2CH_2COOH$, $CH_3CHBrCH_2COOH$, $CH_3CH_2CHBrCOOH$

(I) Solution:

Acidic strength increases with electron-withdrawing groups closer to –COOH:

$$CH_3CH_2CH_2COOH < BrCH_2CH_2CH_2COOH < CH_3CH_2CHBrCOOH < CH_3CHBrCH_2COOH$$

$$\boxed{\text{Increasing acidity:no Br} < \gamma\text{-Br} < \beta\text{-Br} < \alpha\text{-Br}}$$

(II) Benzoic acid, 4-Methoxybenzoic acid, 4-Nitrobenzoic acid, 3,4-Dinitrobenzoic acid

(II) Solution:

Electron withdrawing groups increase acidity, donating groups decrease it.

$$\text{4-Methoxy} < \text{Benzoic acid} < \text{4-Nitro} < \text{3,4-Dinitro}$$

$$\boxed{\text{Increasing acidity:OMe} < \text{H} < \text{NO}_2 < \text{NO}_2, \text{NO}_2}$$

Quick Tip

Acidity increases with electron-withdrawing groups, especially when closer to –COOH.

OR

(b)(i) Identify the products A, B, C and D in the following sequence:

$$CH_3CHO \xrightarrow{[O]} A \xrightarrow{\text{PCl}_5} B \xrightarrow{(CH_3)_2Cd} C \xrightarrow{Zn-Hg/HCl} D$$

(b)(i) Solution:

Step-by-step identification:

- A: Oxidation of CH_3CHO → CH_3COOH (acetic acid)
- B: Acetic acid + PCl_5 → CH_3COCl (acetyl chloride)
- C: Acetyl chloride + $(CH_3)_2Cd$ → CH_3COCH_3 (acetone)
- D: Acetone + Zn–Hg/HCl → $CH_3CH_2CH_3$ (propane)

$$\boxed{\begin{array}{l} A = \mathrm{CH_3COOH} \\ B = \mathrm{CH_3COCl} \\ C = \mathrm{CH_3COCH_3} \\ D = \mathrm{CH_3CH_2CH_3} \end{array}}$$

(b)(ii) How will you bring about the following conversions?

(I) Propanone to Propene

(I) Stepwise:

1. Clemmensen or Wolff-Kishner reduction: CH_3COCH_3 → $CH_3CH_2CH_3$ (propane)
2. Dehydrogenation using Al_2O_3/heat: $CH_3CH_2CH_3$ → $CH_3CH{=}CH_2$

$$\boxed{\mathrm{CH_3COCH_3} \rightarrow \mathrm{CH_3CH_2CH_3} \rightarrow \mathrm{CH_3CH} = \mathrm{CH_2}}$$

(II) Benzoic acid to Benzaldehyde

Use **Rosenmund Reduction**:

1. Convert to benzoyl chloride
2. Reduce with H_2/Pd–$BaSO_4$

$$\mathrm{C_6H_5COOH} \xrightarrow{\mathrm{SOCl_2}} \mathrm{C_6H_5COCl} \xrightarrow{\mathrm{H_2/Pd{-}BaSO_4}} \mathrm{C_6H_5CHO}$$

$$\boxed{\text{Benzoic acid} \rightarrow \text{Benzaldehyde}}$$

(III) Ethanol to But-2-enal

1. Ethanol → Acetaldehyde (oxidation)
2. Aldol condensation of $2CH_3CHO$ → $CH_3CH{=}CHCHO$

$$\boxed{\mathrm{CH_3CH_2OH} \xrightarrow{[O]} \mathrm{CH_3CHO} \xrightarrow{\mathrm{NaOH},\ \Delta} \mathrm{CH_3CH = CHCHO}}$$

Quick Tip

Use functional group interconversions: oxidations, reductions, aldol or Rosenmund reactions to achieve multi-step transformations.