CBSE EXAMINATION PAPER-2025

CHEMISTRY

(Solved)

Time allowed : 3 hours | Maximum Marks : 82

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **39 questions.** All questions are **compulsory.**

ii. This question paper is divided into **5 sections.**

iii. **Section A** – questions number **1 to 3** are case based questions

iv. **Section B** – questions number **4 to 19** are multiple choice questions

v. **Section C** – questions number **20 to 25** are very short answer

vi. **Section D** – questions number **26 to 33** are short answer

vii. **Section E** – questions number **34 to 39** are long answer

viii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.

ix. Use of calculator is NOT allowed.

Section A

Question 1. The Crystal Field Theory (CFT) of coordination compounds is based on the effect of different crystal fields (provided by the ligands taken as point charges) on the degeneracy of d-orbital energies of the central metal atom/ion. The splitting of the d-orbitals provides different electronic arrangements in strong and weak crystal fields. In tetrahedral coordination entity formation, the d-orbital splitting is smaller as compared to the octahedral entity.

Question 2.

The Crystal Field Theory (CFT) of coordination compounds is based on the effect of different crystal fields (provided by the ligands taken as point charges) on the degeneracy of d-orbital energies of the central metal atom/ion. The splitting of the d-orbitals provides different electronic arrangements in strong and weak crystal fields. In tetrahedral coordination entity formation, the d-orbital splitting is smaller as compared to the octahedral entity.

Answer the following questions :

(1)

On the basis of CFT, explain why $[Ti(H_2O)_6]Cl_3$ complex iscoloured ? What happens on heating the complex $[Ti(H_2O)_6]Cl_3$?

Give reason.[Atomic no. : Ti = 22]

[2 Marks]

Answer: $[Ti(H_2O)_6]Cl_3$ is coloured due to the presence of unpaired electrons in the d-orbitals of titanium. According to Crystal Field Theory, the d-orbitals of a transition metal ion split into different energy levels in the presence of ligands. In this case, the water molecules act as ligands which induce a crystal field that causes the d-orbitals to split. The energy difference corresponds to specific wavelengths of light. When light hits the complex, certain wavelengths are absorbed to promote electrons from the lower energy d-orbital to the higher energy d-orbital, resulting in the absorption of light and giving the complex its colour. Typically, $[Ti(H_2O)_6]Cl_3$ displays a blue-green color due to this electronic transition.\nWhen $[Ti(H_2O)_6]Cl_3$ is heated, the gain of energy can lead to further excitation of the electrons. In some cases, this heating can cause the water ligands to be released and replaced with different ligands or even result in changes in the oxidation state of titanium, which may result in a different colour or a complex that is less stable.

Key Points: Titanium has partially filled d-orbitals-colour arises from electronic transitions-d-orbital splitting caused by ligands-water ligands can be released on heating

(2)

What is crystal field splitting energy ?

[1 Marks]

Answer: Crystal field splitting energy (Δ) is the energy difference between the split d-orbitals in a coordination complex. In the context of Crystal Field Theory, d-orbitals of the central metal atom/ion experience electrostatic interactions with the ligands, which leads to the splitting of their energies. Depending on whether the ligands are classified as strong field or weak field, the degree of splitting can vary significantly. In octahedral complexes, the splitting is larger due to stronger interactions by the surrounding ligands, while in tetrahedral complexes, the splitting is relatively smaller. The resulting energy difference plays a crucial role in determining the electronic arrangement and properties of the coordination compound.

Key Points: Crystal field splitting energy (Δ) distinguishes energy levels of d-orbitals-Influenced by ligand field strength-Splitting varies between octahedral and tetrahedral complexes

(3)

On the basis of Δ_o and P (pairing energy), how can youdifferentiate between a strong field ligand and a weak fieldligand ?

[1 Marks]

Answer: In Crystal Field Theory, ligands are classified as strong field or weak field based on their ability to split the d-orbitals of a central metal ion. A strong field ligand leads to a large crystal field splitting energy (Δ_o) compared to the pairing energy (P), resulting in lower spin complexes where electrons prefer to pair up in the lower energy orbitals. In contrast, a weak field ligand has a smaller Δ_o, making the energy required for electron pairing greater than the energy difference between split orbitals, which results in higher spin complexes where electrons occupy the higher energy orbitals singly before pairing occurs. Therefore, if $\Delta_o > P$, the ligand is classified as a strong field ligand, whereas if $\Delta_o < P$, it is considered a weak field ligand.

Key Points: Definition of strong and weak field ligands-Comparison of Δ_o and P-Impact on electron configuration and spin state

(4)

Why are low spin tetrahedral complexes rarely observed ?

[1 Marks]

Answer: Low spin tetrahedral complexes are rarely observed primarily because of the nature of d-orbital splitting in tetrahedral coordination entities. In tetrahedral complexes, the crystal field splitting energy (Δt) is smaller compared to octahedral complexes, which leads to insufficient energy difference to favor the pairing of electrons in the lower energy orbitals. Additionally, tetrahedral complexes typically involve weak field ligands that do not stabilize low spin configurations effectively. As a result, most tetrahedral complexes tend to be high spin, where electrons occupy higher energy orbitals rather than pairing up in lower ones. Thus, the unique combination of smaller splitting energy and the predominance of weak field ligands makes low spin tetrahedral complexes quite uncommon.

Key Points: Tetrahedral complexes have smaller d-orbital splitting-energy (Δt)-Weak field ligands present in tetrahedral complexes do not favor low spin configurations-High spin states are favored due to insufficient energy to pair electrons

Question 3.

Amines are usually formed from amides, imides, halides, nitro compounds, etc. They exhibit hydrogen bonding which influences their physical properties. In alkyl amines, a combination of electron releasing, steric and H-bonding factors influence the stability of the substituted ammonium cations in protic polar solvents and thus affect the basic nature of amines. Alkyl amines are found to be stronger bases than ammonia. Amines being basic in nature, react with acids to form salts. Aryldiazonium salts, undergo replacement of the diazonium group with a variety of nucleophiles to produce aryl halides, cyanides, phenols and arenes.

Answer the following questions :

(1)

How can you convert the following ?

(i) Ethanoic acid to methanamine

(ii) Propanenitrile to 1-aminopropane

[2 Marks]

Answer: (i) Ethanoic acid can be first converted to ethanamide by reaction with ammonia. Then, ethanamide is reduced using $LiAlH_4$ to form ethylamine. Finally, to obtain methanamine, we use methyl halide in nucleophilic substitution with ammonia. (ii) Propanenitrile is reduced using $LiAlH_4$ which converts the nitrile group to a primary amine, producing 1-aminopropane. These methods involve formation of amines from amides and nitriles as explained in the case passage, emphasizing the versatility of amines formation.

Key Points: Ethanoic acid to ethanamide - Reduction of amides to amines using LiAlH4 - Reduction of nitriles to primary amines - Use of nucleophilic substitution to form alkyl amines

(2)

Why is pKb value of aniline more than that of methylamine ?

[1 Marks]

Answer: Answer: The pKb value of aniline is more than that of methylamine because the lone pair of electrons on nitrogen in aniline is delocalized into the benzene ring, reducing its availability to accept protons. In contrast, methylamine has no such delocalization and the lone pair on nitrogen is more available, making it a stronger base with lower pKb. Thus, as per the case, electron donating alkyl groups increase basicity, so methylamine is stronger base than aniline.

Key Points: Aniline lone pair delocalized into benzene ring - Methylamine has localized lone pair on nitrogen - Delocalization reduces basicity - hence aniline pKb is higher than methylamine pKb

(3)

Arrange the following in increasing order of their basic strength in aqueous solution :

CH_3 -NH_2 , $(CH_3)_2NH$, $(CH_3)_3N$

[1 Marks]

Answer: The increasing order of basic strength in aqueous solution is $(CH_3)_3N < CH_3NH_2 < (CH_3)_2NH$. This is because steric hindrance reduces basicity in $(CH_3)_3N$, while electron releasing methyl groups increase basicity as seen in $(CH_3)_2NH$. Hence, secondary amine is the strongest base among these according to the case passage.

Key Points: Basicity depends on electron releasing effect - Steric hindrance reduces basic strength - Order is $(CH_3)_3N < CH_3NH_2 < (CH_3)_2NH$

(4)

Give the structures of A and B in the following reaction :

$$C_6H_5NO_2 \xrightarrow{Fe/HCl} A \xrightarrow[273\,K]{HNO_2} B$$

[1 Marks]

Answer: Structure of A: It is the arenediazonium salt formed when a primary aromatic amine reacts with nitrous acid. It contains the diazonium group ($-N_2^+$) attached to the aromatic ring.
Structure of B: It depends on the nucleophile replacing the diazonium group. For example, if the nucleophile is a halide ion, B will be an aryl halide where the diazonium group is replaced by the halogen atom.
This follows from the passage explaining that arenediazonium salts undergo replacement of the diazonium group with various nucleophiles to form aryl halides, cyanides, phenols, or arenes.

Key Points: A is arenediazonium salt with diazonium group on aromatic ring - B is product after replacement of diazonium group by nucleophile - Arenediazonium salts are intermediates in such substitution reactions

Section B

Question 4.

Which of the following transition metal ion is not coloured?

[1 Marks]

(A) Cu^{+}

(B) Ni^{2+}

(C) Co^{2+}

(D) V^{3+}

Explanation: The correct answer is Cu^{+}. It is colorless in solution because it has a filled d-orbital (3d10), which does not allow for d-d electronic transitions that are responsible for coloration in transition metal ions. The other ions listed (Ni^{2+}, Co^{2+}, and V^{3+}) have unpaired electrons and are thus colored.

Question 5.

Which of the following solutions will have the highest boiling point in water?

[1 Marks]

(A) 1% $CaCl_2$

(B) 1% KCl

(C) 1% urea

(D) 1% glucose

Explanation: The correct answer is 1% $CaCl_2$. Calcium chloride ($CaCl_2$) dissociates into three ions (one Ca^{2+} and two Cl^{-}) when dissolved in water, resulting in a van't Hoff factor (i) of 3. Since the boiling point elevation is proportional to the number of particles in solution, 1% $CaCl_2$ will produce more particles compared to the other options (1% KCl produces 2 particles, 1% urea and 1% glucose produce 1 particle each). Therefore, the solution with the highest boiling point will be the one with the highest number of ions, which in this case is 1% $CaCl_2$.

Question 6.

During electrolysis of dilute H_2SO_4, using platinum electrodes, the gas evolved at the anode is:

[1 Marks]

(A) O_2 gas

(B) SO_3 gas

(C) SO_2 gas

(D) H_2 gas

Explanation: During the electrolysis of dilute H_2SO_4, water molecules are oxidized at the anode to produce oxygen gas (O_2) as per the equation $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$. The other options provided (SO_2, SO_3, H_2) are not the products formed at the anode during this process.

Question 7.

The activation energy (E_a) of a reaction can be determined from the slope of which of the following plots?

[1 Marks]

(A) ln k vs. T

(B) In k /t vs. T

(C) T /In k vs.1/ T

(D) ln k vs. 1/T

Explanation: The correct option is 'ln k vs. 1/T'. According to the provided context, a plot of ln k versus 1/T generates a straight line, and the slope of this line is equal to $-E_a/R$. This confirms that the activation energy can be determined from this specific plot.

Question 8.

Which of the following represents the fraction of molecules with energies equal to or greater than E_a?

[1 Marks]

(A) $+E_a/RT$

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

(C) $e^{+E_a/RT}$

(D) $-E_a/RT$

Explanation: The fraction of molecules with energy equal to or greater than the activation energy E_a is given by the Arrhenius factor e^(-E_a/RT), where R is the gas constant and T is the absolute temperature. The exponent has a negative sign indicating that as the activation energy increases or

temperature decreases, the fraction decreases exponentially. Thus, the correct representation is $e^{-E_a/RT}$.

Question 9.

The number of moles of AgCl precipitated when excess $AgNO_3$ solution is mixed with one mole of $[Co(NH_3)_3Cl_3]$ is:

[1 Marks]

(A) 0

(B) 3

(C) 1

(D) 2

Explanation:

According to the provided context, 1 mole of $[Co(NH_3)_3Cl_3]$ will yield 3 moles of AgCl precipitated upon reaction with excess $AgNO_3$. Therefore, the correct answer is 3.

Question 10.

Which of the following haloalkanes react with aqueous KOH most rapidly by SN_1 reaction?

[1 Marks]

(A) 2-Chlorobutane

(B) 2-Bromo-2-Methylpropane

(C) 1-Bromobutane

(D) 2,2-Dimethyl-1-Chloropropane

Explanation: The SN1 reaction proceeds via the formation of a carbocation intermediate, so the rate depends on the stability of this carbocation. 2-Bromo-2-Methylpropane is a tertiary haloalkane, meaning it forms a highly stabilized tertiary carbocation during the reaction. This makes it react most rapidly in SN1 reactions compared to the other options, which are primary or secondary haloalkanes and form less stable carbocations.

Question 11.

The reaction $R - OH + Na \longrightarrow RO^-Na^+ + 1/2\ H_2$ (g) suggests that alcohols are:

[1 Marks]

(A) Amphoteric

(B) Basic

(C) Acidic

(D) Neutral

Explanation: The correct answer is 'Acidic.' This reaction indicates that alcohols can donate a proton to a stronger base, which is a characteristic of Brönsted acids. The context states that alcohols and phenols are indeed acidic in nature and react with metals to produce alkoxides, further confirming their acidic behavior.

Question 12.

At low temperature, phenol reacts with Br_2 in CS_2 to form:

[1 Marks]

(A) p-bromophenol

(B) 2,4,6-tribromophenol

(C) 2,4-dibromophenol

(D) o-and p-bromophenol

Explanation: At low temperature and in solvents of low polarity such as CS_2, phenol reacts with bromine to form monobromophenols, primarily substituted at the ortho and para positions relative to the -OH group. This results in o- and p-bromophenol rather than polybrominated products like 2,4,6-tribromophenol, which forms under different conditions such as in bromine water at room temperature.

Question 13.

When alkyl iodide is treated with large excess of ammonia, the major product obtained is:

[1 Marks]

(A) Secondary amine

(B) Primary amine

(C) Tertiary amine

(D) Quaternary ammonium salt

Explanation: The major product obtained is primary amine because when alkyl iodide reacts with a large excess of ammonia, it predominantly produces primary amine. This primary amine can act as a

nucleophile and may further react with alkyl halides to form secondary and tertiary amines, and potentially quaternary ammonium salts. However, due to the excess of ammonia, the formation of primary amine is favored.

Question 14.

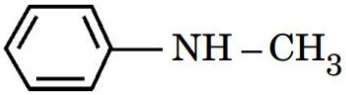
An amine 'X' reacts with Hinsberg reagent and the product obtained is soluble in alkali. The amine 'X' is:

[1 Marks]

(A)

$CH_3 - NH_2$

(B)



(C)

$(CH_3)_2NH$

(D)

$(CH_3)_3N$

Explanation: When a primary amine reacts with Hinsberg reagent (benzenesulphonyl chloride), it forms a sulphonamide that is soluble in alkali due to the acidic NH hydrogen which can be deprotonated, forming a soluble salt. Secondary amines form sulphonamides that are insoluble in alkali because they lack the acidic NH proton. Therefore, since the product is soluble in alkali, amine 'X' must be a primary amine.

Question 15.

α-helix structure refers to:

[1 Marks]

(A) primary structure of protein

(B) quaternary structure of protein

(C) tertiary structure of protein

(D) secondary structure of protein

Explanation: The α-helix is a specific type of secondary structure in proteins, characterized by a helical shape formed by hydrogen bonds between the backbone atoms in a polypeptide chain. This is directly stated in the relevant context, which mentions that the secondary structure of proteins includes α-helix and b-pleated sheet structures.

Question 16.

Assertion (A) : A mixture of o-nitrophenol and p-nitrophenol can be separated by steam distillation.

Reason (R) : o-nitrophenol is steam volatile due to intermolecular hydrogen bonding

[1 Marks]

(A) Assertion (A) is false, but Reason (R) is true

(B) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false

(D) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Explanation:

The assertion is correct because o-nitrophenol and p-nitrophenol can be separated by steam distillation. However, the reason given is incorrect. o-Nitrophenol is steam volatile due to intramolecular hydrogen bonding (within the same molecule), not intermolecular hydrogen bonding. In contrast, p-nitrophenol forms intermolecular hydrogen bonds between molecules, making it less volatile.

Question 17.

Assertion (A) : Cooking time is reduced in pressure cooker.

Reason (R) : Boiling point of water inside the pressure cooker is elevated.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertio

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true

Explanation: In a pressure cooker, the pressure inside increases, which raises the boiling point of water above 100°C. Since water boils at a higher temperature, food cooks faster, thus reducing the cooking time. Therefore, both Assertion (A) and Reason (R) are true, and the elevated boiling point is the correct explanation for reduced cooking time.

Question 18.

Assertion (A) : Actinoids show irregularities in their electronic configurations.

Reason (R) : Actinoids are radioactive in nature.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is false, but Reason (R) is true

(D) Assertion (A) is true, but Reason (R) is false.

Explanation: Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). The irregularities in the electronic configurations of actinoids stem from the unique filling of the 5f orbitals, which is not directly caused by their radioactivity.

Question 19.

Assertion (A) : Vitamin K can be stored in our body.

Reason (R) : Vitamin K is a water soluble vitamin.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true

Explanation: Assertion (A) is true, but Reason (R) is false. Vitamin K is a fat-soluble vitamin, not water-soluble, meaning it can be stored in the body, particularly in the liver and fat tissues. The

provided context clearly distinguishes water-soluble vitamins from fat-soluble ones, indicating that fat-soluble vitamins, such as Vitamin K, are stored in the body.

Section C

Question 20.

What is meant by positive deviation from Raoult's law ? Give an example. What type of azeotrope is formed by positive deviation ?

[2 Marks]

Answer: (a) **Positive deviation** from Raoult's law means the total vapor pressure of a solution is higher than predicted by Raoult's law due to weaker intermolecular forces between different components. (b) An example is a mixture of ethanol and water which shows positive deviation. (c) Such solutions form **minimum boiling azeotropes** at a specific composition.

Key Points: Positive deviation means vapor pressure higher than Raoult's law - Caused by weaker intermolecular forces - Example: Ethanol-water mixture - Forms minimum boiling azeotropes

Question 21.

State a condition under which a bimolecular reaction is kinetically first order reaction. Give an example. For which type of reactions, do order and molecularity have the same value ?

[2 Marks]

Answer: (a) A bimolecular reaction behaves as a first order reaction when one reactant is in large excess so its concentration remains almost constant during the reaction.
Example: The hydrolysis of methyl acetate in presence of large amount of water where water concentration is constant and reaction appears first order:
$CH_3COOCH_3 + H_2O \ (\rightarrow) \ CH_3COOH + CH_3OH$.
(b) Order and molecularity have the same value only for elementary reactions because molecularity is defined for elementary steps and corresponds to the number of reacting species involved, which equals the order of elementary reactions.

Key Points: Bimolecular reaction behaves as first order when one reactant concentration is constant - Example: Hydrolysis of methyl acetate with excess water - Order and molecularity are equal only in elementary reactions

Question 22.

Write the IUPAC name of the complex $[Pt(en)_2Cl2]^{2+}$. Draw the structure of geometrical isomer of this complex which is optically inactive.

[2 Marks]

Answer: The IUPAC name of the complex $[Pt(en)_2Cl2]^{2+}$ is dichlorobis(ethylene diamine)platinum(II). The structure of the geometrical isomer that is optically inactive corresponds to the trans isomer, where the two chloride ions are positioned opposite to each other in the coordination sphere. In this isomer, due to the symmetry, it does not have an optical isomer, making it achiral.

Key Points: IUPAC name: dichlorobis(ethylene diamine)platinum(II) - structure of trans isomer - optically inactive

Question 23.

(i) Write the formula of the following coordination compound :
Pentaamminecarbonatocobalt(III)chloride

(ii) Write the IUPAC name of the linkage isomer of the complex $[Co(NH_3)_5(NO_2)]Cl_2$.

[2 Marks]

Answer: (i) The name Pentaamminecarbonatocobalt(III)chloride shows 'Pentaammine' means 5 ammonia (NH_3) ligands, 'Carbonato' is the carbonate ligand $(CO_3)^{2-}$, 'Cobalt(III)' means cobalt metal in +3 oxidation state, and chloride is the counter ion. The formula of the complex ion is $[Co(NH_3)_5(CO_3)]^+$. To balance the charge, one chloride ion (Cl^-) is outside, so the formula is $[Co(NH_3)_5(CO_3)]Cl$.
(ii) The given complex $[Co(NH_3)_5(NO_2)]Cl_2$ contains NO_2 ligand bonded through oxygen (nitrito-O). The linkage isomer is when NO_2 binds through nitrogen forming nitro ligand. Hence, the IUPAC name of the linkage isomer is Pentaammine(nitro)cobalt(III) chloride.

Key Points: Formula of pentaamminecarbonatocobalt(III)chloride is [Co(NH3)5(CO3)]Cl - Understanding of linkage isomerism in coordination compounds - IUPAC name of the nitro linkage isomer is Pentaammine(nitro)cobalt(III) chloride

Question 24.

Why are haloarenes less reactive towards nucleophilic substitution reaction ? How does the presence of nitro (–NO2) group at ortho- and para-positions in haloarenes increase the reactivity towards nucleophilic substitution reaction ?

[2 Marks]

Answer: (a) Haloarenes are less reactive towards nucleophilic substitution reactions because the C–Cl bond in them has a partial double bond character due to resonance with the aromatic ring, making bond cleavage difficult.
(b) The presence of an electron withdrawing nitro group (–NO2) at ortho- and para-positions stabilizes the negative charge formed in the intermediate during nucleophilic substitution, thereby increasing the reactivity of haloarenes towards nucleophilic substitution at those positions.

Key Points: C–Cl bond has partial double bond character due to resonance - This makes bond cleavage difficult in haloarenes - Electron withdrawing –NO2 group at ortho- and para-positions increases reactivity by stabilizing intermediates

Question 25.

The two strands in DNA are not identical but complementary. Explain. What products would be formed when DNA is hydrolysed ?

[2 Marks]

Answer: (a) The two strands of DNA are complementary because the bases on one strand pair specifically with bases on the other strand: adenine (A) pairs with thymine (T), and cytosine (C) pairs with guanine (G). They are not identical because one strand has A where the other has T, and one has C where the other has G. This complementary base pairing allows the DNA to form a stable double helix.
(b) When DNA is hydrolyzed, it breaks down into three main products:
- Nitrogenous bases (A, T, G, C)
- Deoxyribose sugar
- Phosphate groups
Hydrolysis breaks the bonds between these components in the nucleotide, releasing them separately.

Key Points: DNA strands have complementary bases A-T and C-G - Strands are antiparallel and not identical - Hydrolysis yields nitrogenous bases, deoxyribose sugar, and phosphate groups

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Section D

Question 26.

0.3 g of acetic acid (Molar mass = 60 g mol^{-1}) dissolved in 30 g of benzene shows a depression in freezing point equal to 0.45°C. Calculate the percentage association of acid if it forms a dimer in the solution.

(Given : Kf for benzene = 5.12 K kg mol^{-1})

[3 Marks]

Answer: Step 1: Find the moles of acetic acid, n = mass / molar mass = 0.3 / 60 = 0.005 mol.

Step 2: Calculate the molality of the solution, molality = moles of solute / mass of solvent in kg = 0.005 / 0.03 = 0.1667 mol kg^{-1}.

Step 3: Calculate the expected freezing point depression if no association occurs: $\Delta T_f = K_f$ * molality = 5.12 * 0.1667 = 0.853°C.

Step 4: Actual depression given is 0.45°C, which is less due to association.

Step 5: Degree of association α = (expected ΔT_f - observed ΔT_f) / expected ΔT_f = (0.853 - 0.45) / 0.853 = 0.472.

Step 6: Percentage association = α * 100 = 47.2%.

Note: Since acetic acid forms dimers, the number of particles decreases, leading to a lower freezing point depression.

Answer: The percentage association of acetic acid is 47.2%.

Key Points: Calculate moles of solute - Find molality of solution - Use freezing point depression formula - Calculate expected freezing point depression - Find degree and percentage of association - Understand dimer formation reduces particles in solution

Question 27.

Write the name of the cell which is generally used in inverters. Write the reactions taking place at anode and cathode of this cell, when it is in use.

[3 Marks]

Answer: The cell generally used in inverters is the Lead Acid Battery.

Reactions at Anode (negative electrode):

$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

Reactions at Cathode (positive electrode):

$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

During discharge, the lead and lead dioxide electrodes react with sulfuric acid to form lead sulfate and water while producing electric energy. This process is reversible during charging.

Key Points: Lead Acid Battery - Anode reaction: Pb with SO4 2- forms PbSO4 and electrons - Cathode reaction: PbO2 with SO4 2-, H+ and electrons forms PbSO4 and water

Question 28.

Explain why electrolysis of an aqueous solution of NaCl gives H2gas at cathode and Cl2 gas at anode ? Write overall reaction.

(Given : $E°Na^+/Na + = – 2.71$ V , $E°H_2O/H_2$=-0.83V ,

$E°Cl_2/2Cl$=1.36V , $E°H^+/O_2/H_2O$=+1.23V

[3 Marks]

Answer: Explanation:

During electrolysis of aqueous NaCl, both Na^+ and H^+ ions and Cl^- and OH^- ions are present due to water dissociation.

At cathode (reduction): Na^+ has a very negative reduction potential (-2.71 V) compared to water (-0.83 V), so water is reduced preferentially producing H_2 gas and OH^- ions.

Half reaction at cathode: $2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-$

At anode (oxidation): Cl^- is oxidized to Cl_2 gas because chloride ions have lower oxidation potential (1.36 V) compared to water (1.23 V).

Half reaction at anode: $2Cl^- \rightarrow Cl_2(g) + 2e^-$

Overall reaction:

$2NaCl + 2H_2O \rightarrow 2NaOH + Cl_2(g) + H_2(g)$

Thus, hydrogen gas is produced at cathode by water reduction, and chlorine gas is produced at anode by oxidation of chloride ions. Sodium ions remain in solution combining with OH^- to form NaOH.

> **Key Points: Water is reduced at cathode producing H2 gas - Chloride ions are oxidized at anode producing Cl2 gas - Overall reaction forms NaOH, H2, and Cl2**

Question 29.

The following data were obtained during the first order thermal decomposition of $N_2O_5(g)$ at constant volume :

$2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$

Calculate rate constant.

[Given : log 2 = 0.3010, log 10 = 1]

[3 Marks]

S.No.	Time/s	Total Pressure/atm
1	0	0·5
2	100	0·625

Answer: Given reaction: $2N_2O_5(g) \rightarrow 2N_2O_4(g)+O_2(g)$ is a first order reaction.

Step 1: Use the integrated rate law for first order reaction: $\ln([N_2O_5]\$_0\$/[N_2O_5]) = kt$

Step 2: Initial concentration $[N_2O_5]\$_0\$ = 0.24 * 10^{-2}$ mol L^{-1}

Concentration after 60 min $[N_2O_5] = 0.20 * 10^{-2}$ mol L^{-1}

Time t = 60 min

Step 3: Calculate $\ln([N_2O_5]\$_0\$/[N_2O_5]) = \ln(0.24 * 10^{-2} / 0.20 * 10^{-2}) = \ln(1.2)$

Using log 10 = 1 and log 2 = 0.3010, log 1.2 = log (12/10) = log 12 - log 10 = (log 2 + log 6) - 1 but since log 6 is not given, approximate log 1.2 = 0.07918, so ln(1.2) = 2.303 * 0.07918 = 0.182

Step 4: Calculate rate constant $k = \ln([N_2O_5]\$_0\$/[N_2O_5]) / t = 0.182 / 60 = 0.00303$ min^{-1}

Answer: Rate constant $k = 3.03 * 10^{-3}$ min^{-1}.

Key Points: First order reaction - Use integrated rate law - Calculate $\ln([N_2O_5]\$_0\$/[N_2O_5])$ - Calculate rate constant k

Question 30.

A compound (A) with molecular formula C_4H_9I which is a primary alkyl halide, reacts with alcoholic KOH to give compound (B). Compound (B) reacts with HI to give (C) which is an isomer of (A). When (A) reacts with Na metal in the presence of dry ether, it gives a compound (D), C_8H_{18}, which is different from the compound formed when n-butyl iodide reacts with sodium. Write the structures of (A), (B), (C) and (D). Write thechemical equation when compound (A) is reacted with alcoholic KOH.

[3 Marks]

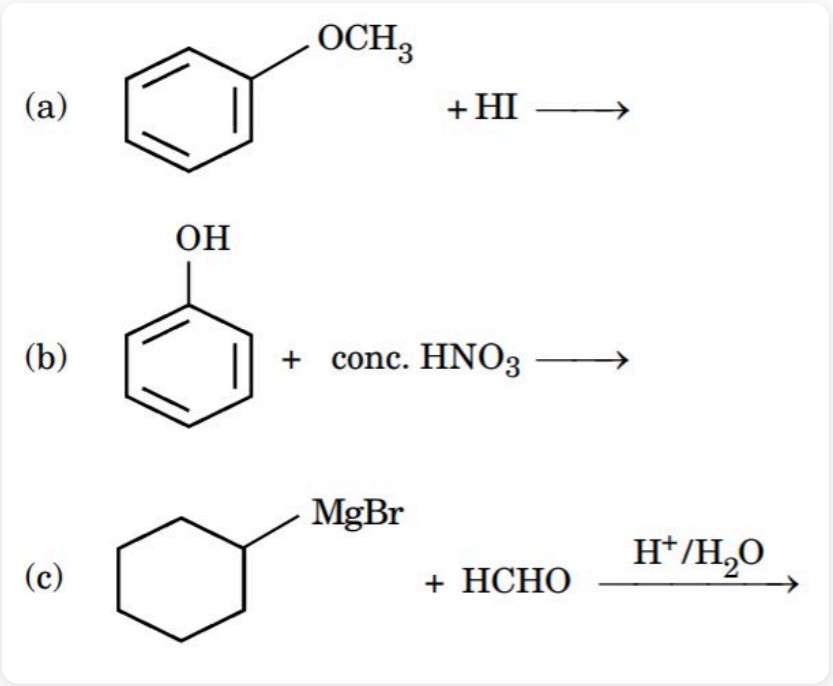
Answer: Compound (A) with molecular formula C_4H_9I is 1-iodobutane. When this alkyl halide reacts with alcoholic KOH, it undergoes elimination to form compound (B), which is butene (C_4H_8). The structure of compound (C), an isomer of (A), is 2-iodobutane. Upon reaction of compound (A) with sodium in dry ether, compound (D), which is octane (C_8H_{18}), is produced through a coupling reaction. The chemical equation for the reaction of (A) with alcoholic KOH is: $C_4H_9I + KOH(alc) \rightarrow C_4H_8 + KI + H_2O$.

Key Points: Identify compound A as 1-iodobutane; Reaction with alcoholic KOH leads to elimination forming butene; 2-iodobutane is an isomer of compound A; Reaction with sodium in dry ether forms octane; Include chemical equation for A with KOH.

Question 31.

Write structure of the products of the following reactions :

[3 Marks]



Answer: (i) Propene (CH_3-CH=CH_2) on reaction with H_2O and acid (H^+) undergoes acid-catalyzed hydration. The double bond breaks and OH group attaches to the more substituted carbon due to Markovnikov's rule, forming CH_3-CH(OH)-CH_3 (2-propanol).

(ii) Mononitration of 3-methylphenol gives mainly 2-nitro-3-methylphenol as the OH group activates ortho and para positions. The product has a nitro group at ortho position relative to OH group.

(iii) Dinitration of 3-methylphenol introduces two nitro groups, mainly at the 2 and 4 positions relative to the OH group, due to strong activating effect.

(iv) Catalytic reduction of a compound generally involves addition of hydrogen (H_2) over a catalyst, reducing double bonds or nitro groups to corresponding amines or alcohols, depending on starting material. The exact product depends on the reactant given.

Key Points: Acid-catalyzed hydration follows Markovnikov's rule - Phenol activates ortho and para positions for nitration - Dinitration introduces nitro groups at activated sites - Catalytic reduction adds hydrogen to reduce bonds

Question 32.

Give reasons for the following :

(a) Benzoic acid does not undergo Friedel-Crafts reaction.

(b) HCHO is more reactive than CH_3CHO towards addition of HCN.

(c) Vinyl group directly attached with carboxylic acid should decrease the acidity of corresponding carboxylic acid due to resonance, but on the contrary it increases the acidity.

[3 Marks]

Answer: (a) Benzoic acid does not undergo Friedel-Crafts reaction because the -COOH group is strongly deactivating and electron withdrawing. It reacts with the catalyst $AlCl_3$, forming a complex, which prevents the formation of the electrophile necessary for the reaction.
(b) HCHO (formaldehyde) is more reactive than CH_3CHO (acetaldehyde) towards addition of HCN because it has no alkyl group that donates electrons. Thus, the carbonyl carbon in HCHO is more electrophilic and easily attacked by nucleophiles like CN^-.
(c) Although a vinyl group is expected to decrease acidity due to resonance donation to the carboxyl group, it actually increases acidity because the vinyl group is sp^2 hybridised and more electronegative. This causes an electron withdrawing inductive effect, stabilising the carboxylate ion and increasing acidity.

Key Points: Benzoic acid deactivates Friedel-Crafts reaction due to -COOH group complexation with AlCl3 - HCHO is more electrophilic than CH3CHO increasing its reactivity towards HCN - Vinyl group has an electron withdrawing inductive effect increasing acidity despite resonance

Question 33.

Write the reaction of D-Glucose with the following :

(a) HCN (b) Br_2 water (c) $(CH_3CO)_2O$

[3 Marks]

Answer: (a) D-Glucose reacts with HCN to form a cyanohydrin by addition of HCN to the aldehyde group (-CHO) of glucose. This confirms the presence of an aldehyde group in glucose.
(b) When D-Glucose is treated with bromine water (Br_2 water), it gets oxidised to gluconic acid by converting the aldehyde group to a carboxylic acid group. This reaction shows glucose behaves as an aldose sugar.
(c) On reaction with acetic anhydride ($(CH_3CO)_2O$), glucose forms glucose pentaacetate by acetylation of all its hydroxyl (-OH) groups. In this reaction, no free aldehyde group is available as it forms a cyclic structure in glucose.

Key Points: D-Glucose forms cyanohydrin with HCN indicating aldehyde group - Glucose oxidises to gluconic acid with Br_2 water confirming it is an aldose - Glucose reacts with $(CH_3CO)_2O$ to form pentaacetate ester by acetylation of hydroxyl groups

Section E

Question 34.

Account for the following:

(I) The E° Mn^{2+}/Mn value for manganese is highly negative, whereas E° Mn^{3+}/Mn^{2+} is highly positive.

(II) Actinoids show wide range of oxidation states.

(III) Transition metals have high melting points

Complete the following ionic equations:

(I) $5SO_3^{2-} + 2MnO_4^- + 6H^+ \longrightarrow$

(II) $2MnO_4^- + H_2O + I^- \longrightarrow$.

[5 Marks]

Answer: (a) The E° Mn^{2+}/Mn value is highly negative because forming Mn^{2+} ion requires a lot of energy; manganese metal is very stable and not easily oxidized to Mn^{2+}. On the other hand, the E° Mn^{3+}/Mn^{2+} value is highly positive since Mn^{3+} is more easily formed from Mn^{2+}, especially in acidic medium, making the Mn^{3+} ion a strong oxidizing agent.

(b) Actinoids show a wide range of oxidation states because the 5f, 6d and 7s orbitals are close in energy, allowing variable electrons to participate in bonding. This results in oxidation states from +3 to +6 or more, reflecting their complex electron configurations.

(c) Transition metals have high melting points due to the presence of strong metallic bonding. This bonding arises from the delocalization of d-electrons which are more numerous and can form stronger bonds, requiring more energy to break, thus leading to high melting points.

Completion of ionic equations:
(I) $5SO_3^{2+} + 2MnO_4^+ + 6H^+ \longrightarrow 5SO_4^{2+} + 2Mn^{2+} + 3H_2O$
(II) $2MnO_4^+ + H_2O + I^+ \longrightarrow 2MnO_2 + 2OH^+ + I_2$

Explanation:
In (I) sulphite ions are oxidized to sulphate, and permanganate ions are reduced to Mn^{2+} in acidic medium.
In (II) permanganate ions are reduced to manganese dioxide (MnO_2) and iodide ions are oxidized to iodine (I_2) in alkaline medium.

Key Points: E° Mn^{2+}/Mn highly negative due to stability of Mn metal - E° Mn^{3+}/Mn^{2+} positive due to ease of Mn^{3+} formation - Actinoids variable oxidation states due to close

energy 5f,6d,7s orbitals - Transition metals high melting points due to strong metallic bonding from d-electrons - Ionic equations show redox reactions with permanganate ions

Question 35.

Answer the following questions :

(i) Name two elements of 3d series for which the third ionisation enthalpies are quite high.

(ii) Out of $KMnO_4$ and K_2MnO_4, which one is paramagnetic and why ?

(iii) Write any one consequence of lanthanoid contraction.

(iv) How do you prepare potassium manganate from pyrolusite ore ?

(v) Why is the ability of oxygen more than fluorine to stabilise higher oxidation states of transition metals ?

[5 Marks]

Answer: (i) The two elements of the 3d series for which the third ionisation enthalpies are quite high are Vanadium (V) and Zinc (Zn). This is because after losing two electrons, the third electron is removed from a stable half-filled or fully filled electronic configuration, making it more difficult.
(ii) $KMnO_4$ is paramagnetic because it contains Mn in +7 oxidation state with one unpaired electron, whereas K_2MnO_4 contains Mn in +6 oxidation state and is diamagnetic as all electrons are paired.
(iii) One consequence of lanthanoid contraction is that the atomic and ionic sizes of elements following lanthanoids decrease unexpectedly, which affects their chemical properties such as similar sizes of 4d and 5d transition elements.
(iv) Potassium manganate is prepared from pyrolusite ore (MnO_2) by fusion with potassium hydroxide (KOH) in the presence of an oxidising agent like potassium nitrate (KNO_3) or air. The reaction produces K_2MnO_4 as shown: $MnO_2 + 2KOH + 0.5O_2 \rightarrow K_2MnO_4 + H_2O$.
(v) Oxygen has a greater ability than fluorine to stabilise higher oxidation states of transition metals because oxygen can form pi bonds through its 2p orbitals which overlap with metal d orbitals, providing extra stability; fluorine lacks this ability due to its high electronegativity and inability to form pi bonds effectively.

Key Points: High third ionisation enthalpy for V and Zn - KMnO4 paramagnetic due to unpaired electron - Lanthanoid contraction causes decrease in size affecting properties - Preparation of K2MnO4 by fusion of MnO2 with KOH and oxidising agent - Oxygen stabilises higher oxidation states via pi bonding while fluorine cannot

Question 36.

(i) An organic compound (X) having molecular formula C5H10O can show various properties depending on its structures. Draw each of the structures if it :

(I) shows Cannizzaro reaction.

(II) reduces Tollens' reagent and has a chiral carbon.

(III) gives positive iodoform test.

(ii) Write the reaction involved in the following :

(I) Clemmensen reduction

(II) Etard reaction

[5 Marks]

Answer: (i) Structures of compound X (C5H10O):

(I) Shows Cannizzaro reaction: Compound must be an aldehyde without alpha hydrogen. Example: Pentanal (CH_3-CH_2-CH_2-CH_2-CHO).

Structure: CH_3-CH_2-CH_2-CH_2-CHO

Cannizzaro reaction occurs as pentanal has no alpha hydrogen.

(II) Reduces Tollens' reagent and has a chiral carbon: This implies it is an aldohexose with chiral center. Example: 2-Methylbutanal (CH_3-CH(CH_3)-CH_2-CHO). The chiral carbon is the second carbon.

Structure: CH_3-CH(CH_3)-CH_2-CHO

Tollens' test positive because it is an aldehyde.

(III) Gives positive iodoform test: Compound has CH_3-CO- group. Example: Methyl ethyl ketone (CH_3-CO-CH_2-CH_3).

Structure: CH_3-CO-CH_2-CH_3

Positive iodoform test due to methyl ketone group.

(ii) Reactions:

(I) Clemmensen reduction: Reduces aldehydes and ketones to alkanes using Zn(Hg) and HCl.

General reaction: R-CO-R/CHO + Zn(Hg)/HCl --> R-CH_2-R/CH_3

(II) Etard reaction: Oxidation of methyl group attached to aromatic ring to aldehyde using CrO_3 in HCl.

General reaction: Toluene + Etard reagent (CrO_3/HCl) --> Benzaldehyde

Key Points: Compound showing Cannizzaro is an aldehyde without alpha hydrogen - Chiral aldehyde reduces Tollens' reagent - Methyl ketone gives positive iodoform test - Clemmensen reduction converts carbonyl to alkane - Etard reaction oxidizes methylbenzene to benzaldehyde

Question 37.

Answer the following questions :

(i) Draw structure of the methyl hemiacetal of methanal.

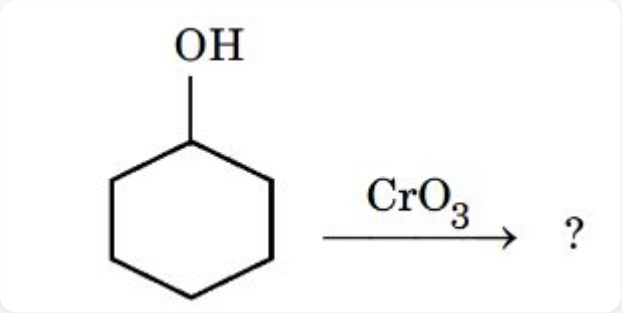
(ii) There are two – NH2 groups in semicarbazide. However only one is involved in the formation of semicarbazones. Give reason.

(iii) How will you convert ethanol to 3-hydroxybutanal ?

(iv) Complete the following equation :

(v) Write the final product formed when phthalic acid is treated with NH3 followed by strong heating.

[5 Marks]



Answer: (i) **Structure of methyl hemiacetal of methanal:**
Methanal (HCHO) reacts with methanol (CH3OH) to form methyl hemiacetal as follows:
H-CH=O + CH3OH → H-CH(OH)-OCH3
Structure: H attached to C, C attached to OH and OCH3 groups.

(ii) **Reason why only one – NH2 group in semicarbazide forms semicarbazones:**
Semicarbazide has two – NH2 groups; one is attached to the carbonyl carbon (part of the urea group) and is less reactive, while the other free amine group (terminal – NH2) is more nucleophilic and involved in the formation of semicarbazones with aldehydes or ketones by condensation reaction.

(iii) **Conversion of ethanol to 3-hydroxybutanal:**
Step 1: Oxidize ethanol (CH3CH2OH) to ethanal (CH3CHO) using PCC or any mild oxidizing agent.
Step 2: Perform aldol condensation of ethanal under base (NaOH) and water to produce 3-hydroxybutanal (CH3CH(OH)CH2CHO).

(iv) **Complete the following equation:**
As the equation is not provided in the question text, no answer can be given.

(v) **Final product when phthalic acid is treated with NH3 followed by strong heating:**
Phthalic acid reacts with ammonia (NH3) to form phthalamic acid, which upon strong heating undergoes cyclization to give phthalimide.

$C_6H_4(CO_2H)_2 + NH_3 \rightarrow C_6H_4(CO)CONH_2$ (phthalamic acid) → strong heat → $C_6H_4(CO)_2NH$ (phthalimide).

> **Key Points: Methyl hemiacetal structure of methanal - Only terminal NH2 group in semicarbazide reacts - Ethanol to ethanal to 3-hydroxybutanal via aldol condensation - Phthalic acid forms phthalimide after NH3 treatment and heating**

Question 38.

Calculate the emf of the following cell at 25°C:

(I)$Zn(s)|Zn^{2+}$ (0.1 M) || H^+ (0.01 M)$|H_2(g)$ (1 bar),Pt(s).

[Given : $E°zn^{2+}/zn$=-0.76v v, $E°2H^+/H_2$=0.00V , log 10 =1]

(II)State Faraday's second law of electrolysis. How much electricity is required in terms of Faraday for the reduction of 1 mol of $Cr_2O_7^{2-}$ to Cr^{3+}?

[5 Marks]

Answer: (I) Calculation of emf of the cell at 25 deg C:
Given cell: $Zn(s) | Zn^{2+}$ (0.1 M) || H^+ (0.01 M) | H_2(g, 1 bar) | Pt(s)
Standard electrode potentials:
$E°Zn^{2+}/Zn$ = -0.76 V
$E°2H^+/H_2$ = 0.00 V
Using Nernst equation: E = E° - (0.059/number of electrons) * log Q
For Zn/Zn^{2+} half cell, n = 2
Reaction at anode: $Zn(s) \rightarrow Zn^{2+} + 2e^-$
Reaction at cathode: $2H^+ + 2e^- \rightarrow H_2$ (g)
Overall cell reaction: $Zn(s) + 2H^+ \rightarrow Zn^{2+} + H_2$ (g)
Reaction quotient $Q = [Zn^{2+}]/[H^+]^2 = 0.1/(0.01)^2 = 0.1/0.0001 = 1000$
Cell emf, E = E°cell - (0.059/2) * log Q
E°cell = E°cathode - E°anode = 0.00 - (-0.76) = +0.76 V
log 1000 = 3
E = 0.76 - (0.059/2)*3 = 0.76 - 0.0885 = 0.6715 V
Therefore, emf of the cell = 0.67 V (approx.)

(II) Faraday's Second Law of Electrolysis:
The mass of an element liberated or deposited during electrolysis is directly proportional to the chemical equivalent weight of the element, which means different substances liberated by the same quantity of electricity are proportional to their equivalent weights.

Reduction of 1 mol of Cr_2O^{42+} to $Cr\square^+$ involves the reaction:
$Cr_2O^{42+} + 14H^+ + 6e^- \rightarrow 2Cr\square^+ + 7H_2O$

Number of electrons required per mole of Cr_2O^{42+} = 6 mol of e^-
Since 1 Faraday = charge of 1 mol of electrons,
Electricity required = 6 Faraday

Summary:
(I) emf = 0.67 V
(II) Faraday's second law relates mass deposited to equivalent weight.
Electricity required for reducing 1 mol Cr_2O^{42+} to Cr^{+} = 6 Faraday.

Key Points: Calculation of emf using Nernst equation - Application of Faraday's second law of electrolysis - Electricity required for reduction calculated by number of electrons involved

Question 39.

Answer the following questions :

(i) The conductivity of 0.20 M solution of KCl is 2.48×10^{-2} S cm^{-1}. Calculate its molar conductivity and degree of dissociation (α).

[Given: $\lambda^0(K^+) = 73.5$ S cm^2 mol^{-1}, $\lambda^0(Cl^-) = 76.5$ S cm^2 mol^{-1}]

(ii) Calculate ΔrG^0 of the following cell: $Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$

[Given: $E^0(Mg^{2+}/Mg) = -2.37$ V, $E^0(Cu^{2+}/Cu) = +0.34$ V 1 F = 96500 C mol^{-1}]

(iii) What type of cell is mercury cell? Why is it more advantageous than dry cell?

[5 Marks]

Answer: (a) Calculation of molar conductivity (Λ) and degree of dissociation (α):
Given concentration, c = 0.20 mol L^{-1}
Conductivity, κ = 2.48×10^{-2} S cm^{-1}
Molar conductivity, $\Lambda = \kappa / c = (2.48 \times 10^{-2}) / 0.20 = 0.124$ S cm^2 $mol^{-1} \times 1000 = 124$ S cm^2 mol^{-1}
Limiting molar conductivity, $\Lambda^0 = \lambda^0(K^+) + \lambda^0(Cl^-) = 73.5 + 76.5 = 150$ S cm^2 mol^{-1}
Degree of dissociation, $\alpha = \Lambda / \Lambda^0 = 124 / 150 = 0.826$ or 82.6%

(b) Calculation of standard Gibbs free energy change (ΔrG^0):
Reaction: $Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$
Calculate standard cell potential:
$E^0cell = E^0cathode - E^0anode = 0.34 - (-2.37) = 2.71$ V
Use relation $\Delta rG^0 = - n F E^0cell$, where n = 2 (number of electrons transferred)
$\Delta rG^0 = - 2 \times 96500 \times 2.71 = -523730$ J $mol^{-1} = -523.73$ kJ mol^{-1}

(c) Mercury cell is a type of primary cell in which mercury oxide acts as the cathode and zinc acts as

the anode.

It is more advantageous than dry cell because:

- It gives a steady voltage output during discharge
- It has a longer shelf life and better storage capacity
- It does not dry out easily
- It produces less pollution compared to dry cells

Key Points: Molar conductivity calculation - Degree of dissociation calculation - Calculation of ΔrG^0 using standard electrode potentials - Identification and advantages of mercury cell

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