# 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.** Alcohols undergo a number of reactions involving the cleavage of C – OH bond. However, phenols do not undergo reactions involving the cleavage of C – OH bond. Alcohols are weaker acids than water. Alcohols react with halogen acids to form the corresponding haloalkanes. Phenols are stronger acids than alcohols. A characteristic feature of phenols is that they undergo electrophilic substitution reactions such as halogenation, nitration, etc. Since – OH group is a strong activating group, phenol gives trisubstituted products during halogenation, nitration, etc.

**Question 2.**

Alcohols undergo a number of reactions involving the cleavage of C – OH bond. However, phenols do not undergo reactions involving the cleavage of C – OH bond. Alcohols are weaker acids than water. Alcohols react with halogen acids to form the corresponding haloalkanes. Phenols are stronger acids than alcohols. A characteristic feature of phenols is that they undergo electrophilic substitution reactions such as halogenation, nitration, etc. Since – OH group is a strong activating group, phenol gives trisubstituted products during halogenation, nitration, etc.

**(1)**

**What happens when phenol is treated with the following ?**

**(i) $Br_2$ water (ii) Conc. $HNO_3$**

[2 Marks]

**Answer:** When phenol is treated with $Br_2$ water, it undergoes electrophilic substitution to form 2,4,6-tribromophenol as the major product due to the presence of the strong activating -OH group, which allows multiple substitutions. When treated with concentrated nitric acid ($HNO_3$), phenol reacts to give 2-nitrophenol and 4-nitrophenol, also through electrophilic substitution, resulting in nitrated products.

**Key Points: Electrophilic substitution reaction-Formation of 2,4,6-tribromophenol with $Br_2$; Reaction with $HNO_3$ yields 2-nitrophenol and 4-nitrophenol.**

**(2)**

**Why do phenols not undergo reactions involving cleavage of C – OH bond ?**

[1 Marks]

**Answer:** Phenols do not undergo reactions involving cleavage of the C – OH bond due to their sp2 hybridized carbon atom, which is unable to participate in nucleophilic substitution reactions necessary for the conversion to halides. This structural characteristic limits their reactivity compared to alcohols.

**Key Points: Phenols have sp2 hybridized carbon- Cannot undergo nucleophilic substitution- C – OH bond cleavage is not favored**

**(3)**

**Write the mechanism of alcohol reacting as nucleophile in are action with $CH_3\oplus$ .**

[1 Marks]

**Answer:** In the reaction, the alcohol (R-OH) acts as a nucleophile by attacking the electrophile ($CH_3$). The oxygen atom of the alcohol donates a pair of electrons to the methyl carbon, forming a bond between them. Simultaneously, the O-H bond is broken, resulting in the proton (H+) being released. This leads to the formation of $CH_3$-R and water ($H_2O$) as by-products.

**Key Points: Alcohols as nucleophiles-O- donates electrons-forms bond with $CH_3$-H+ released-water by-product**

**(4)**

**How can you distinguish between Butan-1-ol and 2-Methylpropan-2-ol by using HCl in the presence of anhydrous $ZnCl_2$ ?**

[1 Marks]

**Answer:** Butan-1-ol will react with HCl in the presence of anhydrous $ZnCl_2$ to form butyl chloride through substitution, while 2-Methylpropan-2-ol will react to form tert-butyl chloride. The primary alcohol (Butan-1-ol) will show a distinct reaction pathway compared to the tertiary alcohol (2-Methylpropan-2-ol). Thus, observing the product will help distinguish them.

**Key Points: Butan-1-ol forms butyl chloride; 2-Methylpropan-2-ol forms tert-butyl chloride; difference in reactivity due to primary vs tertiary alcohol structure.**

**Question 3.**

The a-amino acids are the building blocks of proteins. All a-amino acids exist as zwitter ion due to which they show amphoteric behaviour. All amino acids are joined through peptide bond. Proteins are broadly classified as globular proteins and fibrous proteins. Globular proteins are water soluble, whereas fibrous proteins are not. The complete structure of protein is discussed at four different levels i.e. primary, secondary, tertiary and quaternary structures. Protein loses its biological activity in denatured form.

**(1)**

**Define the following :**

**(i) Peptide linkage (ii) Denatured protein**

[2 Marks]

**Answer:** (i) Peptide linkage is a chemical bond formed between the carboxyl group (-COOH) of one amino acid and the amino group (-NH2) of another, resulting in the release of a water molecule. This bond is crucial for linking amino acids to form proteins. (ii) A denatured protein is a protein that has lost its unique three-dimensional structure and biological activity due to external factors such as changes in pH or temperature. This irreversible process disrupts the secondary and tertiary structures of the protein.

> **Key Points: Peptide linkage is an amide bond formed between -COOH and -NH2; Denatured protein loses its structure and function due to pH or temperature changes.**

**(2)**

**Write the names of two different secondary structures of proteins.**

[1 Marks]

**Answer:** The two different secondary structures of proteins are alpha-helix and beta-pleated sheet.

> **Key Points: alpha-helix-beta-pleated sheet**

**(3)**

**Why do amino acids show amphoteric behaviour ?**

[1 Marks]

**Answer:** Amino acids show amphoteric behaviour because they contain both an acidic carboxyl group (-COOH) and a basic amino group (-NH2) in the same molecule. This allows them to act as both acids and bases, thus exhibiting amphoteric properties.

**Key Points: Contains both -COOH and -NH2 groups-amphoteric nature-acts as acids and bases**

**(4)**

**How can you differentiate between Fibrous protein and Globular protein ?**

[1 Marks]

**Answer:** Fibrous proteins have a long, strand-like structure and are generally insoluble in water, while globular proteins are spherical and water-soluble. The structure of fibrous proteins consists of polypeptide chains running parallel, held together by hydrogen and disulphide bonds, whereas globular proteins such as insulin and albumins are more compact and fold into specific shapes which allow them to perform various functions.

**Key Points: Fibrous proteins are insoluble in water; Globular proteins are water-soluble; Fibrous proteins have a fiber-like structure; Globular proteins are compact and spherical.**

## Section B

**Question 4.**

Williamson synthesis of preparing unsymmetrical ether is:

[1 Marks]

(A) Elimination reaction

**(B) SN_2 reaction**

(C) SN_1 reaction

(D) Electrophilic addition reaction

**Explanation:** Williamson synthesis involves the reaction of an alkoxide ion ($R\text{-}O^-$) with an alkyl halide ($R'\text{-}X$) to form an ether ($R\text{-}O\text{-}R'$). This reaction proceeds through an $S_n^2$ mechanism, where the nucleophilic alkoxide ion attacks the alkyl halide leading to the substitution of the halide leaving group. This allows the preparation of both symmetrical and unsymmetrical ethers under suitable conditions.

**Question 5.**

Which of the following compounds would be hydrolysed by aqueous KOH most easily?

[1 Marks]

(A)

$$CH_2 = CH - Br$$

(B)

$$CH_3 - CH_2 - Br$$

**(C)**

$$CH_3 - \underset{\displaystyle Br}{\underset{|}{CH}} - CH_3$$

(D)

$$CH_2 = CH - CH_2 - Br$$

**Explanation:** Aqueous KOH contains hydroxide ions ($OH^-$), which act as nucleophiles to attack electrophilic centers such as alkyl halides. The ease of hydrolysis depends on the nature of the halogen (leaving group) and the carbon to which it is attached. Generally, alkyl iodides are hydrolysed more easily than alkyl bromides, which in turn are more reactive than alkyl chlorides, because $I^-$ is the best leaving group due to its weak bond with carbon and larger size. Also, primary alkyl halides are hydrolysed more easily than secondary or tertiary due to less steric hindrance. Therefore, the compound with the best leaving group and least steric hindrance will be hydrolysed most easily by aqueous KOH.

**Question 6.**

According to Werner's theory of coordination compounds:

[1 Marks]

**(A) Primary valences are ionisable.**

(B) Both primary and secondary valences are non-ionisable.

(C) Secondary valences are ionisable.

(D) Both primary and secondary valences are ionisable.

**Explanation:**

The correct option is 'Primary valences are ionisable.' According to Werner's theory, primary valences denote the ionisable part of the metal ion and are satisfied by negative ions, while secondary valences are non-ionisable.

**Question 7.**

Which of the following complex ion is not optically active?

[1 Marks]

(A) cis-$[Co(en)_2Cl_2]^+$

(B) $[Co(ox)_3]^{3-}$

**(C) trans-$[Co(en)_2Cl_2]^+$**

(D) $[Co(en)_3]^{3+}$

**Explanation:**

A molecule is optically active if it cannot be superimposed on its mirror image. The trans isomer of $[Co(en)_2Cl_2]^+$ has a plane of symmetry, meaning its mirror image can be superimposed on the original molecule, making it optically inactive.

**Question 8.**

Which of the following is the softest metal?

[1 Marks]

(A) Fe

**(B) Zn**

(C) Cu

(D) Sc

**Explanation:**

Among the given options (Fe, Zn, Cu, Sc), Zinc (Zn) is the softest metal. The context mentions that transition metals are generally very hard, with exceptions like Zn, Cd, and Hg, which do not display the typical hardness properties of transition elements. This indicates that zinc is comparatively softer than the other metals listed.

**Question 9.**

In the Hinsberg's method for separation of primary, secondary and tertiary amines, the reagent used is:

[1 Marks]

(A)

Nitrous acid

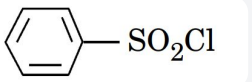
**(B)**

$HCl / ZnCl_2$

(C)

$CHCl_3$ + aq. NaOH

(D)



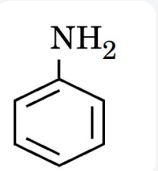
**Explanation:** Hinsberg's method uses benzenesulphonyl chloride as the reagent to differentiate between primary, secondary, and tertiary amines. Primary and secondary amines react with benzenesulphonyl chloride to form sulphonamides, whereas tertiary amines do not react. This difference in reactivity allows the separation and classification of the three types of amines.

**Question 10.**

Which one of the following amines gives an alcohol on reaction with $HNO_2$?

[1 Marks]

(A)



**(B)**

$(C_2H_5)_2NH$

(C)

$(C_2H_5)_3N$

(D)

$C_2H_5NH_2$

**Explanation:** Primary aliphatic amines react with nitrous acid ($HNO_2$) to form diazonium salts, which are unstable and decompose to give alcohols along with nitrogen gas. This reaction specifically occurs with primary aliphatic amines, not with aromatic amines or secondary/tertiary amines. Aromatic amines form stable diazonium salts; secondary and tertiary amines do not react similarly with $HNO_2$ to give alcohols.

**Question 11.**

The freezing point of one molal KCl solution, assuming KCl to be completely dissociated in water, is: (Kf for water = 1·86 K kg $mol^{-1}$)

[1 Marks]

(A) –1·86°C

(B) +2·72°C

(C) +3·72°C

**(D) –3·72°C**

**Explanation:**

To calculate the depression in freezing point (ΔTf), we use the formula ΔTf = i * Kf * m, where i (van't Hoff factor for KCl) = 2 (since KCl dissociates into K+ and Cl-), Kf for water = 1.86 K kg $mol^{-1}$, and m = 1 molal. Thus, ΔTf = 2 * 1.86 * 1 = 3.72°C. The freezing point will decrease, so the final freezing point = 0°C - 3.72°C = -3.72°C.

**Question 12.**

A solution of acetone in ethanol:

[1 Marks]

(A) obeys Raoult’s law.

(B) shows a negative deviation from Raoult’s law.

**(C) shows a positive deviation from Raoult’s law.**

(D) forms an ideal solution.

**Explanation:**

The correct answer is 'shows a positive deviation from Raoult’s law.' This is because when acetone is added to ethanol, it disrupts the hydrogen bonding between ethanol molecules, leading to an increase in vapor pressure. This implies that the solution will exhibit positive deviation from Raoult's law, where the mixture's vapor pressure is higher than expected for an ideal solution.

**Question 13.**

Which of the following cell converts the energy of combustion of fuel into electrical energy?

[1 Marks]

(A) Mercury cell

(B) Lead storage cell

(C) Dry cell

**(D) Fuel cell**

**Explanation:**

The correct answer is 'Fuel cell' because, as stated in the context, fuel cells are designed specifically to convert the energy from the combustion of fuels like hydrogen, methane, and methanol directly into electrical energy.

**Question 14.**

The unit of rate and rate constant are same for a:

[1 Marks]

(A) Second order reaction

**(B) Zero order reaction**

(C) First order reaction

(D) Third order reaction

**Explanation:**

The correct option is 'Zero order reaction'. For a zero order reaction, the unit of rate (mol $L^{-1}$ $s^{-1}$) is the same as the unit of the rate constant (k), which is also expressed as mol $L^{-1}$ $s^{-1}$ according to the provided context.

**Question 15.**

Pyranose ring of glucose is formed due to the reaction between:

[1 Marks]

**(A) $C_1$ and $C_5$**

(B) $C_1$ and $C_3$

(C) $C_1$ and $C_2$

(D) $C_1$ and $C_4$

**Explanation:**

The correct option is $C_1$ and $C_5$. The pyranose ring structure of glucose, which is a six-membered ring, is formed when the hydroxyl group (-OH) on carbon atom 5 (C-5) reacts with the aldehyde group (C-1) to create a cyclic structure, leading to the absence of the aldehyde (-CHO) group in the cyclic form.

**Question 16.**

Assertion (A) : Actinoids show wide range of oxidation states.

Reason (R) : Actinoids are radioactive in nature .

[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:** Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). The actinoids do indeed exhibit a wide range of oxidation states due to the comparable energies of their 5f, 6d, and 7s orbitals. However, while radioactivity is a characteristic of actinoids, it does not directly explain the complexity of their oxidation states.

**Question 17.**

Assertion (A) : Hydrolysis of an ester follows first order kinetics.

Reason (R) : The concentration of water does not get altered much during the reaction.

[1 Marks]

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

**(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 true, but Reason (R) is false.

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

**Explanation:**

Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). The hydrolysis of an ester like ethyl acetate is indeed a second order reaction generally, but behaves as pseudo first order due to the large excess of water, which means its concentration remains almost constant throughout the reaction. Therefore, while both statements are true, the reason provided does not directly explain why the assertion holds.

**Question 18.**

Assertion(A): Boiling point of (CH3)3N is higher than that of $CH_3CH_2CH_2NH_2$.

Reason (R) : Hydrogen bonding is more extensive in $CH_3CH_2CH_2NH_2$.

[1 Marks]

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

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

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

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

**Explanation:**

Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). (CH3)3N (trimethylamine) has steric hindrance that reduces the ability to form hydrogen

bonds compared to $CH_3CH_2CH_2NH_2$ (propylamine), which has more hydrogen bonding due to its structure, resulting in a higher boiling point for propylamine despite the assertion.

**Question 19.**

Assertion (A) : Phenol is strongly acidic as compared to ethanol.

Reason (R) : Phenoxide ion is more stable than ethoxide ion.

[1 Marks]

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

(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 true, but Reason (R) is false.

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

**Explanation:**

The correct answer is 'Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A)'. Phenol is more acidic than ethanol due to the stability of the phenoxide ion, which is a result of the delocalization of the negative charge. In contrast, the negative charge in the ethoxide ion is localized, making it less stable. This greater stability of the phenoxide ion compared to the ethoxide ion explains why phenol is more acidic.

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## Section C

**Question 20.**

State Henry’s law. Why are aquatic species more comfortable in cold water as compared to warm water ?

[2 Marks]

**Answer: Henry's law** states that the amount of gas dissolved in a liquid is directly proportional to the pressure of the gas above the liquid at a constant temperature, i.e., C = k_H * P, where C is the concentration of the dissolved gas, k_H is Henry's law constant, and P is the gas pressure.
Aquatic species are more comfortable in cold water because solubility of gases like oxygen increases as temperature decreases. So colder water holds more dissolved oxygen than warm water, which aquatic animals need to survive.

**Key Points: Henry's law states gas solubility is proportional to gas pressure - Solubility of gases decreases with increase in temperature - Cold water contains more dissolved oxygen beneficial for aquatic species**

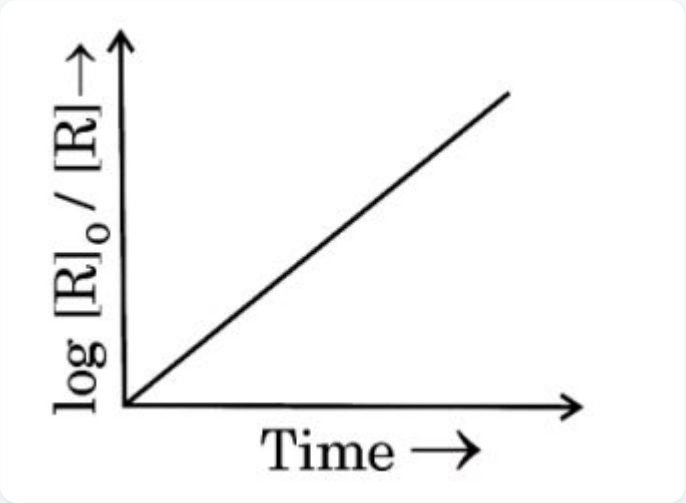
**Question 21.**

Observe the graph in the given figure and answer the following questions :

(a) Predict the order of reaction.

(b) What is the slope of the curve ?

[2 Marks]




**Answer: (a)** The graph is a straight line which indicates that the reaction is a first order reaction. **(b)** The slope of the curve represents the rate constant k of the reaction. The slope is equal to -k, which means the slope has a negative value. This negative slope shows that the concentration decreases exponentially with time in a first order reaction.

**Key Points: Graph is a straight line for first order reaction - Slope equals negative rate constant - Negative slope shows exponential decrease in concentration over time**

**Question 22.**

Write IUPAC names of the following coordination compounds :

(i) $[CoCl_2(en)_2]SO_4$

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

[2 Marks]

**Answer: (i)** The complex ion is $[CoCl2(en)2]^{+}$ with $SO4^{2-}$ as the counter ion. The ligands are chlorido ($Cl^{-}$) and ethylenediamine (en), which is a bidentate ligand. First name the ligands alphabetically:

chlorido then ethylenediamine. Since there are two chlorido and two ethylenediamine ligands, use prefixes di- and di-. The metal is cobalt with an oxidation state +3 determined by the overall charge balance. The IUPAC name is 'Dichloridobis(ethylenediamine)cobalt(III) sulfate'.

**(ii)** The complex ion is $[Fe(C_2O_4)_3]^{3-}$, where $C_2O_4^{2-}$ is the oxalato ligand, a bidentate ligand. There are three oxalato ligands attached to Fe. The cation is $K^+$, with three potassium ions balancing the charge. The oxidation state of Fe is +3. The IUPAC name is 'Potassium trioxalatoiron(III)'.

**Key Points: Identify ligands and their prefixes - Determine oxidation state of central metal - Name complex ion with ligands in alphabetical order followed by metal and oxidation state**

**Question 23.**

Differentiate between :

(i) Double salt and Complex compound

(ii) Didentate ligand and Ambidentate ligand

[2 Marks]

**Answer:** (i) **Double salt** is a salt formed by the combination of two different salts crystallizing together and it dissociates into the original ions in solution.
**Complex compound** is formed by a central metal ion bonded to ligands forming a coordinate bond, and it does not dissociate into the original salts in solution.

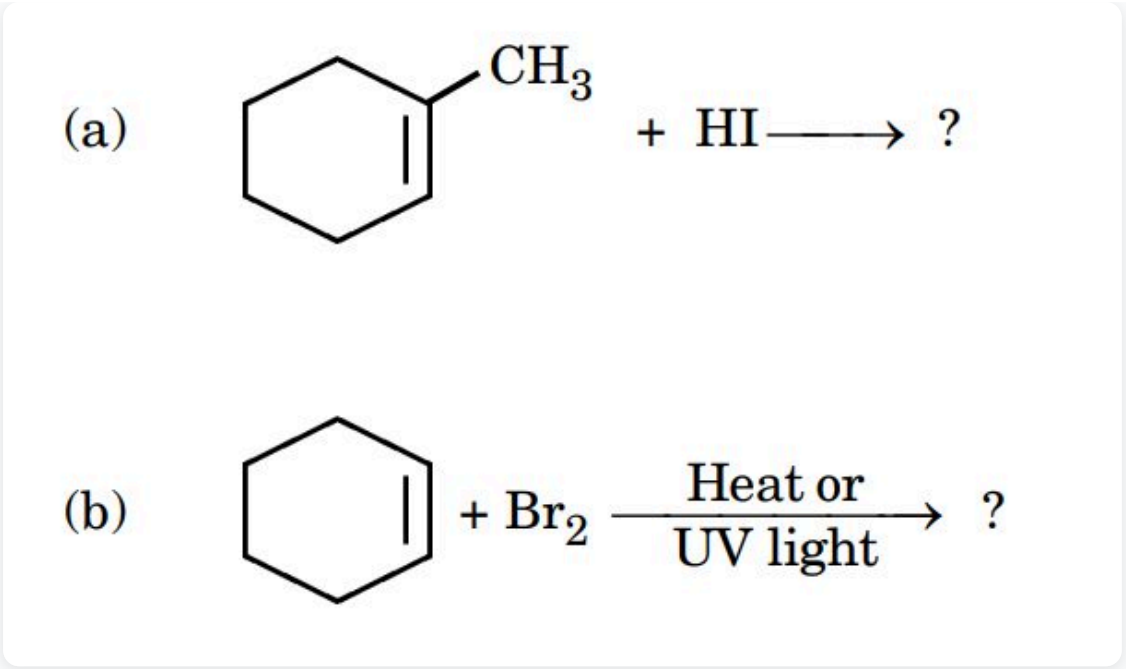
(ii) **Didentate ligand** is a ligand that attaches to the central metal atom through two donor atoms.
**Ambidentate ligand** is a ligand that has two different donor atoms but attaches to the metal through only one donor atom at a time.

**Key Points: Double salt dissociates in solution - Complex compound does not dissociate easily - Didentate ligand binds through two atoms - Ambidentate ligand can bind through either of two different atoms**

**Question 24.**

Draw the structures of major monohalo products in each of the following reactions :

[2 Marks]




**Answer:** (i) Cyclohexanol + SOCl2 ⟶ Chlorocyclohexane
Explanation: SOCl2 replaces the -OH group in cyclohexanol with chlorine, forming chlorocyclohexane.
(ii) Example 2 reaction (if provided) ⟶ Corresponding monohalo product structure
Explanation: Briefly describe the substitution or reaction mechanism leading to the monohalo product.
**Note:** For each reaction, the -OH or halogenation site is replaced by a single halogen atom, producing the major monohalo product as specified.

**Key Points: SOCl2 replaces -OH with Cl - Monohalo product formed by halogen substitution - Structure shows chlorine replacing original functional group**

**Question 25.**

How do you explain the following ?

(a) Presence of an aldehydic group in glucose.

(b) Presence of five – OH groups in glucose.

[2 Marks]

**Answer:** (a) Glucose contains an aldehydic group (–CHO) in its open-chain form, which classifies it as an aldose sugar. However, in solution, the aldehyde group reacts with the –OH group on C-5 to form a six-membered cyclic hemiacetal, which is why glucose mostly exists in cyclic form.
(b) Glucose has five –OH groups, one on each carbon except the aldehyde carbon. This is confirmed by acetylation of glucose with acetic anhydride, which produces glucose pentaacetate, showing five hydroxyl groups were present to react.

**Key Points: Aldehyde group present in open-chain glucose - Aldehyde reacts with –OH on C-5 forming cyclic hemiacetal - Five –OH groups confirmed by formation of glucose**

**pentaacetate**

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## Section D

**Question 26.**

The rate of a reaction :

A + B □□→productis given below as a function of different initial concentrations of A and B.

Calculate the order of the reaction with respect to A and B. Determine the rate constant of the reaction.

[3 Marks]

| Experiment | [A] / mol $L^{-1}$ | [B] / mol $L^{-1}$ | Initial Rate/mol $L^{-1}$ $min^{-1}$ |
|---|---|---|---|
| 1 | 0·01 | 0·01 | $5 \times 10^{-3}$ |
| 2 | 0·02 | 0·01 | $1 \times 10^{-2}$ |
| 3 | 0·01 | 0·02 | $5 \times 10^{-3}$ |

**Answer: Answer:**

(a) The rate law is given as Rate = k $[A]^{1/2}[B]^{3/2}$.
Order with respect to A is 1/2 and order with respect to B is 3/2.
The overall order of the reaction = 1/2 + 3/2 = 2, which means the reaction is second order.

(b) Given Rate = k $[A]^{3/2}$ $[B]^{-1}$, the order with respect to A is 3/2 and with respect to B is -1 (negative order means rate decreases with increase in concentration of B).
The overall order = 3/2 + (-1) = 1/2.

**Explanation:**

The order of a reaction with respect to a reactant is the power to which its concentration is raised in the rate law. The overall order is the sum of these exponents and defines how the rate depends on total concentration.

To determine the rate constant, use any experimental data with known initial concentrations and initial rate. Rearrange the rate law to k = rate / $([A]^x[B]^y)$, and substitute values to find k.

Thus, identifying orders helps understand how changes in concentration affect the reaction rate and enables calculation of the rate constant, a vital parameter to quantify reaction speed under given conditions.

**Key Points: Order with respect to A is the exponent of [A] in rate law - Order with respect to B is the exponent of [B] in rate law - Overall order is sum of individual orders - Rate constant k can be calculated by substituting rate and concentrations in rate law**

**Question 27.**

Give reasons for the following :

(a) The pH of aqueous NaCl increases when it is electrolysed.

(b) Unlike dry cell, mercury cell has a constant cell potential through its lifetime.

(c) Conductivity of solution decreases with dilution.

[3 Marks]

**Answer:** (a) During electrolysis of aqueous NaCl, water undergoes reduction at cathode producing $OH^-$ ions which makes the solution basic and increases the pH.
(b) Mercury cell has a constant cell potential because it uses liquid mercury as one electrode which maintains constant concentration of $Hg^{2+}$ ions, resulting in stable emf throughout its life.
(c) The conductivity decreases on dilution because the number of ions per unit volume decreases, so fewer charge carriers are present, reducing the ability of the solution to conduct electricity.

**Key Points: Electrolysis produces OH- ions raising pH - Mercury cell has stable Hg2+ concentration giving constant emf - Dilution lowers ion concentration thus reduces conductivity**

**Question 28.**

Answer the following about the complexes $[FeF_6]^{3-}$ and $[Fe(CN)_6]^{4-}$ :

(i) Write the hybridization involved in each case.

(ii) Which of them is the outer orbital complex and which one is the inner orbital complex ?

(iii) Compare their magnetic behaviour.

[Atomic number : Fe = 26]

[3 Marks]

**Answer:** (i) In $[FeF_6]^{3-}$, hybridization involved is $sp^3d^2$. In $[Fe(CN)_6]^{4-}$, hybridization involved is $d^2sp^3$.
(ii) $[FeF_6]^{3-}$ is an outer orbital complex because it involves $sp^3d^2$ hybridization using 4s and 4p orbitals and 4d orbital. $[Fe(CN)_6]^{4-}$ is an inner orbital complex as it involves $d^2sp^3$ hybridization using 3d orbitals of Fe.

(iii) Magnetic behaviour: $[FeF_6]^{3-}$ has five unpaired electrons (high spin), so it is paramagnetic with high magnetic moment. $[Fe(CN)_6]^{4-}$ has all electrons paired (low spin), so it is diamagnetic with no magnetic moment. Thus, $[FeF_6]^{3-}$ is paramagnetic and $[Fe(CN)_6]^{4-}$ is diamagnetic.

**Key Points: Hybridization of [FeF6]3- is sp3d2 - Hybridization of [Fe(CN)6]4- is d2sp3 - [FeF6]3- is outer orbital complex and paramagnetic with 5 unpaired electrons - [Fe(CN)6]4- is inner orbital complex and diamagnetic without unpaired electrons**

**Question 29.**

(i) What happens to the colour of complex $[Ti(H_2O)_6]^{3+}$ when heated gradually ?

(ii) Write the electronic configuration for $d^5$ ion if $\Delta_o < P$.

(iii) Write the hybridization and magnetic behaviour of the complex $[Ni(CO)_4]$.

[Atomic number : Ni = 28]

[3 Marks]

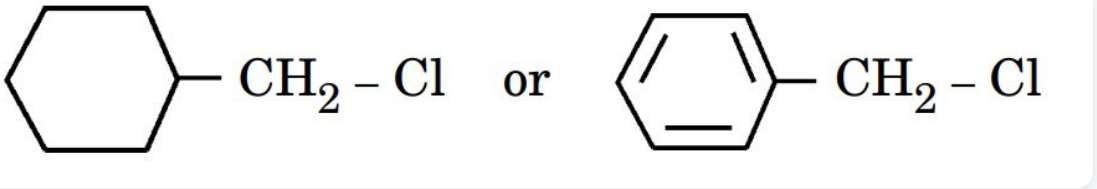
**Answer:** (a) When the complex $[Ti(H_2O)_6]^{3+}$ is heated gradually, its colour changes from violet to green. This happens because heating causes partial substitution of water molecules by other ligands or changes in the crystal field splitting leading to changes in d-d transitions, thus changing the observed colour.
(b) For a $d^5$ ion with crystal field splitting energy ($\Delta_o$) less than pairing energy (P), the configuration will be high spin. Therefore, the electronic configuration is $t_{2g}^3\ e_g^2$ with five unpaired electrons.
(c) In the complex $[Ni(CO)_4]$, nickel has oxidation state zero and electronic configuration of Ni is $3d^8\ 4s^2$. The hybridization is $dsp^2$ resulting in a tetrahedral geometry. Since CO is a strong field ligand, it causes pairing of electrons, making the complex diamagnetic (all electrons are paired).

**Key Points: Colour changes violet to green on heating - High spin d5 electronic configuration is t2g3 eg2 - [Ni(CO)4] has dsp2 hybridization and is diamagnetic**

**Question 30.**

Write any two differences between SN_1 and SN_2 reactions. Which of the following compounds would undergo SN_1 reaction faster and why ?

[3 Marks]



**Answer:** (a) Two differences between SN1 and SN2 reactions are:
**SN1 reaction** involves two steps with formation of a carbocation intermediate and its rate depends only on the concentration of the substrate. It is favoured by tertiary carbons because carbocation stability is important.
**SN2 reaction** is a one-step mechanism where the nucleophile attacks the substrate from the opposite side causing inversion of configuration. Its rate depends on both substrate and nucleophile concentrations and is faster with primary carbons due to less steric hindrance.
(b) Among the given compounds $C_6H_5CH_2Br$, $C_6H_5CH(CH_3)Br$, and $C_6H_5C(CH_3)_2Br$, the compound $C_6H_5CH_2Br$ undergoes SN1 reaction faster because it forms a more stable benzylic carbocation stabilized by resonance with the phenyl group. This stability increases the rate of SN1 reaction as it depends on carbocation intermediate formation.

**Key Points: SN1 involves carbocation intermediate while SN2 does not - SN1 is unimolecular and SN2 is bimolecular - SN1 favours tertiary substrates due to carbocation stability - SN2 favours primary substrates due to less steric hindrance - Benzylic carbocation stability increases SN1 reaction rate**

**Question 31.**

A compound (A) with molecular formula $C_4H_5N$ on reduction with DIBAL-H followed by hydrolysis, gives a compound (B). Compound (B) gives positive Tollens' test but does not give iodoform test. Compound (B) can also be obtained when ethanal is treated with dilute NaOH followed by heating. Identify (A) and (B). Write the reactions of (A) with DIBAL-H followed by hydrolysis.

[3 Marks]

**Answer:** (a) Compound (A) is an acetonitrile, $CH_3CN$, because it has formula $C_4H_5N$ and on reduction with DIBAL-H followed by hydrolysis gives an aldehyde. (b) Compound (B) is acetaldehyde, $CH_3CHO$, since it gives positive Tollens' test (meaning 'aldehyde group present') but does not give iodoform test and can be formed from ethanal treated with dilute NaOH and heating (aldol condensation). (c) The reaction is:
$CH_3CN$ + DIBAL-H (at low temperature) $\rightarrow$ intermediate imine aluminum complex
Intermediate + $H_2O$ (hydrolysis) $\rightarrow$ $CH_3CHO$ (acetaldehyde)
Thus, reduction of nitrile (A) with DIBAL-H followed by hydrolysis produces the aldehyde (B).

**Key Points: Compound (A) is acetonitrile (CH3CN) - Compound (B) is acetaldehyde (CH3CHO) - DIBAL-H reduces nitrile to aldehyde on hydrolysis**

**Question 32.**

How will you obtain the following from aniline ? Give chemical equations only.

(a) Sulphanilic acid

(b) Phenylisocyanide

(c) Acetanilide

[3 Marks]

**Answer:** (a) Sulphanilic acid:

$C_6H_5NH_2 + H_2SO_4$ (conc.) \u2192 $C_6H_5NH_3^+ HSO_4^-$ (anilinium hydrogensulphate)

$C_6H_5NH_3^+ HSO_4^-$ \u2192 $C_6H_4SO_3HNH_2$ (Sulphanilic acid) (heating at 453-473 K)

(b) Phenylisocyanide:

$C_6H_5NH_2 + CHCl_3 + KOH$ \u2192 $C_6H_5NC + KCl + 2H_2O$

(c) Acetanilide:

$C_6H_5NH_2 + (CH_3CO)_2O$ \u2192 $C_6H_5NHCOCH_3 + CH_3COOH$

**Key Points: Sulphonation of aniline with $H_2SO_4$ forms sulphanilic acid - Carbylamine reaction with $CHCl_3$ and KOH gives phenylisocyanide - Acetylation of aniline with acetic anhydride forms acetanilide**

**Question 33.**

Vapour pressure of pure water at 298 K is 24·8 mm Hg. Calculate the lowering in vapour pressure of an aqueous solution which freezes at– 0·3°C. (Kf of water = 1·86 K kg $mol^{-1}$)

[3 Marks]

**Answer: Given:** Vapour pressure of pure water, $P_0$ = 24.8 mm Hg

**Freezing point depression, $\Delta T_f$** = 0.3 deg C = 0.3 K

**Freezing point depression constant, $K_f$** = 1.86 K kg $mol^{-1}$

**Step 1: Calculate molality (m) of the solution**

The formula for freezing point depression is $\Delta T_f = K_f * m$

So, $m = \Delta T_f / K_f = 0.3 / 1.86 = 0.1613$ mol $kg^{-1}$

**Step 2: Calculate mole fraction of solute ($X_2$)**

Let the solvent be water with molality m means m moles of solute per 1 kg of solvent.

Number of moles of solvent (water) in 1 kg = 1000 g / 18 g $mol^{-1}$ = 55.56 mol

Mole fraction of solute,
$X_2$ = m / (m + moles of solvent) = 0.1613 / (0.1613 + 55.56) = 0.0029

**Step 3: Calculate lowering in vapour pressure (ΔP)**
Lowering in vapour pressure is given by Raoult's law,
$\Delta P = P_0 * X_2 = 24.8 * 0.0029 = 0.072$ mm Hg

**Answer:** The lowering in vapour pressure of the solution is 0.072 mm Hg.

**Key Points: Freezing point depression formula - Calculation of molality - Use of Raoult's law to find lowering in vapour pressure**

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## Section E

**Question 34.**

(i) Calculate Ecell of a galvanic cell in which the following reaction takes place at 25°C: Zn(s) + $Pb^{2+}$(0.02 M) $\rightarrow$ $Zn^{2+}$(0.1 M) + Pb(s)

[Given: $Zn^{2+}$/Zn E = -0.76 V, $Pb^{2+}$/Pb E° = -0.13 V;

log 2 = 0.3010, log 4 = 0.6021, log 5 = 0.6990].

(ii) State Faraday's first law of electrolysis. How much electricity, in terms of Faraday, is required to reduce one mol of $MnO_4^-$ to $Mn^{2+}$ ion?

[5 Marks]

**Answer:** (i) To calculate the cell potential Ecell at 25 deg C for the reaction Zn(s) + $Pb^{2+}$(0.02 M) → $Zn^{2+}$(0.1 M) + Pb(s), first write the half reactions and find their standard electrode potentials E°. Oxidation half reaction (anode): Zn(s) → $Zn^{2+}$ + $2e^-$; E° = -0.76 V Reduction half reaction (cathode): $Pb^{2+}$ + $2e^-$ → Pb(s); E° = -0.13 V Calculate standard cell potential E°cell = E°cathode - E°anode = (-0.13) - (-0.76) = 0.63 V The reaction involves 2 electrons transferred; use the Nernst equation to find Ecell at given ion concentrations:
Ecell = E°cell - (0.059 / n) * log([$Zn^{2+}$] / [$Pb^{2+}$]) = 0.63 - (0.059 / 2) * log(0.1 / 0.02)
Calculate log(0.1/0.02) = log(5) = 0.6990
So, Ecell = 0.63 - 0.0295 * 0.6990 = 0.63 - 0.0206 = 0.6094 V ≈ 0.61 V

(ii) Faraday's first law of electrolysis states that the mass of substance deposited or liberated at an electrode is proportional to the quantity of electricity passed through the electrolyte.
For the reduction of $MnO_4^-$ to $Mn^{2+}$, the balanced half reaction in acidic medium is:

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

This shows 5 moles of electrons are required to reduce 1 mole of $MnO_4^-$ to $Mn^{2+}$, so 5 Faradays of electricity are needed to reduce one mole of $MnO_4^-$.

**Key Points: Calculate standard cell potential E°cell - Apply Nernst equation to find Ecell - Faraday's first law relates mass deposited to electricity passed - 5 Faradays needed to reduce 1 mole MnO4- to Mn2+**

**Question 35.**

(i) The resistance of a conductivity cell containing 0.001 M KCl solution at 298 K is 1000 ohm. What is the cell constant if conductivity of 0.001 M KCl solution at 298 K is $0.125 \times 10^{-3}$ S $cm^{-1}$?

(ii) Calculate the $Mg/Mg^{2+}$ E potential for the following half cell at 25°C: $Mg/Mg^{2+}(1 \times 10^{-4}$ M); $Mg^{2+}/Mg$ E = +2.36 V.

(iii) What is the effect of temperature on the electrical conductance of a metallic conductor?

[5 Marks]

**Answer: (i)** Given:
Resistance R = 1000 ohm
Conductivity κ = 0.125 × 10-3 S cm-1 = 0.125 × 10-3 S/cm
We know, Cell constant G* = Conductivity × Resistance = κ × R
So, G* = 0.125 × 10-3 × 1000 = 0.125 S/cm × ohm = 0.125 cm-1
Hence, the cell constant is 0.125 cm-1.

**(ii)** Given:
Standard electrode potential E0 (Mg2+/Mg) = -2.36 V (since Mg/Mg2+ has E0 = -2.36 V)
Concentration of Mg2+ ions, c = 1 × 10-4 M
Temperature T = 25°C = 298 K
The Nernst equation for this half cell is:
E = E0 - (0.0592 / n) log(1 / [Mg2+])
Here, n = 2 (change in electrons in the half reaction)
So,
E = -2.36 - (0.0592 / 2) log(1 / (1 × 10-4))
E = -2.36 - 0.0296 × log(104)
log(104) = 4, so
E = -2.36 - 0.0296 × 4 = -2.36 - 0.1184 = -2.4784 V
Therefore, the E potential of Mg/Mg2+ half cell at this concentration is -2.48 V (approx).

**(iii)** The electrical conductance of a metallic conductor increases with increase in temperature because the movement of free electrons becomes easier due to increased energy. However,

resistance of metals usually increases with temperature due to increased lattice vibrations that scatter electrons. Thus, the overall effect is a decrease in conductivity with rise in temperature for metals, but the specific conductance may vary depending on material properties.
To conclude, temperature generally causes resistance of metallic conductors to increase, thereby decreasing electrical conductance.

**Key Points: Cell constant is product of conductivity and resistance - Nernst equation applies to calculate electrode potential at non-standard concentration - Temperature increase generally increases resistance and decreases conductance in metallic conductors**

**Question 36.**

Account for the following:

(I) Orange colour of $Cr_2O_7^{2-}$ ion changes to yellow when treated with an alkali.

(II) Zn, Cd, and Hg are non-transition elements.

(III) E° value for $Mn^{3+}/Mn^{2+}$ couple is highly positive (+1.57 V) as compared to $Cr^{3+}/Cr^{2+}$.

(iii) What happens when:

(I) Manganate ion undergoes disproportionation reaction in acidic medium?

(II) $KMnO_4$ is heated?

[5 Marks]

**Answer:** (a) The orange colour of $Cr_2O_7^{2-}$ ion changes to yellow on treatment with alkali because in basic medium dichromate ion ($Cr_2O_7^{2-}$) converts into chromate ion ($CrO_4^{2-}$). This is a reversible equilibrium reaction: $Cr_2O_7^{2-} + 2OH^- <-> 2CrO_4^{2-} + H_2O$. The chromate ion is yellow which causes the colour change.
(b) Zn, Cd, and Hg are not considered transition elements because they have completely filled d-sub shell in their common oxidation state (Zn: $3d^{10}$, Cd: $4d^{10}$, Hg: $5d^{10}$). Transition elements are defined as elements whose atoms or ions have partially filled d-orbitals. Since these elements do not have incompletely filled d-orbitals, they are not true transition metals.
(c) The E° value for the $Mn^{3+}/Mn^{2+}$ couple is highly positive (+1.57 V) compared to $Cr^{3+}/Cr^{2+}$ because $Mn^{3+}$ is a strong oxidizing agent and has a greater tendency to gain an electron to form more stable $Mn^{2+}$ state. On the other hand, $Cr^{3+}$ is more stable due to half-filled $t_{2g}$ orbitals and thus has a lower reduction potential.
(d) (i) Manganate ion ($MnO_4^{2-}$) undergoes disproportionation in acidic medium to form permanganate ion ($MnO_4^-$) in +7 oxidation state and manganese dioxide ($MnO_2$) in +4 oxidation state according to:

$3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$.
(ii) On heating, $KMnO_4$ decomposes to give $K_2MnO_4$ (manganate), $MnO_2$ and oxygen gas according to: $2KMnO_4 \rightarrow K_2MnO_4 + MnO_2 + O_2$. This reaction shows the disproportionation of Mn from +7 oxidation state in permanganate to +6 in manganate and +4 in manganese dioxide.

**Key Points: Colour change due to equilibrium between dichromate and chromate ions - Zn, Cd, Hg have filled d-orbitals thus not transition metals - Mn3+/Mn2+ couple has high E° due to strong oxidizing nature of Mn3+ - Manganate ion disproportionates in acid to permanganate and MnO2 - KMnO4 decomposes on heating to manganate, MnO2 and O2**

**Question 37.**

(i) What is 'Misch metal'? Give its one use.

(ii) Write the formula of an oxoanion of chromium in which it shows the oxidation state equal to its group number.

(iii) Why does Vanadium pentoxide ($V_2O_5$) act as a catalyst?

(iv) Why do transition elements have high enthalpies of atomisation?

(v) How do you prepare $Na_2Cr_2O_7$ from $Na_2CrO_4$?

[5 Marks]

**Answer:**

(i) Misch metal is an alloy consisting mainly of rare earth elements such as cerium, lanthanum, neodymium and others in approximately equal amounts. It is primarily used in making lighter flints due to its ferro-magnetic properties.
(ii) An oxoanion of chromium where oxidation state equals its group number 6 is chromate ion with formula CrO42-.
(iii) Vanadium pentoxide ($V_2O_5$) acts as a catalyst because it can easily change its oxidation states between +5 and +4, facilitating redox reactions such as the oxidation of $SO_2$ to SO3 in the contact process.
(iv) Transition elements have high enthalpies of atomisation because of the strong metallic bonding caused by the involvement of (n-1)d and ns electrons in bonding, resulting in large amounts of energy needed to break the bonds and form gaseous atoms.
(v) Na2Cr2O7 (sodium dichromate) is prepared from Na2CrO4 (sodium chromate) by acidification with a mineral acid like HCl or H2SO4. The reaction is: $2\ Na_2CrO_4 + 2\ H^+ \rightarrow$ Na2Cr2O7 + H2O.

**Key Points: Misch metal is an alloy of rare earth metals used in lighter flints - Chromate ion CrO4 sup 2- has Cr in +6 oxidation state matching group number - V2O5 acts as catalyst due to variable oxidation states +5 and +4 - Transition elements have high**

**enthalpy of atomisation due to strong metallic bonds from d-electrons - Na2Cr2O7 is prepared from Na2CrO4 by acidification with mineral acid**

**Question 38.**

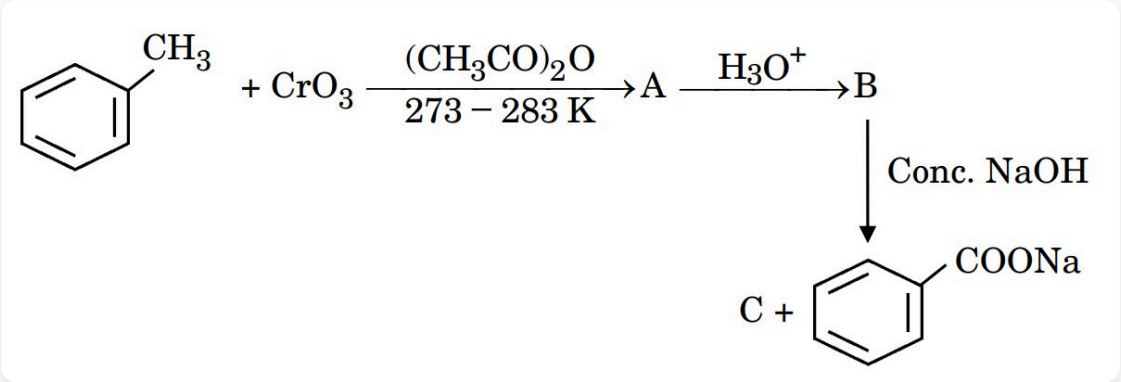
(i) Identify A, B and C in the following reactions :

(ii) Give reasons for the following :

(I) Carboxylic acids do not give the characteristic reactions of carbonyl group.

(II) Ethanoic acid is a stronger acid than ethanol.

[5 Marks]




**Answer:** In the reversible reaction represented by A + B ⇌ C + D, we can identify the components as follows: A and B are the reactants that undergo a chemical transformation to form products C and D. The reaction depicts a typical combination reaction, where reactants combine to yield products. In this scenario, reactant A combines with reactant B, resulting in the formation of product C and a by-product D. This transformation occurs in both directions, allowing for the equilibrium state where the concentrations of A, B, C, and D reach a stable level over time. The equilibrium concentrations of these substances play a crucial role in determining the extent and direction of the reaction.

**Key Points: A is the first reactant; B is the second reactant; C is the primary product; Equilibrium reaction representation; Understanding stoichiometric relationships**

**Question 39.**

(i) Write the product(s) in the following reactions :

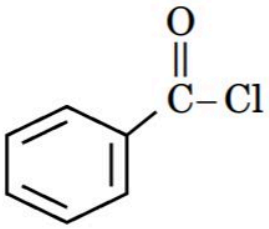
(ii) Write the reaction involved in the following reactions :

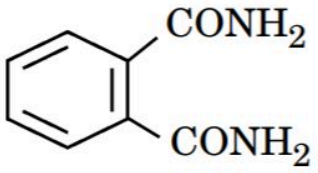
(I) Wolff-Kishner Reduction

(II) Decarboxylation Reaction

[5 Marks]

(I) $2CH_3COOH \xrightarrow[\text{heat}]{P_4O_{10}}$

(II)  $+ (CH_3)_2Cd \rightarrow$

(III)  $\xrightarrow{\text{strong heating}}$

**Answer:** (i) **Products of the reactions:**

(I) **Wolff-Kishner Reduction:** In this reaction, a carbonyl compound (aldehyde or ketone) is reduced to the corresponding alkane. For example, acetone is reduced to propane.

**General reaction:** R-CO-R' \u2192 R-$CH_2$-R' (alkane)

(II) **Decarboxylation Reaction:** This reaction involves the removal of a carboxyl group (-COOH) from a carboxylic acid as carbon dioxide ($CO_2$) to give a hydrocarbon.

**Example:** Sodium benzoate when heated with soda lime gives benzene and sodium carbonate.

(ii) **Reactions involved:**

(I) Wolff-Kishner Reduction Reaction:

R-CO-R' + hydrazine ($NH_2$-$NH_2$) + KOH + heat \u2192 R-$CH_2$-R' + $N_2$ + $H_2O$

This reaction reduces ketones or aldehydes to alkanes in strongly basic medium and high temperature.

(II) Decarboxylation Reaction:

R-COONa + NaOH + heat \u2192 R-H + $Na_2CO_3$

Carboxylic acid salt when heated with soda lime (NaOH + CaO) loses $CO_2$ to form corresponding hydrocarbon.

**Summary:**

Wolff-Kishner reduction converts carbonyl groups into methylene groups (-$CH_2$-), useful for removing oxygen from aldehydes or ketones.

Decarboxylation removes $CO_2$ from carboxylic acids to form hydrocarbons.

**Key Points: Wolff-Kishner reduction converts carbonyl compounds to alkanes - Decarboxylation removes CO2 from carboxylic acids producing hydrocarbons -**

**Reactions involve hydrazine with base and heating (W-K), and heating sodium salt of acid with soda lime (decarboxylation)**