CBSE EXAMINATION PAPER-2023

CHEMISTRY

(Solved)

Time allowed : 3 hours | Maximum Marks : 79

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **41 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 21** are multiple choice questions

v. **Section C** – questions number **22 to 30** are very short answer

vi. **Section D** – questions number **31 to 36** are short answer

vii. **Section E** – questions number **37 to 41** 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 polarity of C–X bond of alkyl halides is responsible for their nucleophilic substitution, elimination and their reaction with metal atoms to form organometallic compounds. Alkyl halides are prepared by the free radical halogenation of alkanes, addition of halogen acids to alkenes, replacement of OH group of alcohols with halogens using phosphorus halides, thionyl chloride or halogen acids. Aryl halides are prepared by electrophilic substitution of arenes. Nucleophilic substitution reactions are categorised into SN1 and SN2 on the basis of their kinetic properties. Chirality has a profound role in understanding the SN1 and SN2 mechanism.

Question 2.

The following questions are case-based questions. Read the case carefully and answer the questions that follow

The polarity of C- X bond of alkyl halides is responsible for their nucleophilic substitution, elimination and their reaction with metal atoms to form organometallic compounds. Alkyl halides are prepared by the free radical halogenation of alkanes, addition of halogen acids to alkenes, replacement of - OH group of alcohols with halogens using phosphorus halides, thionyl chloride or halogen acids. Aryl halides are prepared by electrophilic substitution of arenes. Nucleophilic substitution reactions are categorised into SN1 and SN2 on the basis of their kinetic properties. Chirality has a profound role in understanding the SN1 and SN2 mechanism.

(1)

What happens when bromobenzene is treated with Mg in the presence of dry ether ?

[1 Marks]

Answer: When bromobenzene is treated with magnesium in dry ether, it forms phenyl magnesium bromide, a Grignard reagent. This organometallic compound is very useful in organic synthesis and confirms the reaction of alkyl halides with metals to form organometallic compounds as mentioned in the case study.

Key Points: Bromobenzene reacts with Mg - Requires dry ether - Formation of phenyl magnesium bromide (Grignard reagent) - Organometallic compound formation

(2)

Write the equations for the preparation of 1-iodobutane from

(1) 1-chlorobutane

(2) but-1-ene.

[2 Marks]

Answer: (1) 1-chlorobutane reacts with sodium iodide in acetone to give 1-iodobutane by nucleophilic substitution: C_4H_9Cl + NaI \u2192 C_4H_9I + NaCl

(2) But-1-ene reacts with hydrogen iodide (HI) to form 1-iodobutane by electrophilic addition: CH_2=$CHCH_2CH_3$ + HI \u2192 C_4H_9I

These methods align with the case passage that alkyl halides can be prepared by halogen substitution and addition of halogen acids to alkenes.

Key Points: Preparation of 1-iodobutane from 1-chlorobutane by nucleophilic substitution with NaI - Preparation of 1-iodobutane from but-1-ene by electrophilic addition of HI - Reference to polarity of C-X bond and types of alkyl halide preparations from the case passage

(3)

Which compound in each of the following pairs will react faster in SN1 reaction with OH- ?

(1) CH_2 = CH- CH_2- Cl or CH_3- CH_2- CH_2- Cl

(2) $(CH_3)_3$C- Cl or CH_3Cl

[1 Marks]

Answer: Answer: (1) CH2 = CH- CH2- Cl reacts faster than CH3- CH2- CH2- Cl because allylic carbons stabilize carbocation better, aiding SN1 reaction.

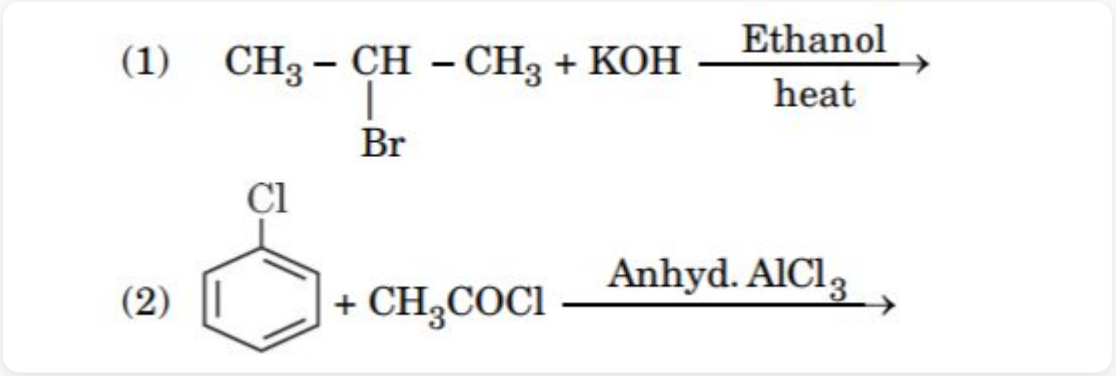
(2) (CH3)3C- Cl reacts faster than CH3Cl as tertiary carbocation formed is more stable, favoring SN1 mechanism.

This is due to polarity of C-X bond and carbocation stability shown in the case passage.

Key Points: SN1 reaction rate depends on carbocation stability - Tertiary carbocations are more stable than primary - Allylic carbocations stabilize via resonance, increasing SN1 rate

(4)

Write the structure of the major products in each of the following reactions :



[2 Marks]

Answer:

(1) Reactant: **2-bromopropane (isopropyl bromide)**
Reagent: **KOH in ethanol, heat → Alcoholic KOH** favors **elimination (E2)**.

So, **dehydrohalogenation** occurs:

CH3−CH(Br)−CH3alc. KOHheatCH2=CH−CH3+KBr+H2O

Major product: 👉 Propene (CH_2=CH–CH_3)

(2) Reactants: **Chlorobenzene + CH_3COCl**
Reagent: **Anhydrous $AlCl_3$ → Friedel–Crafts acylation**.

- **Cl** is **ortho/para directing** (though deactivating).
- **Para product** is major due to **less steric hindrance**.

So, acyl group **–$COCH_3$** enters mainly at **para position**.

Major product: 👉 p-Chloroacetophenone

Structure (in words):
Benzene ring with **Cl** and **–$COCH_3$** in **para** position.

i.e. **4-chloroacetophenone**

> **Key Points: Polarity of C-X bond influences reactions - Alkyl halides undergo nucleophilic substitution and elimination - Products depend on reagents like CH3COO- and reaction conditions**

Question 3.

Coordination compounds are widely present in the minerals, plant and animal worlds and are known to play many important functions in the area of analytical chemistry, metallurgy, biological systems and medicine. Alfred Werner's theory postulated the use of two types of linkages (primary and secondary), by a metal atom/ion in a coordination compound. He predicted the geometrical shapes of a large number of coordination entities using the property of isomerism. The Valence Bond Theory (VBT) explains the formation, magnetic behaviour and geometrical shapes of coordination compounds. It, however, fails to describe the optical properties of these compounds. The Crystal Field Theory (CFT) explains 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.

(1)

When a coordination compound $NiCl_2 . 6H_2O$ is mixed with $AgNO_3$ solution, 2 moles of AgCl are precipitated per mole of the compound. Write the structural formula of the complex and secondary valency for Nickel ion.

[1 Marks]

Answer: When $NiCl_2 . 6H_2O$ reacts with $AgNO_3$, 2 moles of AgCl precipitate, indicating 2 chloride ions are outside the coordination sphere. So, the complex ion is $[Ni(H_2O)_4Cl]^+$ with 2 Cl^- ions outside. Thus, the structural formula is $[Ni(H_2O)_4Cl]Cl_2$. The secondary valency (coordination number) for Nickel is 5.

Key Points: 2 moles of AgCl means 2 Cl ions are outside coordination sphere - Structural formula is [Ni(H2O)4Cl]Cl2 - Secondary valency (coordination number) of Ni is 5

(2)

Write the IUPAC name of the ionisation isomer of $[Co(NH_3)_5(SO_4)]Cl$.

Answer: The ionisation isomer of [Co(NH3)5(SO4)]Cl is [Co(NH3)5Cl]SO4. The IUPAC name of this complex is pentaamminechloridocobalt(III) sulfate. Ionisation isomers differ in the position of ions inside and outside the coordination sphere. This concept is explained by Werner's theory mentioned in the passage.

Key Points: Ionisation isomers differ by interchange of ions inside and outside the coordination sphere - Ionisation isomer of [Co(NH3)5(SO4)]Cl is [Co(NH3)5Cl]SO4 - IUPAC name is pentaamminechloridocobalt(III) sulfate

(3)

Using Valence Bond Theory, predict the geometry and magnetic nature of :

(1) $[Ni(CO)_4]$

(2) $[Fe(CN)_6]^{3-}$

[Atomic number : Ni = 28, Fe = 26]

[2 Marks]

Answer: Using Valence Bond Theory, (1) In [Ni(CO)4], Ni has electronic configuration 3d8 4s2. CO is a strong field ligand causing pairing of electrons, so hybridisation involves dsp2 giving a tetrahedral geometry and diamagnetic nature.
(2) In [Fe(CN)6]3-, Fe3+ has configuration 3d5 4s0. CN- is strong field leading to pairing of electrons and d2sp3 hybridisation giving octahedral geometry and diamagnetic behavior as electrons are paired. This explanation is based on VBT as stated in the case passage.

Key Points: Valence Bond Theory explains magnetic behaviour - CO is strong field ligand causing pairing - [Ni(CO)4] is tetrahedral and diamagnetic - CN- causes pairing in Fe3+ - [Fe(CN)6]3- is octahedral and diamagnetic

(4)

Give reasons :

(1) Low spin tetrahedral complexes are not formed.

(2) $[Co(NH_3)_6]^{3+}$ is an inner orbital complex whereas $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex.

[Atomic number : Co = 27, Ni = 28]

[2 Marks]

Answer:

(1) Low spin tetrahedral complexes are not formed because tetrahedral complexes have weak ligand fields and cause small splitting of d orbitals, which is never enough to force pairing of electrons. Hence, tetrahedral complexes are always high spin according to Crystal Field Theory.
(2) $[Co(NH_3)_6]^{3+}$ is an inner orbital complex because Co^{3+} ion (d^6 configuration) undergoes dsp2 hybridisation using 3d orbitals after pairing electrons. In contrast, $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex because Ni^{2+} ion (d□ configuration) uses s and p orbitals only (sp3 hybridisation) without pairing electrons in d orbitals. This explains their different electronic structures as described by Valence Bond Theory in the case passage.

Key Points: Low spin tetrahedral complexes not formed due to weak ligand field and small d orbital splitting - Co(III) has d6 configuration allowing pairing and dsp2 hybridisation forming inner orbital complex - Ni(II) has d8 configuration with unpaired electrons using sp3 hybridisation forming outer orbital complex

Section B

Question 4.

Which of the following is not true about enantiomers?

[1 Marks]

(A) They have the same specific rotation.

(B) They have the same chemical reactivity.

(C) They have the same density.

(D) They have the same melting or boiling point.

Explanation:

Enantiomers are chiral molecules that are mirror images of each other. They have the same chemical reactivity, density, and melting or boiling points, but they possess different specific rotations because they rotate plane-polarized light in opposite directions. Thus, the correct option is that they have the same specific rotation, which is not true.

Question 5.

Aspirin is obtained by the acetylation of which of the following compounds?

[1 Marks]

(A) Salicylic acid

(B) Phenol

(C) Acetyl salicylic acid

(D) Salicylaldehyde

Explanation:

The correct answer is Salicylic acid. Aspirin, also known as acetylsalicylic acid, is synthesized through the acetylation of salicylic acid, which introduces an acetyl group to the compound, leading to the formation of aspirin.

Question 6.

The reactivities of the carbonyl compounds HCHO (I), CH_3CHO (II) and CH_3COCH_3 (III) towards nucleophilic addition reaction decreases in the order:

[1 Marks]

(A) II > III > I

(B) I > III > II

(C) III > II > I

(D) I > II > III

Explanation: The reactivity of carbonyl compounds towards nucleophilic addition depends on the steric and electronic effects. Formaldehyde (HCHO, I) is the most reactive due to its less steric hindrance and stronger electrophilic character. Acetaldehyde (CH_3CHO, II) is less reactive than formaldehyde because the methyl group adds steric hindrance and slightly donates electron density.

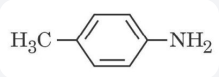
Acetone (CH_3COCH_3, III), having two methyl groups, is the least reactive due to increased steric hindrance and lower electrophilicity. Therefore, the correct order of reactivity is I > II > III.

Question 7.

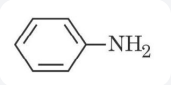
Among the following, which is the strongest base?

[1 Marks]

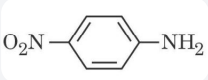
(A)



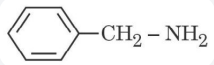
(B)



(C)



(D)



Explanation: Dimethylamine is the strongest base among the listed options because it has the largest ionization constant (K_b). The larger the K_b value, the stronger the base as it ionizes more in solution to accept hydrogen ions. Chemically, dimethylamine has an amine group with two methyl groups attached, increasing its electron-donating ability and thus its basicity. Therefore, based on the ionization constant and chemical structure, dimethylamine is the strongest base here.

Question 8.

On hydrolysis, which of the following carbohydrates gives only glucose?

[1 Marks]

(A) Lactose

(B) Sucrose

(C) Starch

(D) Fructose

Explanation:

The correct answer is Starch. Starch is a polysaccharide made up entirely of glucose units. Upon hydrolysis, it breaks down into individual glucose molecules. Lactose and sucrose yield other monosaccharides upon hydrolysis; lactose yields glucose and galactose, while sucrose yields glucose and fructose.

Question 9.

Which of the following vitamins is water soluble?

[1 Marks]

(A) Vitamin E

(B) Vitamin A

(C) Vitamin D

(D) Vitamin C

Explanation:

Vitamin C is a water-soluble vitamin, meaning it dissolves in water and is readily absorbed by the body. In contrast, Vitamins A, E, and D are fat-soluble, which means they are stored in the body's fatty tissues.

Question 10.

The unit of the rate of reaction is the same as that of the rate constant for a:

[1 Marks]

(A) first order reaction

(B) it cannot be same

(C) zero order reaction

(D) second order reaction

Explanation:

The correct answer is 'first order reaction'. For a first order reaction, the rate of reaction is expressed as concentration per unit time (M/s), and the rate constant also has the same unit (s^{-1}). This means that their units are indeed the same, making this option correct.

Question 11.

Kohlrausch gave the following relation for strong electrolyte:

$\Lambda = \Lambda_0 - A\sqrt{C}$ Which of the following equality holds true?

[1 Marks]

(A) $\Lambda = \Lambda_0$ as $C \rightarrow 1$

(B) $\Lambda = \Lambda_0$ as $C \rightarrow 0$

(C) $\Lambda = \Lambda_0$ as $C \rightarrow \infty$

(D) $\Lambda = \Lambda_0$ as $C \rightarrow \sqrt{A}$

Explanation:

The correct option is $\Lambda = \Lambda_0$ as $C \rightarrow 0$. This is because at infinite dilution (when concentration C approaches zero), the conductivity of the electrolyte is at its maximum, and the limiting molar conductivity (Λ_0) reflects this complete dissociation. Thus, as C approaches 0, the term $A\sqrt{C}$ becomes negligible, leading to $\Lambda = \Lambda_0$.

Question 12.

An azeotropic mixture of two liquids has a boiling point higher than either of the two liquids when it:

[1 Marks]

(A) obeys Raoult's law.

(B) shows large positive deviation from Raoult's law.

(C) shows no deviation from Raoult's law.

(D) shows large negative deviation from Raoult's law.

Explanation:

The correct answer is 'shows large negative deviation from Raoult's law.' This is because a maximum boiling azeotrope, which has a boiling point higher than either of its components, results from large negative deviations from Raoult's law. The context explains that such mixtures involve stronger intermolecular attractions between the different components, leading to a boiling point that is higher than that of the individual liquids.

Question 13.

Which of the following colligative property is used to find the molar mass of proteins?

[1 Marks]

(A) Depression in freezing point

(B) Relative lowering of vapour pressure

(C) Elevation in boiling point

(D) Osmotic pressure

Explanation:

The correct option is 'Osmotic pressure' because it is a colligative property that depends on the number of solute particles in a solution. By measuring the osmotic pressure, we can determine the molar mass of the solute, which in this case can be proteins.

Question 14.

Among the following outermost configurations of transition metals which one shows the highest oxidation state?

[1 Marks]

(A) $3d^5 4s^2$

(B) $3d^3 4s^2$

(C) $3d^5 4s^1$

(D) $3d^6 4s^2$

Explanation:

The outermost configuration $3d^5 4s^1$ corresponds to the highest oxidation state because it indicates one electron in the 4s subshell and five in the 3d subshell, allowing the metal to lose a total of six electrons when oxidized, maximizing the oxidation state.

Question 15.

How many ions are produced in the solution from the complex $[Ni(NH_3)_6]Cl_2$?

[1 Marks]

(A) 5

(B) 3

(C) 2

(D) 4

Explanation:

The complex $[Ni(NH_3)_6]Cl_2$ dissociates into one $[Ni(NH_3)_6]^{2+}$ ion and two Cl^- ions in solution. Therefore, the total number of ions produced is 1 + 2 = 3.

Question 16.

Which of the following species is not expected to be a ligand?

[1 Marks]

(A) NH_3

(B) NH_4^+

(C) CO

(D) H_2O

Explanation:

The correct answer is NH_4^+. A ligand is a molecule that can donate a pair of electrons to a metal ion to form a coordinate bond. NH_4^+ (ammonium ion) does not have a lone pair of electrons to donate, whereas NH_3, CO, and H_2O do have available lone pairs to act as ligands.

Question 17.

Which of the following is the most stable complex species?

[1 Marks]

(A) $[Fe(C_2O_4)_3]^{3-}$

(B) $[Fe(CO)_5]$

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

(D) $[Fe(H_2O)_6]^{3+}$

Explanation:

$[Fe(CN)_6]^{3-}$ is the correct answer because cyanide (CN^-) is a strong field ligand that forms stable complexes with iron, resulting in a high degree of stability due to strong ligand field stabilization. In comparison, other ligands such as oxalate ($C_2O_4^{2-}$), carbon monoxide (CO), and water (H_2O) do not provide as much stability as cyanide.

Question 18.

Assertion (A) : Order and molecularity of a reaction are always same.

Reason (R) : Complex reactions involve a sequence of elementary reactions and the slowest step is rate determining.

[1 Marks]

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

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

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

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

Explanation:

Assertion (A) is false, but Reason (R) is true. The order of a reaction, which is determined by the rate law and the concentration of reactants, does not always match its molecularity, which is the number of molecules involved in an elementary reaction. Complex reactions can have different orders compared to their molecularity due to multiple steps involved.

Question 19.

Assertion (A) : Electrolysis of aqueous solution of NaCl gives chlorine gas at anode instead of oxygen gas.

Reason (R) : Formation of oxygen gas at anode requires overpotential.

[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, but Reason (R) is not the correct explanation of the Assertion (A).

(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 assertion is true because during the electrolysis of NaCl solution, chlorine gas is preferentially produced at the anode due to the lower energy barrier for chlorine ion discharge compared to oxygen formation. The reason is also true, as the formation of oxygen does indeed

require overpotential, but it does not directly explain why chlorine is formed instead of oxygen in this specific electrolysis scenario.

Question 20.

Assertion (A) : Nucleophilic substitution of iodoethane is easier than chloroethane.

Reason (R): Bond energy of C Cl bond is less than C I bond.

[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.

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

Explanation:

Assertion (A) is true, but Reason (R) is false. The nucleophilic substitution of iodoethane is indeed easier than that of chloroethane because the C-I bond is weaker than the C-Cl bond, making it easier for the nucleophile to attack and displace the iodine atom. However, the reason given in (R) is incorrect as it states the opposite regarding bond energies.

Question 21.

Assertion (A): Zinc is not regarded as a transition element.

Reason (R): In zinc, 3d orbitals are completely filled in its ground state as well as in its oxidised state.

[1 Marks]

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

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

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

(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). Zinc is not regarded as a transition element because it does not have an incomplete d subshell in either its elemental or oxidized state, as its 3d orbitals are fully filled. However, the reason does not explain why zinc is classified this way, since other factors also define transition metals.

Section C

Question 22.

Write the structures and IUPAC names of the products expected from the following reactions:

(a) Reaction of methanal with $(CH_3)_2CHMgBr$ followed by hydrolysis.

(b) Reaction of phenol with conc. HNO_3 .

[2 Marks]

Answer: (a) Methanal (HCHO) reacts with isopropylmagnesium bromide ($(CH_3)_2CHMgBr$) followed by hydrolysis to form 2-propanol methanol addition product: **2-methylpropan-1-ol**. The Grignard reagent adds to the carbonyl carbon forming an alkoxide intermediate which upon hydrolysis gives the alcohol. The structure is $(CH_3)_2CH\text{-}CH_2OH$.

(b) Phenol reacts with concentrated nitric acid (conc. HNO_3) undergoing electrophilic substitution to give mainly **2-nitrophenol** and **4-nitrophenol**. The nitro group ($-NO_2$) substitutes at ortho and para positions relative to the hydroxyl group due to activating effect of OH group.
Major products are shown as:
2-nitrophenol: OH group at carbon 1, NO_2 at carbon 2 (ortho)
4-nitrophenol: OH group at carbon 1, NO_2 at carbon 4 (para)

Key Points: Grignard reagent adds to methanal forming an alcohol - Hydrolysis converts alkoxide to alcohol - Phenol undergoes electrophilic substitution with conc. HNO3 - Nitro group substitutes ortho and para to OH group - Major products are 2-nitrophenol and 4-nitrophenol

Question 23.

A chemical reaction $2N_2O_5$ (g) $\longrightarrow$ $4NO_2$ (g) + O_2 (g) in gas phase was carried out in a closed vessel. The concentration of NO2 was found to increase by 5* 10^{-3} mol L^{-1} in 10 seconds. Calculate :

(a) the rate of formation of NO_2.

(b) the rate of consumption of N_2O_5 .

[2 Marks]

Answer: (a) The rate of formation of NO_2 is the change in concentration of NO_2 divided by the time interval.

Rate of formation of NO_2 = (5 * 10^{-3} mol L^{-1}) / 10 s = 5 * 10^{-4} mol L^{-1} s^{-1}.

(b) From the balanced equation $2N_2O_5 \longrightarrow 4NO_2 + O_2$, 2 moles of N_2O_5 produce 4 moles of NO_2. So, rate of consumption of N_2O_5 is half the rate of formation of NO_2.

Rate of consumption of N_2O_5 = (1/2) * Rate of formation of NO_2 = (1/2) * 5 * 10^{-4} = 2.5 * 10^{-4} mol L^{-1} s^{-1}.

Key Points: Calculate rate using change in concentration and time - Use stoichiometric ratio to relate rates of reactants and products - Rate of consumption of N_2O_5 is half the rate of formation of NO_2

Question 24.

Define fuel cell and write its two advantages.

[2 Marks]

Answer: Fuel cell: A fuel cell is a device that produces electricity directly through a chemical reaction between a fuel and an oxidizing agent without combustion.

Advantages of fuel cells: (1) Fuel cells are pollution free as they produce electricity without burning fuel and releasing harmful gases.

(2) They have higher efficiency of about 70% compared to thermal power plants which have about 40% efficiency.

Key Points: Fuel cell definition - Pollution free energy - Higher efficiency

Question 25.

(i) How are carbohydrates stored in animal body ? Mention any one organ where they are present.

(ii) What is the basic structural difference between starch and cellulose ?

[2 Marks]

Answer: (i) Carbohydrates are stored in animal body in the form of glycogen. Glycogen is a branched polysaccharide similar to amylopectin and is stored mainly in the liver.
(ii) The basic structural difference between starch and cellulose is that starch is made up of alpha glucose units linked mainly by alpha-1,4-glycosidic bonds while cellulose is made up of beta glucose units linked by beta-1,4-glycosidic bonds. This difference causes starch to be digestible by humans while cellulose is not.

Key Points: Carbohydrates stored as glycogen in animals - Glycogen present mostly in liver - Starch contains alpha glucose with alpha-1,4 bonds - Cellulose contains beta glucose with beta-1,4 bonds - Structural difference leads to digestibility difference

Question 26.

Differentiate between :

(i) Peptide linkage and Glycosidic linkage

(ii) Nucleoside and Nucleotide

[2 Marks]

Answer: (i) **Peptide linkage:** It is a bond formed between the carboxyl group of one amino acid and the amino group of another, resulting in a –CO–NH– (amide) bond.
Glycosidic linkage: It is a bond formed between the sugar molecules in carbohydrates by linking the anomeric carbon of one sugar to the hydroxyl group of another.

(ii) **Nucleoside:** A molecule consisting of a nitrogenous base attached to the 1' position of a sugar (pentose).
Nucleotide: A nucleoside with one or more phosphate groups attached at the 5' position of the sugar.

Key Points: Peptide linkage is amide bond between amino acids - Glycosidic linkage connects sugars in carbohydrates - Nucleoside is base + sugar - Nucleotide is nucleoside + phosphate group

Question 27.

Give reasons for the following :

(a) Carboxylic carbon is less electrophilic than Carbonyl carbon of aldehydes and ketones.

(b) Propanal is more reactive than Propanone towards addition of HCN.

[2 Marks]

Answer: (a) Carboxylic carbon is less electrophilic because in carboxylic acids, the carbonyl carbon is bonded to an -OH group which donates electron density through resonance and inductive effects,

decreasing the positive character of the carbon. Also, resonance delocalization over the -OH reduces the partial positive charge on the carbonyl carbon, making it less susceptible to nucleophilic attack.
(b) Propanal is more reactive than propanone towards HCN addition because propanal is an aldehyde and has only one alkyl group attached to the carbonyl carbon, resulting in less steric hindrance and less electron donation compared to propanone which is a ketone with two alkyl groups. Alkyl groups donate electron density, reducing electrophilicity of the carbonyl carbon, so propanal is more electrophilic and more reactive towards nucleophiles like HCN.

Key Points: Carboxylic carbon less electrophilic due to resonance and electron donation from -OH - Resonance decreases partial positive charge on carbonyl carbon - Propanal less steric hindrance than propanone - Ketones have two alkyl groups donating electrons reducing electrophilicity - Aldehydes more reactive towards nucleophilic addition

Question 28.

Write the chemical equation involved in the following reactions :

(a) Carbylamine reaction

(b) Gabriel phthalimide synthesis

[2 Marks]

Answer: (a) Carbylamine reaction: Primary amines react with chloroform ($CHCl_3$) and ethanolic potassium hydroxide (KOH) on heating to form isocyanides (carbylamines), which have a foul smell.
Example:
$R\text{-}NH_2 + CHCl_3 + 3KOH \rightarrow R\text{-}NC + 3KCl + 3H_2O$

(b) Gabriel phthalimide synthesis:
This is used to prepare primary amines. Phthalimide reacts with potassium hydroxide to give potassium phthalimide, which then reacts with an alkyl halide to form N-alkyl phthalimide. Hydrolysis or hydrazinolysis of this compound yields the primary amine.
Steps:
Phthalimide + KOH $\rightarrow$ Potassium phthalimide + H_2O
Potassium phthalimide + R-X $\rightarrow$ N-alkyl phthalimide + KX
N-alkyl phthalimide + Hydrazine ($NH_2\text{-}NH_2$) $\rightarrow$ Primary amine ($R\text{-}NH_2$) + Phthalhydrazide

Key Points: Carbylamine reaction forms isocyanides using primary amines - Gabriel synthesis involves phthalimide reacting with alkyl halides to produce primary amines - Both reactions are important methods for preparing amines

Question 29.

Give reasons for the following :

(a) Aquatic animals are more comfortable in cold water in comparison to warm water.

(b) Sprinkling of salt helps in clearing the snow-covered roads in hilly areas.

[2 Marks]

Answer: (a) Aquatic animals are more comfortable in cold water because gases like oxygen and nitrogen dissolve better in cold water than in warm water. This means more oxygen is available in cold water for aquatic animals to breathe.
(b) Sprinkling salt on snow-covered roads lowers the freezing point of water, so the ice or snow melts even if the temperature is below 0 deg Celsius. This helps clear the roads and makes them safer for travel.

Key Points: Oxygen solubility is higher in cold water - Aquatic animals get more oxygen in cold water - Salt lowers freezing point of water - Salt melts ice and snow below 0 deg Celsius - Roads become safer due to salt application

Question 30.

Using E° values of X and Y given below, predict which is better for coating the surface of Iron to prevent corrosion and why ?

Given : E° X^{2+}/X = -2.36V

E° Y^{2+}/Y = -0.14V

E° Fe^{2+}/Fe = -0.44V

[2 Marks]

Answer: Answer: To prevent corrosion of iron, a metal used for coating should have a more negative standard electrode potential (E°) than iron so it can act as a sacrificial anode. Given E° values are: X = -2.36 V, Y = -0.14 V, and Fe = -0.44 V. Metal X with E° = -2.36 V is more negative than Fe, so it will oxidize first, protecting iron from corrosion. Metal Y has E° = -0.14 V which is higher than Fe, so it will not protect iron. Therefore, metal X is better for coating iron to prevent corrosion because it corrodes sacrificially, protecting iron.

Key Points: Metal with more negative E° acts as sacrificial anode - Metal X has E° more negative than iron - Metal X protects iron by corroding first

Section D

Question 31.

(a) Write the mechanism of the following reaction :

(b) Write the equation of the reaction for the preparation of phenol from cumene.

[3 Marks]

$$CH_3 - CH_2 - OH \xrightarrow[443\ K]{H^+} CH_2 = CH_2 + H_2O$$

Answer:

(a) This is **acid-catalyzed dehydration of ethanol** to give **ethene** at **443 K**.

Below is a **clean, exam-ready, copy-paste mechanism**:

Step 1: Protonation of alcohol

CH3CH2OH+H+→CH3CH2OH2+

The –OH group is protonated to form a good leaving group (water).

Step 2: Loss of water (formation of carbocation)

CH3CH2OH2+→CH3CH2++H2O

Water leaves, forming an **ethyl carbocation**.

Step 3: Deprotonation (formation of alkene)

CH3CH2+→CH2=CH2+H+

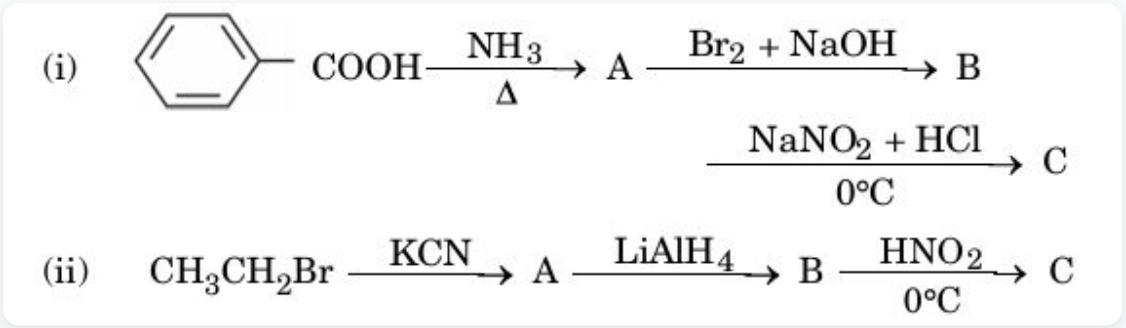
A proton is removed from the β-carbon, giving **ethene** and regenerating the acid catalyst.
(b) **Preparation of phenol from cumene:** Cumene hydroperoxide is then treated with dilute acid (H2SO4) which causes rearrangement and cleavage of the hydroperoxide to produce phenol (C6H5OH) and acetone (CH3COCH3). The overall reaction is:
Cumene (C6H5CH(CH3)2) + O2 --oxidation--> Cumene hydroperoxide (C6H5C(CH3)2OOH)
Cumene hydroperoxide + H+ --acidic cleavage--> Phenol (C6H5OH) + Acetone (CH3COCH3)

Key Points: Cumene is oxidised to cumene hydroperoxide - Cumene hydroperoxide undergoes acidic cleavage - Phenol and acetone are formed

Question 32.

Write the structures of A, B and C in the following reactions :

[3 Marks]



Answer:

(i) Starting compound: Benzoic acid (C_6H_5–COOH)

Step 1: With NH_3, Δ
Carboxylic acid + NH_3 on heating gives amide.

C6H5COOH→NH3,ΔC6H5CONH2

A = Benzamide ($C_6H_5CONH_2$)

Step 2: With Br_2 + NaOH (Hofmann bromamide reaction)
Amide → amine with one carbon less.

C6H5CONH2 (Br2/NaOH) → C6H5NH2

B = Aniline ($C_6H_5NH_2$)

Step 3: With $NaNO_2$ + HCl at 0°C (diazotization)
Aniline → benzene diazonium chloride.

C6H5NH2 (0∘C , NaNO2 /HCl) → C6H5N2+Cl−

C = Benzene diazonium chloride (C_6H_5–$N_2^+Cl^-$)

(ii) Starting compound: Ethyl bromide (CH_3CH_2Br)

Step 1: With KCN
Alkyl halide + KCN → nitrile (chain length increases by one carbon).

CH3CH2Br→KCNCH3CH2CN

Step 2: With $LiAlH_4$
Nitrile is reduced to primary amine.

CH3CH2CN→LiAlH4CH3CH2CH2NH2

B = Propylamine ($CH_3CH_2CH_2NH_2$)

Step 3: With HNO_2 at 0°C
Primary aliphatic amine + HNO_2 → alcohol (via unstable diazonium).

$CH3CH2CH2NH2 \rightarrow^{0\circ C} HNO2CH3CH2CH2OH$

C = 1-Propanol ($CH_3CH_2CH_2OH$)

Key Points: Identify starting material-A; Describe intermediate product-B; Illustrate final product-C; Use correct functional groups; Show molecular bonding

Question 33.

0.3 g of acetic acid (M = 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: Calculate molality (m) of the solution
Molality (m) = moles of solute / kg of solvent
Moles of acetic acid = 0.3 g / 60 g mol^{-1} = 0.005 mol
Mass of benzene = 30 g = 0.03 kg
Molality, m = 0.005 / 0.03 = 0.1667 mol kg^{-1}

Step 2: Calculate the expected freezing point depression for non-association
$\Delta Tf = Kf * m = 5.12 * 0.1667 = 0.853$ °C

Step 3: Calculate effective molality from observed depression
Observed $\Delta Tf = 0.45$ °C
Effective molality, $m_{eff} = \Delta Tf / Kf = 0.45 / 5.12 = 0.0879$ mol kg^{-1}

Step 4: Relate association and molality
Let the degree of association be α (fractions that form dimers). Initial moles = n = 0.005
Since molecules form dimers, the total number of particles after association = n * (1 - α) + n * α / 2 = n (1 - α/2)
So, effective molality $m_{eff} = m * (1 - \alpha/2)$

From this, $0.0879 = 0.1667 * (1 - \alpha/2)$
$1 - \alpha/2 = 0.0879 / 0.1667 = 0.527$
$\alpha/2 = 1 - 0.527 = 0.473$
$\alpha = 0.946$

Step 5: Calculate percentage association
Percentage association = α * 100 = 94.6%

Final answer: The percentage association of acetic acid forming dimers in benzene is 94.6%.

> **Key Points: Calculate molality - Use freezing point depression formula - Calculate effective molality - Use relationship between association and particle number - Calculate percentage association**

Question 34.

The rate of a reaction doubles when temperature changes from 27 °C to 37 °C. Calculate energy of activation for the reaction.

(R = 8 .314 J K^{-1} mol^{-1})

(Given : log 2 = 0.3010, log 3 = 0.4771, log 4 = 0.6021)

[3 Marks]

Answer: Solution:
Given:
Rate constant ratio k2 / k1 = 2
Initial temperature T1 = 27 deg C = 27 + 273 = 300 K
Final temperature T2 = 37 deg C = 37 + 273 = 310 K
Gas constant R = 8.314 J mol^{-1} K^{-1}

Using the Arrhenius equation ratio form:
$\ln(k2 / k1) = (E_a / R) * (1 / T1 - 1 / T2)$
$\ln 2 = (E_a / 8.314) * (1 / 300 - 1 / 310)$
ln 2 = 0.693 (approximate)

Calculate (1 / 300 - 1 / 310) = (310 - 300) / (300 * 310) = 10 / 93000 = 0.0001075

So,
$0.693 = (E_a / 8.314) * 0.0001075$
$E_a = 0.693 * 8.314 / 0.0001075 = 53626$ J/mol = 53.6 kJ/mol

Therefore, the energy of activation E_a for the reaction is approximately 53.6 kJ/mol.

> **Key Points: Arrhenius equation used - temperature conversion to Kelvin - calculation of**

activation energy step by step

Question 35.

Write the structure of product when D-Glucose reacts with the following : (any three)

(a) HI

(b) Conc. HNO_3

(c) Br_2 water

(d) HCN

[3 Marks]

Answer: (a) When D-Glucose reacts with HI, the primary alcohol group at C-6 is converted into an iodoalkane, and the rest of the molecule is reduced to an alkane chain, giving n-hexane iodide as the product.
(b) When D-Glucose reacts with concentrated HNO_3, all the $-CH_2OH$ groups are oxidized to -COOH groups forming glucaric acid (saccharic acid).
(c) When D-Glucose reacts with Br_2 water, the aldehyde group at C-1 is selectively oxidized to a carboxylic acid forming D-gluconic acid.
(d) When D-Glucose reacts with HCN, hydrogen cyanide adds to the aldehyde group forming a cyanohydrin intermediate known as glucose cyanohydrin.

Key Points: Reaction with HI forms iodoalkane at C-6 - Reaction with conc. HNO3 oxidizes all -CH2OH groups to -COOH - Reaction with Br2 water oxidizes aldehyde group to carboxylic acid - Reaction with HCN forms cyanohydrin at aldehyde group

Question 36.

How will you convert the following :

(i) Aniline to p-bromoaniline

(ii) Ethanoic acid to methanamine

(iii) Butanenitrile to 1-aminobutane

[3 Marks]

Answer: (i) To convert Aniline to p-bromoaniline, first protect the amino group by reacting aniline with acetic anhydride to form acetanilide. Then, brominate acetanilide with Br_2 water; bromination mainly occurs at the para position. Finally, hydrolyse the product with dilute acid to remove the acetyl group, yielding p-bromoaniline.
(ii) To convert Ethanoic acid to methanamine, first convert ethanoic acid to ethyl cyanide

(ethanenitrile) by reaction with PCl_5 followed by reaction with KCN. Then, reduce the nitrile using $LiAlH_4$ or catalytic hydrogenation to obtain ethylamine. Finally, to get methanamine, instead directly convert methanoic acid to methanamide by heating with ammonia, followed by reduction with $LiAlH_4$ to get methanamine.
(iii) To convert Butanenitrile to 1-aminobutane, reduce butanenitrile using $LiAlH_4$ in dry ether. This reaction converts the nitrile group to a primary amine group, yielding 1-aminobutane as the product.

Key Points: Protect amino group by acetylation - Brominate acetanilide to get para product - Hydrolyse to get p-bromoaniline - Convert acid to amide and reduce to amine - Reduce nitrile to primary amine using LiAlH4

Section E

Question 37.

(i) Account for the following:

(1) Transition metals form complex compounds;

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

(3) Cu^{2+} ion is unstable in aqueous solution.

(ii) Write the equations involved in the preparation of $KMnO_4$ from Pyrolusite ore (MnO_2).

[5 Marks]

Answer:

(i) Account for the following:
(1) Transition metals form complex compounds: Transition metals have partially filled d-orbitals which can accept lone pairs of electrons from ligands to form coordinate bonds. This ability leads to the formation of complex compounds where the metal ion is centrally bonded to surrounding ligands.
(2) The E^+ for Mn^{2+}/Mn is highly negative whereas E^+ for MnO_4^-/Mn^{2+} is highly positive: The standard electrode potential (E°) for Mn^{2+}/Mn is highly negative because manganese metal is difficult to oxidize to Mn^{2+} due to its stable metallic state. However, the E° for MnO_4^-/Mn^{2+} is highly positive because Mn in permanganate ion (MnO_4^-) is in a very high oxidation state (+7), which makes it a strong oxidizing agent and easily reduced to Mn^{2+}.
(3) Cu^{2+} ion is unstable in aqueous solution: Cu^{2+} ions have a strong tendency to gain electrons and get reduced to $Cu±^+$ or metallic Cu due to the high stability of $Cu±^+$ or Cu metal. Also, Cu^{2+} undergoes hydration that makes it susceptible to disproportionation or reduction in aqueous solution.
(ii) Preparation of $KMnO_4$ from Pyrolusite (MnO_2):
Step 1: Fusion with KOH and Oxidation

$MnO_2 + 2KOH + (1/2)O_2 \rightarrow K\square MnO_4 + H_2O$

Step 2: Acidification and Disproportionation

$KMnO_4 + HCl \rightarrow KMnO_4 + MnCl_2 + KCl + H_2O$

This process converts MnO_2 to potassium permanganate ($KMnO_4$), which is a strong oxidizing agent used in many applications.

> **Key Points: Transition metals have partially filled d-orbitals - Difference in electrode potentials due to oxidation states - Cu^{2+} ion instability due to reduction tendency - Preparation of $KMnO_4$ involves fusion with KOH and oxidation - Acidification leads to disproportionation forming $KMnO_4$ and $MnCl_2$**

Question 38.

(i) Identify the following :

(1) Transition metal of 3d series that exhibits only one oxidation state.

(2) Transition metal of 3d series that acts as a strong reducing agent in +2 oxidation state in aqueous solution.

(ii) Complete and balance the following equations :

(1) $Cr_2O^{2-}_7 + 14H^+ + 6Fe^{2+} \longrightarrow$

(2) $KMnO_4$ (heat) $\longrightarrow$

(iii) What is Misch metal ? Write its one use.

[5 Marks]

Answer: (i) Identification :

(1) **Zn (Zinc)** is the transition metal of 3d series that exhibits only one oxidation state, which is +2.

(2) **Fe (Iron)** in the +2 oxidation state acts as a strong reducing agent in aqueous solution.

(ii) Complete and balanced equations :

(1) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \longrightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

(2) $4KMnO_4$ (heat) $\longrightarrow 4MnO_2 + 3K_2MnO_4 + O_2$

(iii) Misch metal :

Misch metal is an alloy of rare earth metals, mainly Lanthanum (La) and Cerium (Ce) along with small amounts of other rare earth elements. It is used in manufacturing of **lighters (flints)** due to its easy ignition property.

Key Points: Zn exhibits only +2 oxidation state - Fe^{2+} is strong reducing agent in aqueous solution - Balanced redox reactions for dichromate and potassium permanganate - Misch metal is a rare earth alloy used in lighter flints

Question 39.

(i) An organic compound (X) having molecular formula $C_5H_{10}O$ can show various properties depending on its structures. Draw each of the structures if it

(1) gives positive iodoform test.

(2) shows Cannizzaro's reaction

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

(ii) Write the reaction involved in the following :

(1) Wolff-Kishner reduction

(2) Hell-Volhard-Zelinsky reaction

[5 Marks]

Answer: (i) Structures of compound X ($C_5H_{10}O$):

(1) Gives positive iodoform test: This indicates presence of a methyl ketone group. An example is 2-pentanone.

Structure: CH_3-CO-CH_2-CH_2-CH_3

(2) Shows Cannizzaro's reaction: Compound must be an aldehyde without alpha hydrogen. Here pentanal cannot show Cannizzaro but an isomer like 3,3-dimethylbutanal (if possible). More correctly, the compound is an aldehyde with no alpha hydrogen, for example, pivaldehyde (2,2-dimethylpropanal): $(CH_3)_3C$-CHO

(3) Reduces Tollens' reagent and has chiral carbon: This is an aldehyde with at least one chiral center. Example: 3-methylbutanal (isovaleraldehyde). Structure: CH_3-CH(CH_3)-CH_2-CHO

(ii) Reactions:

(1) Wolff-Kishner reduction:

It is the reduction of a carbonyl group (aldehyde or ketone) to a hydrocarbon by treating with hydrazine (NH_2NH_2) in alkaline medium and heat.

R-CO-R' + NH_2NH_2 → R-CH_2-R' + N_2 + H_2O

(2) Hell-Volhard-Zelinsky reaction:

It is the alpha-halogenation of carboxylic acids in presence of PCl_3 and halogen (Br_2 or Cl_2).

R-CH_2-COOH + Br_2 + PCl_3 → R-CHBr-COCl (acyl halide) → R-CHBr-COOH after hydrolysis.

This reaction introduces a halogen atom at the alpha position of carboxylic acid.

Summary:
(i) (1) 2-pentanone; (2) pivaldehyde; (3) 3-methylbutanal
(ii) (1) Wolff-Kishner reduction converts carbonyl group to methylene group using hydrazine and base. (2) Hell-Volhard-Zelinsky halogenates alpha carbon of carboxylic acid using halogen and PCl_3.

Key Points: Structure for positive iodoform test indicates methyl ketone - Cannizzaro reaction occurs with aldehyde lacking alpha hydrogen - Tollens test positive aldehyde with chiral carbon - Wolff-Kishner reduction reduces carbonyl to hydrocarbon using hydrazine and base - Hell-Volhard-Zelinsky reaction halogenates alpha carbon of carboxylic acid using halogen and PCl3

Question 40.

(i) How can you convert each of the following compounds to Benzoic acid ?

(1) Acetophenone

(2) Ethylbenzene

(3) Bromobenzene

(ii) Arrange the following compounds in increasing order of their property as indicated :

(1) O_2N -CH_2 -COOH, F -CH_2- COOH, CN- CH_2COOH (Acidic character)

(2) Ethanal, Propanal, Butanone, Propanone (Reactivity in nucleophilic addition reactions)

[5 Marks]

Answer: (i) Conversion of compounds to Benzoic acid:
1. Acetophenone to Benzoic acid: Acetophenone ($C_6H_5COCH_3$) is oxidized using a strong oxidizing agent like alkaline potassium permanganate ($KMnO_4$) under heating. The methyl group attached to the ketone is cleaved and converted to carboxyl group resulting in benzoic acid (C_6H_5COOH).
2. Ethylbenzene to Benzoic acid: Ethylbenzene ($C_6H_5CH_2CH_3$) on oxidation with alkaline $KMnO_4$ and heat converts the side chain completely to a carboxyl group forming benzoic acid.
3. Bromobenzene to Benzoic acid: Bromobenzene (C_6H_5Br) is first reacted with magnesium in dry ether to form phenylmagnesium bromide (Grignard reagent). This is then reacted with carbon dioxide (dry ice) followed by acidic workup (H^+) to give benzoic acid.
(ii) Arrangement of compounds:
1. Acidic character of substituted acetic acids: The acidic strength depends on the electron withdrawing nature of the substituent. The order is F-CH_2-COOH (fluoro group, strong -I effect) > O_2N-CH_2-COOH (nitro group, strong -I effect) > CN-CH_2-COOH (cyano group, moderate -I effect). So increasing order is CN-CH_2-COOH < O_2N-CH_2-COOH < F-CH_2-COOH.

2. Reactivity in nucleophilic addition: Aldehydes are generally more reactive than ketones because of less steric hindrance and less electron donation to the carbonyl carbon. Among aldehydes: ethanal (2 carbons) > propanal (3 carbons). Among ketones: propanone (acetone, 3 carbons) > butanone (4 carbons). So overall increasing order of reactivity is Butanone < Propanone < Propanal < Ethanal.

Key Points: Acetophenone and Ethylbenzene are oxidized by alkaline KMnO4 to Benzoic acid - Bromobenzene converted to Grignard reagent then reacted with CO2 followed by acid workup to give Benzoic acid - Acidic strength depends on electron withdrawing group, increasing order CN < NO2 < F - Reactivity in nucleophilic addition decreases with increasing alkyl substitution; Aldehydes more reactive than ketones

Question 41.

(a) Calculate the emf of the following cell at 25° C :

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

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

(b) State Kohlrausch law of independent migration of ions. Why does the conductivity of a solution decrease with dilution ?

[5 Marks]

Answer: (a) To calculate the emf of the cell: Zn (s) | Zn^{2+} (0.1M) || H^+ (0.01M) | H (g) (1 bar), Pt (s) at 25 deg C.

Given: E^o Zn^{2+}/Zn = -0.76 V, E^o H^+/H = 0.00 V, log 10 = 1.

The cell reaction is: Zn (s) -> Zn^{2+} (aq) + 2 e^- (oxidation at anode)

2 H^+ (aq) + 2 e^- -> H_2 (g) (reduction at cathode)

Standard emf, $E^o_{cell} = E^o_{cathode} - E^o_{anode}$ = 0.00 V - (-0.76 V) = +0.76 V.

Using Nernst equation:

$E_{cell} = E^o_{cell} - (0.059 / n) * \log Q$, where n = 2 (number of electrons), $Q = [Zn^{2+}] / [H^+]^2 = 0.1 / (0.01)^2$ = 0.1 / 0.0001 = 1000.

log Q = log 1000 = 3.

Therefore, E_{cell} = 0.76 - (0.059 / 2) * 3 = 0.76 - 0.0885 = 0.6715 V.

Hence, the emf of the cell at 25 deg C is approximately 0.67 V.

(b) Kohlrausch law of independent migration of ions states that the total molar conductivity of an electrolyte at infinite dilution is the sum of the ionic contributions of the individual ions, each moving independently of others. In other words, each ion contributes to the total conductivity independent of the other ions present in the solution.

The conductivity of a solution decreases with dilution because as the solution is diluted, the number of ions per unit volume decreases, reducing the total charge carriers available to conduct electricity.

Although molar conductivity increases with dilution due to decreased ion interactions, the overall conductivity decreases since it depends on both molar conductivity and concentration. Thus, dilution lowers conductivity as fewer ions are present in the solution volume to carry current.

Key Points: EMF calculation using Nernst equation - Kohlrausch law states molar conductivity is sum of independent ionic contributions - Conductivity decreases with dilution due to decreased ion concentration