# CBSE EXAMINATION PAPER-2023

## CHEMISTRY

### (Solved)

Time allowed : 3 hours | Maximum Marks : 83

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**General Instructions :**

Read the following instructions carefully and follow them :

i. This question paper contains **42 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 42** 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 carbon – oxygen double bond is polarised in aldehydes and ketones due to higher electronegativity of oxygen relative to carbon. Therefore they undergo nucleophilic addition reactions with a number of nucleophiles such as HCN, NaHSO3, alcohols, ammonia derivatives and Grignard reagents. Aldehydes are easily oxidised by mild oxidising agents as compared to ketones. The carbonyl group of carboxylic acid does not give reactions of aldehydes and ketones. Carboxylic acids are considerably more acidic than alcohols and most of simple phenols.

**Question 2.**

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

The carbon – oxygen double bond is polarised in aldehydes and ketones due to higher electronegativity of oxygen relative to carbon. Therefore they undergo nucleophilic addition reactions with a number of nucleophiles such as HCN, $NaHSO_3$, alcohols, ammonia derivatives and Grignard reagents. Aldehydes are easily oxidised by mild oxidising agents as compared to ketones. The carbonyl group of carboxylic acid does not give reactions of aldehydes and ketones. Carboxylic acids are considerably more acidic than alcohols and most of simple phenols.

**(1)**

**Write the name of the product when an aldehyde reacts with excess alcohol in presence of dry HCl.**

[1 Marks]

**Answer:** When an aldehyde reacts with excess alcohol in presence of dry HCl, it forms an acetal. This reaction occurs due to nucleophilic addition followed by elimination of water. Acetals are stable products and are used as protective groups for aldehydes as per the explanation in the passage.

**Key Points: aldehyde reacts with alcohol in dry HCl - formation of acetal - reaction involves nucleophilic addition and elimination of water**

**(2)**

**Why carboxylic acid is a stronger acid than phenol ?**

[1 Marks]

**Answer: Carboxylic acid is a stronger acid than phenol because its conjugate base, the carboxylate ion, is stabilized by two resonance structures which spread out the negative charge over two oxygen atoms.** This stabilization makes it easier to lose the proton.
In contrast, the phenol ion has resonance but the negative charge is less delocalized.
Hence, carboxylic acids are more acidic than phenols as explained in the passage.

**Key Points: Carboxylic acid conjugate base stabilized by resonance - Negative charge delocalized over two oxygens - Phenol ion less resonance stabilization**

**(3)**

**(i) Arrange the following compounds in increasing order of their reactivity towards $CH_3MgBr$ :**

**(ii) Write a chemical test to distinguish between propanal and propanone.**

$$CH_3CHO,\ (CH_3)_3C-\overset{\overset{O}{\|}}{C}-CH_3,\ CH_3-\overset{\overset{O}{\|}}{C}-CH_3$$

[2 Marks]

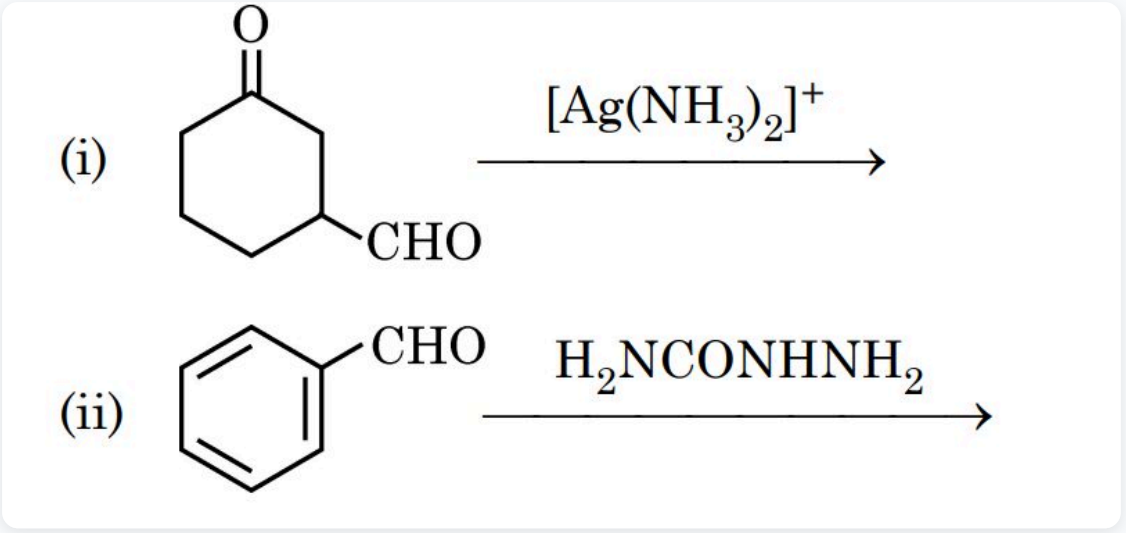
**Answer: (i) Reactivity order:** Ketones like propanone and butanone are less reactive than aldehydes like propanal towards $CH_3MgBr$ due to steric hindrance. Hence, the increasing order is: butanone < propanone < propanal.

**(ii) Chemical test:** Propanal gives a positive Tollens test forming a silver mirror, whereas propanone does not. This distinguishes propanal (an aldehyde) from propanone (a ketone).

**Key Points: Aldehydes are more reactive than ketones towards Grignard reagent - Propanal gives positive Tollens test while propanone does not - Aldehydes have less steric hindrance making nucleophilic addition easier**

**(4)**

**Write the main product in the following :**




[2 Marks]

**Answer:**

(i) Substrate: A cyclohexanone ring bearing an –CHO (aldehyde) side group.
Reagent: [Ag(NH3)2]+[Ag(NH3)2]+[Ag(NH3)2]+ = Tollens' reagent.

What it does: Tollens' reagent oxidizes aldehydes to carboxylic acids (or carboxylate in basic medium) but does not oxidize ketones.

So here:

- The –CHO group → –COOH
- The ketone (>C=O in ring) remains unchanged

Main product:
👉 Cyclohexanone ring with –COOH instead of –CHO
(i.e., the aldehyde side chain is oxidized to a carboxylic acid)

In words: Formyl group → Carboxylic acid group; ketone unchanged.

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## (ii)Substrate: Benzaldehyde ($C_6H_5$–CHO)
## Reagent: $H_2NCONHNH_2$ (semicarbazide)

What it does:
Aldehydes react with semicarbazide to form semicarbazones.

So:

C6H5CHO+H2NCONHNH2→C6H5CH=N−NHCONH2+H2

Main product:

👉 Benzaldehyde semicarbazone

- $C_6H_5CH=N-NHCONH_2$

**Key Points: Carbonyl group is polarised - Nucleophilic addition occurs on carbonyl carbon - Aldehydes are more reactive than ketones - Products depend on nucleophile (e.g., cyanohydrin from HCN addition)**

**Question 3.**

Carbohydrates are optically active polyhydroxy aldehydes and ketones. They are also called saccharides. All those carbohydrates which reduce Fehling's solution and Tollen's reagent are referred to as reducing sugars. Glucose, the most important source of energy for mammals, is obtained by the hydrolysis of starch. Vitamins are accessory food factors required in the diet. Proteins are the polymers of α-amino acids and perform various structural and dynamic functions in the organisms. Deficiency of vitamins leads to many diseases.

**(1)**

**The penta-acetate of glucose does not react with Hydroxylamine. What does it indicate ?**

[1 Marks]

**Answer:** The penta-acetate of glucose not reacting with Hydroxylamine indicates the absence of a free aldehyde group (-CHO) in it. This shows that the aldehyde group of glucose is involved in forming the penta-acetate and thus not free to react. This is important because, as given in the case, reducing sugars have a free aldehyde or ketone group, and here it is not free in the penta-acetate form.

**Key Points: Penta-acetate of glucose does not react with Hydroxylamine - Indicates absence of free -CHO group - Shows aldehyde group is involved in acetylation and not free to react**

**(2)**

**Why cannot vitamin C be stored in our body ?**

[1 Marks]

**Answer: Vitamin C cannot be stored in our body because it is a water-soluble vitamin and excess amount is excreted through urine**. The case passage mentions vitamins as accessory food factors needed in diet, indicating they must be replenished regularly since the body does not store them.

**Key Points: Vitamin C is water-soluble - Excess vitamin C is excreted in urine - Vitamins are required regularly in diet**

**(3)**

**Define the following as related to proteins :**

**(i) Peptide linkage**

**(ii) Denaturation**

[2 Marks]

**Answer: Peptide linkage:** It is the bond formed between the amino group of one amino acid and the carboxyl group of another amino acid in proteins.
**Denaturation:** It is the process in which proteins lose their native structure and function due to external factors like heat or chemicals, as proteins are polymers of a-amino acids as mentioned in the passage.

**Key Points: Peptide linkage is bond between amino acids - Denaturation is loss of protein structure and function - Proteins are polymers of a-amino acids**

**(4)**

**Define the following as related to carbohydrates :**

**(i) Anomers**

**(ii) Glycosidic linkage**

[2 Marks]

**Answer: (i) Anomers** are the isomers of monosaccharides that differ only in the configuration about the anomeric carbon atom, which is the carbon derived from the carbonyl carbon in the open-chain form.
**(ii) Glycosidic linkage** is a covalent bond that joins a carbohydrate molecule to another molecule, such as between two sugar units in disaccharides or polysaccharides, formed by a dehydration reaction. These definitions relate to carbohydrates, which are optically active and may reduce Fehling's and Tollens' reagents as mentioned in the case passage.

**Key Points: Anomers differ at anomeric carbon - Glycosidic linkage joins carbohydrate molecules - Both are important in carbohydrate structure and function**

## Section B

**Question 4.**

The conversion of an alkyl halide into an alkene by alcoholic KOH is classified as

[1 Marks]

**(A) a dehydrohalogenation reaction**

(B) an addition reaction

(C) a dehydration reaction

(D) a substitution reaction

**Explanation:**

The correct option is 'a dehydrohalogenation reaction' because the context states that alkyl halides react with alcoholic KOH to eliminate one molecule of halogen acid, forming alkenes. This process is specifically termed dehydrohalogenation, which involves the removal of halide and hydrogen, leading to the formation of a double bond in the alkene.

**Question 5.**

The oxidation state of Fe in $[Fe(CO)_5]$ is

[1 Marks]

(A) +5

(B) +3

(C) +2

**(D) 0**

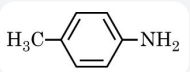
**Explanation:** The correct answer is 0. In the complex $[Fe(CO)_5]$, carbon monoxide (CO) is a neutral ligand that does not contribute to the oxidation state. Since there are five CO ligands and they are neutral, the oxidation state of the iron (Fe) must also be 0 to balance the overall charge of the complex.

**Question 6.**

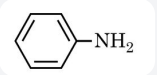
Among the following, which is the strongest base?

[1 Marks]

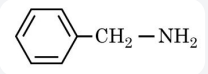
(A)



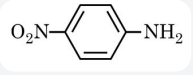
(B)



**(C)**



(D)



**Explanation:**

The strongest base is determined by its ability to accept protons (H+) or donate electron pairs. Among common strong bases, compounds like NaOH or KOH tend to be stronger than others. The relevant context provided does not explicitly mention specific bases, but in general, strong bases have low electronegativity which allows them to easily dissociate and accept protons.

**Question 7.**

The slope in the plot of ln[R] vs. time for a first order reaction is

[1 Marks]

(A) + k

(B) – k

(C) + k/2.303

**(D) – k/2.303**

**Explanation:**

The correct answer is -k/2.303. In a first order reaction, the natural logarithm of the concentration of the reactant [R] versus time yields a straight line where the slope is equal to -k, the rate constant. The factor 2.303 is used to convert the natural logarithm to logarithm base 10, which is standard in reaction kinetics.

**Question 8.**

An α-helix is a structural feature of

[1 Marks]

(A) Nucleotides

(B) Starch

**(C) Polypeptides**

(D) Sucrose

**Explanation:**

The correct answer is Polypeptides. An α-helix is a common secondary structure found in proteins (which are made of polypeptides). It is characterized by a right-handed coil, stabilized by hydrogen bonds between the backbone of the polypeptide chain.

**Question 9.**

Racemisation occurs in

[1 Marks]

**(A) $S_n1$ reaction**

(B) $S_n2$ reaction

(C) $S_n2$ reaction as well as $S_n1$ reaction

(D) Neither $S_n1$ nor $S_n2$ reaction

**Explanation:**

Racemisation occurs in $S_n1$ reaction because this reaction involves the formation of a carbocation intermediate, which can lead to the production of both enantiomers, resulting in racemisation. In contrast, $S_n2$ reactions do not involve intermediates and therefore do not lead to racemisation.

**Question 10.**

Value of Henry's constant $K_h$:

[1 Marks]

(A) decreases with increase in temperature.

(B) remains constant.

(C) increases with increase in temperature.

**(D) increases with decrease in temperature.**

**Explanation:**

The correct answer is 'increases with decrease in temperature.' Henry's law states that the solubility of a gas in a liquid is inversely related to temperature. Therefore, as temperature decreases, more gas can dissolve in the liquid, resulting in an increase in Henry's constant.

**Question 11.**

Which of the following solutions of KCl will have the highest value of molar conductivity?

[1 Marks]

(A) 1 M

(B) 0.1 M

(C) 0.5 M

**(D) 0.01 M**

**Explanation:** The molar conductivity is highest for the 0.01 M KCl solution, as indicated in the context provided. According to Table 2.3, the molar conductivity for 0.01 M is 141.0 S $m^2$ $mol^{-1}$, which is greater than that of all other concentrations listed (0.1 M has 129.0, 0.5 M has 111.3, and 1 M has

111.3 S $m^2$ $mol^{-1}$). At lower concentrations, the number of ions per unit volume is higher relative to their interactions, leading to higher molar conductivity.

**Question 12.**

Which of the following reactions are feasible?

[1 Marks]

**(A) Both (a) and (b)**

(B) $CH_3CH_2Br + Na^+ O–C(CH_3)_3 \rightarrow CH_3CH_2–O–C(CH_3)_3$

(C) Neither (a) nor (b)

(D) $(CH_3)_3C–Cl + Na^+ O–CH_2CH_3 \rightarrow CH_3CH_2–O–C(CH_3)_3$

**Explanation:**

The correct answer is 'Both (a) and (b)'. Both reactions involve the reaction between alkyl halides and sodium alkoxide, which are feasible under appropriate conditions. $(CH_3)_3C–Cl$ can react with $Na^+ O–CH_2CH_3$ to form an ether, while $CH_3CH_2Br$ can react with $Na^+ O–C(CH_3)_3$ to also form an ether. Both reactions are classified as nucleophilic substitutions, which are feasible in organic chemistry.

**Question 13.**

Which of the following is most reactive in nucleophilic addition reactions?

[1 Marks]

(A) $CH_3COC_2H_5$

(B) $CH_3CHO$

(C) $CH_3COCH_3$

**(D) HCHO**

**Explanation:**

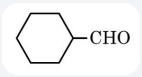
HCHO (formaldehyde) is the most reactive in nucleophilic addition reactions due to its structure, which has a highly polarized carbonyl group. The carbon atom in formaldehyde is more electrophilic and thus more susceptible to attack by nucleophiles compared to the other options, which have steric hindrance or less polarization in their carbonyl groups.

**Question 14.**

Which of the following does not give aldol condensation reaction?

[1 Marks]

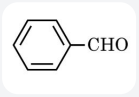
(A)



**(B) $CH_3$–CHO**

(C) $CH_3COCH_3$

(D)



**Explanation:**

The option $CH_3$–CHO (acetaldehyde) does not undergo aldol condensation because it lacks a suitable alpha hydrogen to participate in the reaction. Aldol condensation requires the presence of at least one alpha hydrogen for the formation of an enolate ion and subsequent aldol product.

**Question 15.**

For the reaction 3A → 2B, rate of reaction + d[B]/dt is equal to

[1 Marks]

(A) +(2d[A]/dt)

(B) –(3/2)d[A]/dt

**(C) –(2/3)d[A]/dt**

(D) –(1/3)d[A]/dt

**Explanation:**

The correct option is –(2/3)d[A]/dt. This is because the stoichiometry of the reaction shows that for every 3 moles of A that react, 2 moles of B are produced. Hence, the rate of formation of B is related to the rate of consumption of A by the ratio of their coefficients in the balanced equation: d[B]/dt = -(2/3)d[A]/dt.

**Question 16.**

Which of the following characteristics of transition metals is associated with their catalytic activity?

[1 Marks]

(A) High enthalpy of atomisation

**(B) Variable oxidation states**

(C) Paramagnetic nature

(D) Colour of hydrated ions

**Explanation:**

The correct option is 'Variable oxidation states'. Transition metals exhibit variable oxidation states, which allow them to easily gain or lose electrons during reactions. This characteristic is essential for their role as catalysts in various chemical processes, as they can facilitate the conversion of reactants to products by providing alternate pathways with lower activation energies.

**Question 17.**

The formula of the complex dichloridobis(ethane–1, 2-diamine) platinum(IV) nitrate is

[1 Marks]

(A) $[Pt(en)_2(NO_3)_2]Cl_2$

(B) $[Pt\ Cl_2(en)_2\ (NO_3)]NO_3$

**(C) $[Pt\ Cl_2(en)_2](NO_3)_2$**

(D) $[Pt\ Cl_2(en)_2\ (NO_3)_2]$

**Explanation:**

$[Pt\ Cl_2(en)_2](NO_3)_2$ is correct because it indicates that the platinum is in the +4 oxidation state, has 2 chloride ligands ($Cl_2$), 2 ethane-1,2-diamine ligands (en), and is coordinated with 2 nitrate ions ($NO_3$) as counterions, matching the IUPAC nomenclature for the complex.

**Question 18.**

Assertion (A) : Osmotic pressure is a colligative property.

Reason (R) : Osmotic pressure is proportional to the molality.

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

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

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

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

**Explanation:**

Both (A) and (R) are true, but (R) is not the correct explanation of (A). Osmotic pressure is indeed a colligative property, which depends on the number of solute particles in a solution rather than their identity. However, while osmotic pressure is related to the concentration of solute molecules, it is commonly expressed in terms of molarity rather than molality, thus making (R) inaccurate in directly explaining (A).

**Question 19.**

Assertion (A) : Conductivity decreases with decrease in concentration of electrolyte.

Reason (R) : Number of ions per unit volume that carry the current in a solution decreases on dilution.

[1 Marks]

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

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

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

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

**Explanation:**

Both (A) and (R) are true and (R) is the correct explanation of (A). As the concentration of an electrolyte decreases, the number of ions available to conduct electricity also decreases, which directly leads to a decrease in conductivity.

**Question 20.**

Assertion (A) : Copper is a non-transition element.

Reason (R) : Copper has completely filled d-orbitals in its ground state.

[1 Marks]

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

**(B) (A) is false, but (R) is true.**

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

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

**Explanation:**

(A) is false, but (R) is true. Copper is actually a transition element as it is found in the d-block of the periodic table. Although it has a stable electronic configuration of 3d10 4s1, the d-orbitals are not

completely filled in a traditional sense, thus making (R) true since it discusses the configuration correctly, but (A) incorrect.

**Question 21.**

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

Reason (R) : Bond enthalpy of C-I bond is less than that of C-Cl bond.

[1 Marks]

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

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

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

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

**Explanation:**

Both (A) and (R) are true and (R) is the correct explanation of (A) because the C-I bond is weaker than the C-Cl bond due to lower bond enthalpy, making it easier for nucleophiles to attack iodoethane compared to chloroethane.

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## Section C

**Question 22.**

The vapour pressure of pure liquid X and pure liquid Y at 25 °C are 120 mm Hg and 160 mm Hg respectively. If equal moles of X and Y are mixed to form an ideal solution, calculate the vapour pressure of the solution.

[2 Marks]

**Answer: Given:** Vapour pressure of pure liquid X, $P^0_X$ = 120 mm Hg, Vapour pressure of pure liquid Y, $P^0_Y$ = 160 mm Hg, Mole fraction of X = Mole fraction of Y = 0.5 (equal moles mixed)

**Using Raoult's Law:** Vapour pressure of solution, $P = x_X P^0_X + x_Y P^0_Y$

Substitute values: $P = (0.5)(120) + (0.5)(160) = 60 + 80 = 140$ mm Hg

**Therefore,** the vapour pressure of the solution is 140 mm Hg.

**Key Points: Raoult's law - mole fraction of components - vapour pressure calculation**

**Question 23.**

Give reasons :

(i) Mercury cell delivers a constant potential during its life time.

(ii) In the experimental determination of electrolytic conductance, Direct Current (DC) is not used.

[2 Marks]

**Answer:** (i) Mercury cell delivers a constant potential because its electrode and electrolyte changes very little during discharge, so the voltage remains stable.
(ii) DC is not used in electrolytic conductance experiments because it causes electrolysis and electrode polarization, which affect the accuracy of conductance measurement. Alternating Current (AC) is used to avoid these problems.

> **Key Points: Mercury cell stable electrode reaction - negligible electrolyte change - DC causes electrolysis and electrode polarization - AC used for accurate conductance measurements**

**Question 24.**

Define fuel cell with an example. What advantages do the fuel cells have over primary and secondary batteries ?

[2 Marks]

**Answer:** (a) **Fuel cell:** A fuel cell is a device that produces electricity by converting the chemical energy of a fuel and an oxidizing agent directly into electrical energy. For example, a hydrogen-oxygen fuel cell uses hydrogen as fuel and oxygen as oxidant to produce electricity.
(b) **Advantages of fuel cells over batteries:** Fuel cells can produce electricity continuously as long as fuel is supplied, unlike primary and secondary batteries which store limited energy. Fuel cells have higher efficiency and are pollution free. They do not require recharging like secondary batteries and produce less harmful waste compared to batteries.

> **Key Points: Definition of fuel cell - Example of hydrogen-oxygen fuel cell - Continuous electricity generation - Higher efficiency - Pollution free - No need for recharging**

**Question 25.**

(a) The conversion of molecule A to B followed second order kinetics. If concentration of A increased to three times, how will it affect the rate of formation of B ?

(b) Define Pseudo first order reaction with an example.

[2 Marks]

**Answer:** (a) For a second order reaction, rate is proportional to $[A]^2$. If [A] becomes 3 times, rate increases by $3^2 = 9$ times. So, rate of formation of B will be 9 times higher.
(b) A pseudo first order reaction occurs when one reactant concentration is in large excess and remains nearly constant, so the reaction behaves like first order with respect to the other reactant. Example: The hydrolysis of ester in excess water where water concentration remains constant, making it pseudo first order with respect to ester.

**Key Points: Second order rate depends on square of concentration - Rate increases 9 times if concentration triples - Pseudo first order reaction definition and example**

**Question 26.**

Write the IUPAC names of the following :

(i) $[Co(NH_3)_5(ONO)]^{2+}$

(ii) $K_2[NiCl_4]$

[2 Marks]

**Answer:** (i) The complex ion is $[Co(NH_3)_5(ONO)]^{2+}$. Here, $NH_3$ is 'ammine' ligand and ONO represents the nitrito ligand bonded through oxygen. The ligands are named in alphabetical order: ammine before nitrito. The oxidation state of Co is +3 to balance charge. Therefore, the name is **pentaammine nitrito-O cobalt(III) ion**.
(ii) $K_2[NiCl_4]$ is an ionic compound consisting of 2 $K^+$ ions and the complex ion $[NiCl_4]^{2+}$. The ligands are chloride ions, so name is 'tetrachlorido'. Nickel has oxidation state +2. Hence, the name is **potassium tetrachloridonickelate(II)**.

**Key Points: Identify ligands and name them alphabetically - Determine oxidation state of the central metal ion - Use proper ligand names and metal oxidation state in Roman numerals**

**Question 27.**

(i) What is a chelate complex ? Give one example.

(ii) What are heteroleptic complexes ? Give one example.

[2 Marks]

**Answer:** (i) A chelate complex is one in which a ligand binds to the central metal atom through two or more donor atoms forming a ring-like structure. Such ligands are called multidentate ligands. Example: $[Ni(en)_3]^{2+}$ where en is ethylenediamine, a bidentate ligand.

(ii) Heteroleptic complexes are coordination compounds where the central metal ion is bonded to more than one kind of ligand. Example: $[Co(NH_3)_4Cl_2]^+$, which contains both $NH_3$ and Cl ligands.

**Key Points: Chelate complexes have multidentate ligands - Chelate complexes form ring structures - Heteroleptic complexes contain different types of ligands - Example of chelate is $[Ni(en)_3]^{2+}$ - Example of heteroleptic is $[Co(NH_3)_4Cl_2]^+$**

**Question 28.**

Write the chemical equation involved in the following reactions :

(a) Reimer-Tiemann reaction

(b) Acetylation of Salicylic acid

[2 Marks]

**Answer: (a) Reimer-Tiemann reaction:**

Phenol ($C_6H_5OH$) reacts with chloroform ($CHCl_3$) in the presence of aqueous sodium hydroxide (NaOH) to form salicylaldehyde ($C_7H_6O_2$). The chemical equation is:

$C_6H_5OH + CHCl_3 + 3NaOH \rightarrow C_6H_4OHCHO$ (salicylaldehyde) $+ 3NaCl + 2H_2O$

**(b) Acetylation of Salicylic acid:**

Salicylic acid ($C_7H_6O_3$) reacts with acetic anhydride ($C_4H_6O_3$) in the presence of an acid catalyst to form acetylsalicylic acid (aspirin, $C_9H_8O_4$) and acetic acid ($CH_3COOH$). The equation is:

$C_7H_6O_3 + (CH_3CO)_2O \rightarrow C_9H_8O_4 + CH_3COOH$

**Key Points: Reimer-Tiemann reaction forms salicylaldehyde from phenol - Acetylation of salicylic acid produces aspirin - Both involve specific reagents and distinct products**

**Question 29.**

Do the following conversions in not more than two steps :

[2 Marks]

(a) $CH_3CN$ to $CH_3-\overset{\overset{O}{\|}}{C}-CH_3$

(b)  to 

**Answer:**

(a) $CH_3CN \rightarrow CH_3–CO–CH_3$ (Acetone)

Use Grignard + hydrolysis on nitrile.

Step 1: Add Grignard reagent
$CH_3CN + CH_3MgBr \rightarrow$ (imine magnesium complex)

Step 2: Acidic hydrolysis
$\rightarrow CH_3–CO–CH_3$ (acetone)

So:

$CH_3CN \xrightarrow{(1)\ CH_3MgBr\ (2)\ H_3O^+} CH_3COCH_3$

---

(b) Benzoic acid ($C_6H_5COOH$) $\rightarrow$ Benzene ($C_6H_6$)

Use soda lime decarboxylation (first convert to salt if counting strictly in steps).

Step 1: Convert to sodium salt
$C_6H_5COOH + NaOH \rightarrow C_6H_5COONa$

Step 2: Heat with soda lime (NaOH/CaO)
$C_6H_5COONa \xrightarrow{(\text{soda lime},\ \Delta)} C_6H_6 + Na_2CO_3$

So:

$C_6H_5COOH \rightarrow C_6H_5COONa \xrightarrow{(\text{soda lime},\ \Delta)} C_6H_6$

**Key Points:**

**Nitrile + Grignard → Ketone and Carboxylate + soda lime → Decarboxylation → Alkane (or arene)**

**Question 30.**

Write two differences between DNA and RNA.

[2 Marks]

**Answer: Differences between DNA and RNA:**

1. Sugar present: DNA contains deoxyribose sugar, whereas RNA contains ribose sugar.
2. Strands: DNA is double-stranded; RNA is single-stranded.
3. Nitrogenous bases: DNA contains thymine (T), but RNA contains uracil (U) instead of thymine.
4. Function: DNA stores genetic information; RNA helps in protein synthesis.

**Key Points: Sugar type difference - Strand number difference - Base difference thymine vs uracil - Functional difference in genetic information and protein synthesis**

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## Section D

**Question 31.**

(i) Write the mechanism of the following reaction :

(ii) Why ortho-nitrophenol is steam volatile while para-nitrophenol is not ?

[3 Marks]

$$2CH_3CH_2OH \xrightarrow[413\ K]{H^+} CH_3 - CH_2 - O - CH_2 - CH_3 + H_2O$$

**Answer:**

(i) This reaction is acid-catalyzed intermolecular dehydration of ethanol to form diethyl ether.

Mechanism:

Step 1: Protonation of ethanol

CH3CH2OH+H+→CH3CH2OH2+

The –OH group gets protonated and becomes a good leaving group (water).

Step 2: Nucleophilic attack by another ethanol molecule (SN2 step)

$CH_3CH_2OH + CH_3CH_2OH_2^+ \rightarrow CH_3CH_2-O^+-CH_2CH_3 + H_2O$

One ethanol molecule attacks the ethyl group of protonated ethanol, and water leaves, forming a protonated ether (oxonium ion).

Step 3: Deprotonation

$CH_3CH_2-O^+-CH_2CH_3 \rightarrow CH_3CH_2-O-CH_2CH_3 + H^+$

Loss of a proton gives diethyl ether and regenerates the acid catalyst.

Conclusion:
At about 413 K, ethanol undergoes intermolecular dehydration in the presence of acid to form diethyl ether.

(ii) Ortho-nitrophenol is steam volatile because it forms intramolecular hydrogen bonding between the -OH and -NO2 groups, which reduces intermolecular forces and makes it easier to vaporize with steam. Para-nitrophenol, on the other hand, forms intermolecular hydrogen bonding resulting in strong molecular association that decreases its volatility and makes it less steam volatile.

**Key Points:**

**Acid-catalyzed intermolecular dehydration of ethanol to form diethyl ethermechanism - Intramolecular hydrogen bonding in ortho-nitrophenol - Intermolecular hydrogen bonding in para-nitrophenol affects volatility**

**Question 32.**

Answer any 3 of the following:

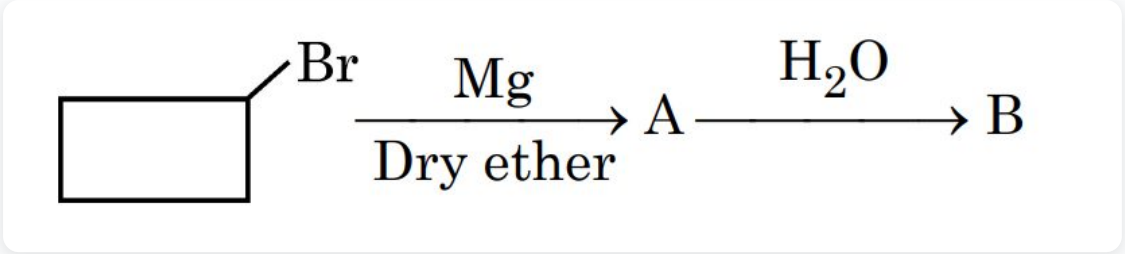
(a) Which isomer of $C_5H_{10}$ gives a single monochloro compound $C_5H_9Cl$ in bright sunlight ?

(b) Arrange the following compounds in increasing order of reactivity towards SN2 reaction : 2-Bromopentane, 1-Bromopentane, 2-Bromo-2-methylbutane

(c) Why p-dichlorobenzene has higher melting point than those of ortho and meta-isomers ?

(d) Identify A and B in the following :

[3 Marks]




**Answer:**

(a) The isomer of C5H10 that gives a single monochloro compound C5H9Cl in bright sunlight is cyclopentane. This is because all hydrogen atoms in cyclopentane are equivalent; hence substitution of one hydrogen by chlorine leads to only one monochloro derivative.
(b) Increasing order of reactivity towards SN2 reaction is: 2-Bromo-2-methylbutane < 2-Bromopentane < 1-Bromopentane. This is because SN2 reactions occur fastest with primary alkyl halides due to less steric hindrance, slower with secondary, and slowest with tertiary alkyl halides.
(c) p-Dichlorobenzene has a higher melting point than ortho and meta isomers because in p-isomer the molecules are more symmetrical and can pack more efficiently in the solid state, leading to stronger intermolecular forces and higher melting point.
(d) Given compound is bromocyclobutane.

Step 1 (with Mg in dry ether):
An alkyl bromide reacts with Mg in dry ether to form a Grignard reagent.

Cyclobutyl–Br(dry ether and Mg)→MgBr- Cyclobutyl

So,
A = Cyclobutyl magnesium bromide (Grignard reagent)

Step 2 (hydrolysis with water):
Grignard reagent on hydrolysis gives the corresponding alkane.

Cyclobutyl–MgBr+H2O→Cyclobutane+Mg(OH)Br

So,
B = Cyclobutane

**Key Points: Cyclopentane gives single monochloro derivative - SN2 reactivity order depends on steric hindrance - p-Dichlorobenzene has higher symmetry and melting point - Molecular structure affects melting and reactivity**

**Question 33.**

A first order reaction is 50% complete in 30 minutes at 300 K and in 10 minutes at 320 K. Calculate activation energy ($E_a$) 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: Given:** $t_{1/2}$ at $T_1$ = 30 min, $T_1$ = 300 K, $t_{1/2}$ at $T_2$ = 10 min, $T_2$ = 320 K, R = 8.314 J $K^{-1}$ $mol^{-1}$

**Step 1:** For a first order reaction, $t_{1/2} = 0.693/k$, so rate constant $k = 0.693 / t_{1/2}$

At 300 K, $k_1 = 0.693 / 30 = 0.0231\ min^{-1}$

At 320 K, $k_2 = 0.693 / 10 = 0.0693\ min^{-1}$

**Step 2:** Use Arrhenius equation: $\ln(k_2/k_1) = E_a/R * (1/T_1 - 1/T_2)$

Calculate $\ln(k_2/k_1)$: $k_2/k_1 = 0.0693 / 0.0231 = 3$

ln 3 = 2.303 * log 3 = 2.303 * 0.4771 = 1.098

**Step 3:** Calculate $(1/T_1 - 1/T_2)$: (1/300 - 1/320) = (320 - 300) / (300 * 320) = 20 / 96000 = 0.0002083 $K^{-1}$

**Step 4:** Rearranged formula: $E_a = (R * \ln(k_2/k_1)) / (1/T_1 - 1/T_2)$

$E_a$ = (8.314 * 1.098) / 0.0002083 = 43818 J/mol = 43.82 kJ/mol

**Answer:** The activation energy $E_a$ for the reaction is approximately 43.8 kJ/mol.

> **Key Points: Use first order half-life formula to find rate constants - Apply Arrhenius equation in logarithmic form - Calculate activation energy using given data and constants**

**Question 34.**

When 19.5 g of F – $CH_2$ – COOH (Molar mass = 78 g $mol^{-1}$), is dissolved in 500 g of water, the depression in freezing point is observed to be 1°C. Calculate the degree of dissociation of F – $CH_2$ – COOH.

[Given : Kf for water = 1.86 K kg $mol^{-1}$]

[3 Marks]

**Answer: Given:** Mass of solute = 19.5 g, Molar mass = 78 g $mol^{-1}$, Mass of solvent (water) = 500 g = 0.5 kg, Depression in freezing point ($\Delta T_f$) = 1°C, $K_f$ = 1.86 K kg $mol^{-1}$

**Step 1: Calculate moles of solute**

Moles = Mass / Molar mass = 19.5 / 78 = 0.25 mol

**Step 2: Calculate molality (m)**

Molality, m = moles of solute / mass of solvent in kg = 0.25 / 0.5 = 0.5 mol $kg^{-1}$

**Step 3: Use freezing point depression formula**

$\Delta T_f = i * K_f * m$, where i = van't Hoff factor

$1 = i * 1.86 * 0.5$

$i = 1 / (1.86 * 0.5) = 1.08$

**Step 4: Calculate degree of dissociation (α)**

For F – $CH_2$ – COOH, which dissociates as HA → $H^+ + A^-$,

i = 1 + α (since it dissociates into 2 ions)

1.08 = 1 + α

α = 0.08

**Answer:** Degree of dissociation of F – $CH_2$ – COOH is 0.08 or 8%.

**Key Points: Calculate moles of solute - Calculate molality - Use $\Delta T_f = i * K_f * m$ to find i - Use i = 1 + α to find degree of dissociation**

**Question 35.**

(a) Draw the geometrical isomers of $[Co(en)_2Cl_2]^{2+}$. Which geometrical isomer of $[Co(en)_2Cl_2]^{2+}$ is not optically active and why ?

(b) Write the hybridisation and magnetic behaviour of $[CoF_6]^{3-}$.

[Given : Atomic number of Co = 27]

[3 Marks]

**Answer: (a)** The complex $[Co(en)_2Cl_2]^{2+}$ has two geometrical isomers:

Cis-isomer: The two Cl ligands are adjacent to each other. This isomer is optically active because it lacks a plane of symmetry and can exhibit optical isomerism.

Trans-isomer: The two Cl ligands are opposite to each other. This isomer is not optically active because it has a plane of symmetry and does not form non-superimposable mirror images.

**Reason:** Trans-isomer has a plane of symmetry making it achiral and hence, not optically active.

**(b)** In $[CoF_6]^{3-}$, Co has oxidation state +3 ($Co^{3+}$). Electronic configuration of Co is [Ar] $3d^7\ 4s^2$. For $Co^{3+}$, configuration is $3d^6$. Fluoride ($F^-$) is a weak field ligand causing high spin complex. Hence, hybridisation is $sp^3d^2$. Magnetic behavior is paramagnetic due to presence of 4 unpaired electrons.

**Summary:**

Cis and trans isomers of $[Co(en)_2Cl_2]^{2+}$ exist. Trans isomer is not optically active due to plane of symmetry.

$[CoF_6]^{3-}$ is high spin octahedral with $sp^3d^2$ hybridisation and is paramagnetic.

**Key Points: Cis and trans geometrical isomers of $[Co(en)_2Cl_2]^{2+}$ - Trans isomer is not optically active due to symmetry - $[CoF_6]^{3-}$ has $sp^3d^2$ hybridisation - It is a high spin complex - Paramagnetic with 4 unpaired electrons**

**Question 36.**

What happens when:

(i) Anisole is treated with $CH_3Cl$/anhydrous $AlCl_3$ ?

(ii) Phenol is oxidised with $Na_2Cr_2O_7/H^+$ ?

(iii) $(CH_3)_3$ C - OH is heated with Cu/574K?

Write chemical equation in support of your answer.

[3 Marks]

**Answer:** (a) When anisole (methoxybenzene) is treated with $CH_3Cl$ in the presence of anhydrous $AlCl_3$, a Friedel-Crafts alkylation occurs at the ortho and para positions. The reaction produces ortho- and para-methylanisole.

$C_6H_5OCH_3 + CH_3Cl + AlCl_3 \rightarrow$ o-$CH_3C_6H_4OCH_3$ + p-$CH_3C_6H_4OCH_3$ + HCl

(b) Phenol when oxidised with sodium dichromate ($Na_2Cr_2O_7$) in acidic medium ($H^+$) undergoes oxidation to form benzoquinone (p-benzoquinone).

$C_6H_5OH + Na_2Cr_2O_7/H^+ \rightarrow C_6H_4O_2$ (Benzoquinone) + $H_2O$

(c) When tert-butyl alcohol ($(CH_3)_3$ C - OH) is heated with copper at 574K, it undergoes dehydrogenation to give isobutylene (2-methylpropene).

$(CH_3)_3COH \rightarrow$ (heat, Cu, 574K) $(CH_3)_2C=CH_2 + H_2$

**Key Points: Anisole undergoes Friedel-Crafts alkylation with CH3Cl/AlCl3 - Phenol oxidises to benzoquinone with Na2Cr2O7/H+ - Tert-butyl alcohol dehydrates to isobutylene on heating with Cu at 574K**

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## Section E

**Question 37.**

Account for the following :

(i) Eo value for $Mn^{3+}/ Mn^{2+}$ couple is much more positive than that for $Cr^{3+}/ Cr^{2+}$.

(ii) $Sc^{3+}$ is colourless whereas $Ti^{3+}$ is coloured in an aqueous solution.

(iii) Actinoids show wide range of oxidation states.

[5 Marks]

**Answer:** (i) The Eo value for $Mn^{3+}/ Mn^{2+}$ is more positive than for $Cr^{3+}/ Cr^{2+}$ because $Mn^{3+}$ has greater tendency to get reduced to $Mn^{2+}$, meaning $Mn^{3+}$ is a stronger oxidising agent than $Cr^{3+}$. This is due to the half-filled $d^5$ configuration of $Mn^{2+}$ which makes it more stable. In contrast, $Cr^{3+}$ has a $d^3$ configuration and $Cr^{2+}$ is less stable, so its reduction potential is less positive.

(ii) $Sc^{3+}$ is colourless as it has electronic configuration with empty d-orbitals ($3d^0$) in aqueous solution and no d-d transitions occur causing colour. $Ti^{3+}$ has one d-electron ($3d^1$) which allows d-d electronic transitions upon absorbing visible light, making $Ti^{3+}$ coloured.

(iii) Actinoids show a wide range of oxidation states because 5f, 6d and 7s orbitals are very close in energy and can participate in bonding. This leads to the variable oxidation states from +3 to +6 and sometimes higher, unlike lanthanoids where 4f electrons are more buried and less involved in bonding causing fewer oxidation states.

**Key Points: Eo value of Mn3+/Mn2+ is more positive due to stability of half-filled d5 configuration in Mn2+ - Sc3+ is colourless due to empty d-orbitals, Ti3+ is coloured due to d-d transitions - Actinoids have variable oxidation states due to participation of 5f, 6d and 7s orbitals in bonding**

**Question 38.**

Write the chemical equations for the preparation of $KMnO_4$ from $MnO_2$.

[5 Marks]

**Answer: Preparation of Potassium Permanganate ($KMnO_4$) from Manganese Dioxide ($MnO_2$)**

Potassium permanganate is prepared by fusing manganese dioxide ($MnO_2$) with potassium hydroxide (KOH) in the presence of an oxidising agent like oxygen ($O_2$) or potassium nitrate ($KNO_3$). The process involves two main steps:

**(a) Formation of Potassium Manganate ($K_2MnO_4$)**

$MnO_2$ is fused with KOH and oxygen which oxidises Mn(IV) to Mn(VI) forming $K_2MnO_4$:

$2\ MnO_2 + 4\ KOH + O_2 \rightarrow 2\ K_2MnO_4 + 2\ H_2O$

**(b) Disproportionation of Potassium Manganate to Potassium Permanganate ($KMnO_4$)**

Potassium manganate (green colour) undergoes disproportionation in acidic medium or upon electrolysis to form potassium permanganate (purple colour):

$3\ K_2MnO_4 + 4\ H^+ \rightarrow 2\ KMnO_4 + MnO_2 + 2\ H_2O$

In summary, manganese dioxide reacts under alkaline fused conditions with an oxidising agent to form

manganate which then converts into permanganate by disproportionation. This method is the commercial preparation of $KMnO_4$.

**Key Points: MnO2 fused with KOH and oxidising agent - Formation of potassium manganate K2MnO4 - Disproportionation of manganate to permanganate KMnO4**

**Question 39.**

(I) Account for the following :

(i) Transition metals form alloys.

(ii) $Ce^{4+}$ is a strong oxidising agent.

(II) Write one similarity and one difference between chemistry of Lanthanoids and Actinoids.

(III) Complete the following ionic equation : $Cr_2O_7^{2-} + 2OH^- \rightarrow$

[5 Marks]

**Answer: (I)** (i) Transition metals form alloys because they have similar atomic sizes and their atoms can easily replace each other in the crystal lattice, creating a mixture of metals with enhanced properties like strength and corrosion resistance.
(ii) $Ce^{4+}$ is a strong oxidising agent because it can easily gain electrons to get reduced to $Ce^{3+}$ due to the stability of the 4f orbitals in $Ce^{3+}$ state.
**(II)** Similarity: Both lanthanoids and actinoids mainly exhibit +3 oxidation state and have inner f-orbitals being filled.
Difference: Lanthanoids have mostly +3 oxidation state and less variable, whereas actinoids show multiple oxidation states ranging from +3 to +6 due to involvement of 5f, 6d and 7s electrons.
**(III)** The ionic equation can be completed as:
$Cr_2O_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$. This shows dichromate ion reacting with hydroxide ion to form chromate ion and water in basic medium.

**Key Points: Transition metals form alloys due to similar atomic sizes-Ce4+ is a strong oxidising agent because it gets reduced to Ce3+-Lanthanoids and actinoids both show +3 oxidation state-Lanthanoids mostly +3 state; Actinoids multiple oxidation states-Dichromate ion reacts with hydroxide ion to form chromate ion and water**

**Question 40.**

(I) Give reasons :

(i) Aniline on nitration gives good amount of m-nitroaniline, though – NH2 group is o/p directing in electrophilic substitution reactions.

(ii) $(CH_3)_2$ NH is more basic than $(CH_3)_3N$ in an aqueous solution.

(iii) Ammonolysis of alkyl halides is not a good method to prepare pure primary amines.

(II) Write the reaction involved in the following :

(i) Gabriel phthalimide synthesis

(ii) Carbyl amine test

[5 Marks]

**Answer:** (I) Give reasons:
(i) Although the –NH2 group is an ortho/para directing group, aniline in acidic medium forms anilinium ion (C6H5NH3+), where the nitrogen's lone pair is protonated and less available for resonance. This decreases the activating effect of –NH2, making the meta position more reactive during nitration, hence more m-nitroaniline is formed.
(ii) (CH3)2NH (dimethylamine) is more basic than (CH3)3N (trimethylamine) in aqueous solution because in trimethylamine, the lone pair on nitrogen is sterically hindered by three methyl groups, making it less available to accept a proton. In dimethylamine, less hindrance allows easier protonation, resulting in higher basicity.
(iii) Ammonolysis of alkyl halides gives a mixture of primary, secondary, tertiary amines and quaternary ammonium salts due to multiple alkylations. Hence, pure primary amines cannot be prepared by this method.

(II) Reactions involved:
(i) Gabriel phthalimide synthesis:
Phthalimide + KOH → Potassium phthalimide + H2O
Potassium phthalimide + RCH2Br → N-alkyl phthalimide + KBr
N-alkyl phthalimide + 2NH2NH2 → Primary amine (RCH2NH2) + phthalhydrazide

(ii) Carbyl amine test:
Primary amine + CCl4 + KOH → isocyanide (R–NC) + KCl + H2O
The formation of isocyanide with a foul smell confirms the presence of primary amine.

**Key Points: Aniline protonation leads to meta substitution - Steric hindrance affects amine basicity - Ammonolysis causes multiple alkylation products - Gabriel synthesis yields primary amines from phthalimide - Carbyl amine test detects primary amines by isocyanide formation**

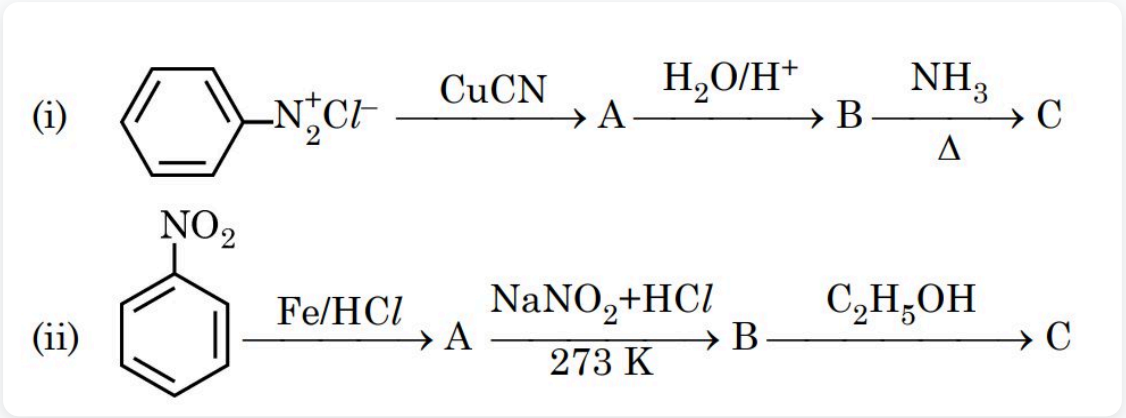
**Question 41.**

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

(II) Why aniline does not undergo Friedal-Crafts reaction ?

(III) Arrange the following in increasing order of their boiling point : $C_2H5OH$, $C_2H_5NH_2$, $(C_2H_5)_3N$

[5 Marks]




**Answer:**

(I) Starting compound: **Benzene diazonium chloride ($C_6H_5–N_2^+Cl^-$)**

**Step 1: With CuCN (Sandmeyer reaction)**
Diazonium group is replaced by **–CN**.

C6H5–N2+Cl− → CuCNC6H5–CN

**A = Benzonitrile ($C_6H_5–CN$)**

**Step 2: With $H_2O$ / $H^+$ (acidic hydrolysis of nitrile)**
Nitrile hydrolyses to **carboxylic acid**.

C6H5–CN → H2O/H+C6H5–COOH

**B = Benzoic acid ($C_6H_5–COOH$)**

**Step 3: With $NH_3$, Δ (heating)**
Carboxylic acid + $NH_3$ on heating gives **amide**.

C6H5–COOH → NH3,ΔC6H5–CONH2

**C = Benzamide ($C_6H_5–CONH_2$)**

**(ii)**Starting compound: **Nitrobenzene ($C_6H_5–NO_2$)**

**Step 1: With Fe/HCl (reduction)**
Nitro group is reduced to **amine**.

C6H5–NO2 → Fe/HClC6H5–NH2

**A = Aniline ($C_6H_5–NH_2$)**

**Step 2: With $NaNO_2$ + HCl at 273 K (diazotization)**
Aniline → **benzene diazonium chloride**.

$$C6H5–NH2 \xrightarrow{273\,K} NaNO2/HClC6H5–N2+Cl−$$

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

**Step 3: With $C_2H_5OH$ (ethanol)**
Diazonium salt is reduced to **benzene**.

$$C6H5–N2+Cl− \rightarrow C2H5OHC6H6$$

**C = Benzene ($C_6H_6$)**

(II) Aniline does not undergo Friedel-Crafts reaction because the amino group ($–NH_2$) on the benzene ring is a strong activating group and also a Lewis base which reacts with the Lewis acid catalyst (like $AlCl_3$) used in Friedel-Crafts reaction, forming a complex. This complex formation deactivates the catalyst and prevents the electrophilic substitution from occurring on the aromatic ring.

(III) Increasing order of boiling points among $C_2H_5OH$ (ethanol), $C_2H_5NH_2$ (ethylamine), and $(C_2H_5)_3N$ (triethylamine) is: $(C_2H_5)_3N < C_2H_5NH_2 < C_2H_5OH$. This is because ethanol has stronger hydrogen bonding than ethylamine, and triethylamine, being a tertiary amine, has weaker hydrogen bonding and lower polarity, leading to lowest boiling point among the three.

> **Key Points: Aniline forms complex with Lewis acid catalyst - Complex formation prevents Friedel-Crafts reaction on aniline - Boiling points depend on hydrogen bonding and molecular structure - Ethanol has strongest hydrogen bonding - Triethylamine has lowest boiling point due to less hydrogen bonding**

**Question 42.**

(a) Conductivity of $2* 10^{-3}$ M methanoic acid is $8 * 10^{-5}$ S $cm^{-1}$. Calculate its molar conductivity and degree of dissociation if $\Lambda°_m$ m for methanoic acid is 404 S $cm^2$ $mol^{-1}$.

(b) Calculate the $\Delta_rG°$ and log Kc for the given reaction at 298 K :

$$Ni_{(s)} + 2Ag^+(aq) \rightleftharpoons Ni^{2+}(aq) + 2Ag_{(s)}$$

Given: $E° Ni^{2+}/Ni = -0.25$ V, $E° Ag^+/Ag = +0.80$V

$1F = 96500$ C $mol^{-1}$.

[5 Marks]

**Answer:** (a) Given data:
Concentration, $c = 2 * 10^{-3}$ mol $L^{-1}$

Conductivity, \u03ba = $8 * 10^{-5}$ S $cm^{-1}$

Molar conductivity at infinite dilution, $\u03bb_m^0$ = 404 S $cm^2$ $mol^{-1}$

Step 1: Calculate molar conductivity $\u03bb_m$ at given concentration

$\u03bb_m$ = \u03ba / c = ($8 * 10^{-5}$ S $cm^{-1}$) / ($2 * 10^{-3}$ mol $L^{-1}$) = 40 S $cm^2$ $mol^{-1}$

Step 2: Calculate degree of dissociation \u03b1

\u03b1 = $\u03bb_m$ / $\u03bb_m^0$ = 40 / 404 \approx 0.099

This means about 9.9% of methanoic acid molecules are dissociated in solution.

(b) Given reaction:

Ni (s) + $2Ag^+$ (aq) \u21cc $Ni^{2+}$ (aq) + 2Ag (s)

Standard electrode potentials:

$E^0_{Ni^{2+}/Ni}$ = -0.25 V

$E^0_{Ag^+/Ag}$ = +0.80 V

Step 1: Calculate standard cell potential $E^0_{cell}$

Anode (oxidation): Ni \u2192 $Ni^{2+}$ + $2e^-$, $E^0$ = -0.25 V

Cathode (reduction): $Ag^+$ + $e^-$ \u2192 Ag, $E^0$ = +0.80 V

Since $2Ag^+$ ions involved, use 2 electrons overall.

$E^0_{cell} = E^0_{cathode} - E^0_{anode}$ = 0.80 - (-0.25) = 1.05 V

Step 2: Calculate standard Gibbs free energy change $\u0394_rG^0$

$\u0394_rG^0$ = -n F $E^0_{cell}$

Here n = 2 (number of electrons)

F = 96500 C $mol^{-1}$

$\u0394_rG^0$ = $-2 * 96500 * 1.05 = -202650$ J $mol^{-1}$ = -202.65 kJ $mol^{-1}$

Step 3: Calculate log $K_c$

$\u0394_rG^0$ = -RT ln $K_c$

ln $K_c$ = -$\u0394_rG^0$ / RT

R = 8.314 J $mol^{-1}$ $K^{-1}$, T = 298 K

ln $K_c$ = 202650 / (8.314 * 298) = 81.7

log $K_c$ = ln $K_c$ / 2.303 = 81.7 / 2.303 \approx 35.47

**Final answers:**

(a) Molar conductivity \u03bb$_m$ = 40 S cm$^2$ mol$^{-1}$, degree of dissociation \u03b1 = 0.099 (9.9%)

(b) \u0394$_r$G$^0$ = -202.65 kJ mol$^{-1}$, log $K_c$ = 35.47

**Key Points: Calculate molar conductivity using conductivity and concentration - Use ratio of molar conductivity to calculate degree of dissociation - Apply standard electrode potentials to find cell potential, Gibbs free energy change, and equilibrium constant**