

CBSE Class 12 Chemistry 2024 Question Paper (Set 2 - 56/4/2)

Time Allowed :3 Hours	Maximum Marks :70	Total Questions :33
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General Instructions

Read the following instructions very carefully and strictly follow them:

1. This question paper contains 33 questions. All questions are compulsory.
2. This question paper is divided into five sections Sections A, B, C, D and E.
3. In Section A Questions no. 1 to 16 are Multiple Choice type questions. Each question carries 1 mark.
4. In Section B Questions no. 17 to 21 are Very Short Answer type questions. Each question carries 2 marks.
5. In Section C Questions no. 22 to 28 are Short Answer type questions. Each question carries 3 marks.
6. In Section D Questions no. 29 and 30 are case study based questions. Each question carries 4 marks.
7. In Section E Questions no. 31 to 33 are Long Answer type questions. Each question carries 5 marks.
8. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section A.
9. Kindly note that there is a separate question paper for Visually Impaired candidates.
10. Use of calculators is not allowed.

1. The molar ionic conductivities of Mg^{2+} and SO_4^{2-} are $106.0 \text{ S cm}^2 \text{ mol}^{-1}$ and $160.0 \text{ S cm}^2 \text{ mol}^{-1}$ respectively. The value of limiting molar conductivity of MgSO_4 will be:

- (A) $266 \text{ S cm}^2 \text{ mol}^{-1}$
- (B) $622 \text{ S cm}^2 \text{ mol}^{-1}$
- (C) $288 \text{ S cm}^2 \text{ mol}^{-1}$
- (D) $822 \text{ S cm}^2 \text{ mol}^{-1}$

Correct Answer: (A) $266 \text{ S cm}^2 \text{ mol}^{-1}$

Solution:

The limiting molar conductivity (Λ_m) of MgSO_4 is given by the sum of the limiting conductivities of its ions:

$$\Lambda_m = \lambda_{\text{Mg}^{2+}} + \lambda_{\text{SO}_4^{2-}}$$

Where: - $\lambda_{\text{Mg}^{2+}} = 106.0 \text{ S cm}^2 \text{ mol}^{-1}$ (given),

- $\lambda_{\text{SO}_4^{2-}} = 160.0 \text{ S cm}^2 \text{ mol}^{-1}$ (given).

Thus, the limiting molar conductivity of MgSO_4 is:

$$\Lambda_m = 106.0 + 160.0 = 266.0 \text{ S cm}^2 \text{ mol}^{-1}$$

💡 Quick Tip

The limiting molar conductivity of an ionic compound is the sum of the limiting conductivities of its individual ions.

2. From the elements of 3d series given below, which element shows the maximum number of oxidation states?

- (A) Scandium
- (B) Manganese
- (C) Chromium
- (D) Titanium

Correct Answer: (B) Manganese

Solution:

Manganese (Mn) has the highest number of oxidation states among the given elements of the 3d series. Manganese can exhibit oxidation states from +2 to +7 in its compounds, giving it a total of 7 possible oxidation states. These oxidation states include +2, +3, +4, +5, +6, +7, and sometimes 0 (in its elemental form).

- Scandium (Sc) shows a maximum oxidation state of +3,
- Chromium (Cr) shows a maximum oxidation state of +6,
- Titanium (Ti) shows a maximum oxidation state of +4.

Therefore, Manganese has the most oxidation states among the 3d transition elements in this group.

💡 Quick Tip

Manganese exhibits the maximum number of oxidation states in the 3d transition series, ranging from +2 to +7.

3. Which alkyl halide from the given options will undergo S_N1 reaction faster?

- (A) $(CH_3)_3C-Br$
- (B) $(CH_3)_2CH-Br$
- (C) CH_3CH_2-Br
- (D) $(CH_3)_3C-CH_2-Br$

Correct Answer: (A) $(CH_3)_3C-Br$

Solution: S_N1 reactions are favored by the formation of a stable carbocation. Among the given options, $(CH_3)_3C-Br$ (tert-butyl bromide) forms a highly stable tertiary carbocation, making it the most reactive towards S_N1 reactions. The tertiary carbocation is more stable than the secondary or primary carbocations formed from the other alkyl halides.

Step 1: Stability of carbocations is crucial in S_N1 reactions. **Step 2:** Tertiary carbocations are the most stable, thus $(CH_3)_3C-Br$ undergoes the reaction faster.

💡 Quick Tip

S_N1 reactions are favored by tertiary carbocations due to their stability.

4. Which of the following acids represents Vitamin C?

- (A) Saccharic acid
- (B) Gluconic acid
- (C) Ascorbic acid
- (D) Benzoic acid

Correct Answer: (C) Ascorbic acid

Solution: Vitamin C is chemically known as ascorbic acid ($C_6H_8O_6$). It is a water-soluble vitamin that plays an important role in the body as an antioxidant and in collagen synthesis. The other acids listed, such as saccharic acid, gluconic acid, and benzoic acid, do not represent Vitamin C.

Step 1: Ascorbic acid is widely known as Vitamin C. **Step 2:** It is essential for the proper functioning of the immune system and collagen formation.

💡 Quick Tip

Ascorbic acid (Vitamin C) is an essential nutrient for humans, playing a role in tissue repair and antioxidant activity.

5. Rosenmund reduction is used for the preparation of aldehydes. The catalyst used in this reaction is:

- (A) $Pd - BaSO_4$

- (B) Anhydrous AlCl_3
- (C) Iron (III) oxide
- (D) HgSO_4

Correct Answer: (A) $\text{Pd} - \text{BaSO}_4$

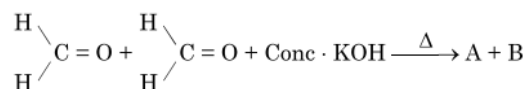
Solution: The Rosenmund reduction is used to reduce acyl chlorides (RCOCl) to aldehydes. The catalyst used in this reaction is palladium on barium sulfate ($\text{Pd} - \text{BaSO}_4$). The presence of barium sulfate acts as a poison to the catalyst, which prevents over-reduction to the corresponding alcohol, allowing the selective formation of the aldehyde.

Step 1: Palladium (Pd) is the catalyst that facilitates the reduction of acyl chlorides. **Step 2:** Barium sulfate (BaSO_4) is used to poison the palladium and prevent over-reduction.

 Quick Tip

Rosenmund reduction requires $\text{Pd} - \text{BaSO}_4$ as the catalyst to selectively reduce acyl chlorides to aldehydes.

6. Consider the following reaction:



Identify A and B from the given options:

- (A) A – Methanol, B – Potassium formate
- (B) A – Ethanol, B – Potassium formate
- (C) A – Methanal, B – Ethanol
- (D) A – Methanol, B – Potassium acetate

Correct Answer: (A) A – Methanol, B – Potassium formate

Solution: The reaction described is a Formose reaction, where two molecules of formaldehyde (HCHO) react with concentrated KOH under heat to form methanol (CH_3OH) and potassium formate (HCOOK). The formose reaction typically involves the condensation of formaldehyde in the presence of an alkaline catalyst, producing methanol and potassium formate.

Step 1: Two molecules of formaldehyde undergo condensation. **Step 2:** Methanol and potassium formate are the expected products.

 Quick Tip

The Formose reaction with formaldehyde and KOH produces methanol and potassium formate.

7. In effective collisions the colliding molecules must have:

- (A) Proper orientation only
- (B) A certain minimum amount of activation energy.
- (C) Threshold energy only.
- (D) Threshold energy and proper orientation both.

Correct Answer: (D) Threshold energy and proper orientation both.

Solution:

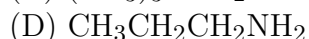
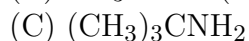
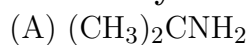
In effective collisions, the colliding molecules must not only have sufficient energy to overcome the activation energy barrier (threshold energy), but they must also collide with the proper orientation so that the reacting molecules can form new bonds.

Activation energy is required to initiate a reaction.

Proper orientation ensures that the colliding molecules can align in a way that promotes bond formation.

💡 Quick Tip

For a reaction to occur, colliding molecules must have sufficient energy (threshold energy) and proper orientation.

8. Identify the secondary amine from the given options:

Correct Answer: (B) $\text{CH}_3\text{NHCH}(\text{CH}_3)_2$

Solution:

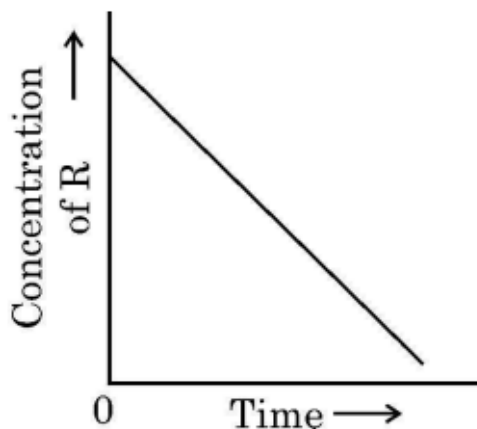
A secondary amine has two alkyl or aryl groups attached to the nitrogen atom. Option (B), $\text{CH}_3\text{NHCH}(\text{CH}_3)_2$, is the secondary amine because the nitrogen is bonded to one methyl group (CH_3) and one ethyl group (CH_2CH_3), making it a secondary amine.

Step 1: Secondary amines have two substituents on the nitrogen atom.

Step 2: In option (B), the nitrogen is attached to two different alkyl groups, confirming it as a secondary amine.

💡 Quick Tip

Secondary amines have two substituents attached to the nitrogen atom, as seen in option (B).

9. In a given graph of zero order reaction, the slope and intercept are:

- (A) Slope = k , Intercept = $[R]_0$
 (B) Slope = $-k$, Intercept = $[R]_0$
 (C) Slope = $k/2.303$, Intercept = $\ln[R]_0$
 (D) Slope = $-k/2.303$, Intercept = $\ln A$
Correct Answer: (B) Slope = $-k$, Intercept = $[R]_0$

Solution:

For a zero-order reaction, the integrated rate law is given by:

$$[R] = [R]_0 - kt$$

Where:

- $[R]$ is the concentration of the reactant at time t ,
- $[R]_0$ is the initial concentration of the reactant,
- k is the rate constant,
- t is the time.

The graph of $[R]$ vs. t is a straight line with a slope of $-k$ and an intercept of $[R]_0$.

Step 1: The slope of the line is the rate constant $-k$.

Step 2: The intercept is the initial concentration of the reactant $[R]_0$.

💡 Quick Tip

For a zero-order reaction, the slope of the plot of $[R]$ vs. time is $-k$, and the intercept is the initial concentration $[R]_0$.

10. The general electronic configuration of d-block elements is:

- (A) $(n-1) d^{10} ns^{1-2}$
 (B) $(n-1) d^{10} ns^{1-2}$
 (C) $(n-1) d^{10} ns^{2-3}$
 (D) $(n-1) d^0 ns^{1-2}$

Correct Answer: (A) $(n-1) d^{10} ns^{1-2}$

Solution:

The general electronic configuration for the d-block elements (transition metals) is:

$$(n-1)d^{1-10}ns^{1-2}$$

Where n represents the principal quantum number. The transition elements fill the d -orbitals after filling the s -orbitals of the outermost shell.

Step 1: Transition metals are characterized by the filling of the d -orbitals.

Step 2: The d -orbitals are filled after the ns -orbitals, leading to the general configuration $(n-1)d^{1-10}ns^{1-2}$.

💡 Quick Tip

The electronic configuration of d-block elements follows the pattern $(n-1)d^{1-10}ns^{1-2}$, where n is the principal quantum number.

11. Nucleophilic addition of Grignard reagent to ketones followed by hydrolysis with dilute acids forms:

- (A) Alkene
- (B) Primary alcohol
- (C) Tertiary alcohol
- (D) Secondary alcohol

Correct Answer: (C) Tertiary alcohol

Solution: The reaction of a Grignard reagent (RMgX) with a ketone results in the formation of a tertiary alcohol. The mechanism involves the nucleophilic attack of the Grignard reagent on the carbonyl carbon of the ketone, followed by hydrolysis to yield a tertiary alcohol. This is because the Grignard reagent adds a second alkyl group to the carbonyl carbon, resulting in a tertiary alcohol.

Step 1: Grignard reagent attacks the carbonyl carbon of the ketone to form a tetrahedral intermediate.

Step 2: Hydrolysis of the intermediate yields a tertiary alcohol.

 Quick Tip

Grignard reagents add to the carbonyl carbon of ketones to form tertiary alcohols after hydrolysis.

12. Match the reagents required for the given reactions:

- I. Oxidation of primary alcohols to aldehydes (p) NaBH_4
 - II. Butan-2-one to Butan-2-ol (q) 85% phosphoric acid at 440 K
 - III. Bromination of Phenol to 2, 4, 6- (r) PCC Tribromophenol
 - IV. Dehydration of propan-2-ol to (s) Bromine water propene
- (A) I — (r), II — (p), III — (s), IV — (q)
 - (B) I — (q), II — (r), III — (p), IV — (s)
 - (C) I — (s), II — (q), III — (p), IV — (r)
 - (D) I — (p), II — (s), III — (r), IV — (q)

Correct Answer: (A) I — (r), II — (p), III — (s), IV — (q)

Solution: - The oxidation of primary alcohols to aldehydes is done using PCC Tribromophenol.

- Butan-2-one is reduced to Butan-2-ol using NaBH_4 .

- Bromination of Phenol to 2, 4, 6-tribromophenol is done using Bromine water propene.

- Dehydration of propan-2-ol leads to propene when treated with 85% phosphoric acid at 440 K

 Quick Tip

For oxidation reactions, NaBH_4 is commonly used, and for reduction reactions, phosphoric acid is often the reagent.

13. Assertion (A): Bromination of Phenol can be carried out even in the absence

of Lewis acid. Reason (R): OH group of Phenol has the high activation effect.

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

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

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

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

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

Solution: The Assertion (A) is true as phenol undergoes bromination even without the presence of a Lewis acid due to the activating effect of the OH group. The Reason (R) is also true as the OH group in phenol increases the electron density on the ring, making it more reactive toward electrophilic substitution reactions like bromination. Thus, Reason (R) correctly explains Assertion (A).

 Quick Tip

Phenol is more reactive in electrophilic aromatic substitution reactions due to the electron-donating nature of the hydroxyl group (-OH).

14. Assertion (A): Fructose is a reducing sugar.

Reason (R): Fructose does not reduce Fehling solution and Tollen's reagent.

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

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

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

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

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

Solution:

- Assertion (A) is true because fructose is a reducing sugar. It contains a carbonyl group in the form of a ketone, which can reduce Fehling's solution and Tollen's reagent under certain conditions.

- Reason (R) is false because fructose, being a reducing sugar, can reduce Tollen's reagent and Fehling's solution. The statement that fructose does not reduce these reagents is incorrect.

Step 1: Fructose, though a ketose, has reducing properties due to its ability to undergo isomerization into an aldose form.

Step 2: Fructose is a reducing sugar and can reduce Fehling's solution and Tollen's reagent.

 Quick Tip

Fructose is a reducing sugar because it can isomerize to an aldose form, which is capable of reducing Tollen's and Fehling's solutions.

15. Assertion (A): For a Daniell cell, $\text{Zn}/\text{Zn}^{2+}(1\text{M}) \text{ --- } \text{Cu}^{2+}(1\text{M})/\text{Cu}$ with $E_{\text{cell}} = 1.1 \text{ V}$, if the external opposing potential is more than 1.1 V, the electrons flow from Cu to Zn.

Reason (R): Cell acts like a galvanic cell.

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

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

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

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

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

Solution:

- Assertion (A) is correct because, in a Daniell cell, when the external opposing potential exceeds 1.1 V, the electron flow is reversed, causing electrons to flow from Cu to Zn.

- Reason (R) is false because a galvanic cell operates without an external opposing potential. A Daniell cell is a type of galvanic cell, but the external potential in this case is artificially introduced, which is not a typical condition for a galvanic cell.

Step 1: In a Daniell cell, electron flow is from the anode (Zn) to the cathode (Cu), but if an external voltage is applied, it can reverse the flow of electrons.

Step 2: A galvanic cell generates electrical energy spontaneously, but external voltages disrupt the normal flow.

 Quick Tip

In a Daniell cell, if the external potential is greater than the cell potential, the direction of electron flow is reversed.

16. Assertion (A): Benzoic acid does not undergo Friedel – Crafts reaction.

Reason (R): Carboxyl group is deactivating and the catalyst aluminium chloride gets bonded to the carboxyl group.

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

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

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

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

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

Solution:

- Assertion (A) is correct because benzoic acid does not undergo Friedel – Crafts reactions due to the deactivating effect of the carboxyl group.

- Reason (R) is also true. The carboxyl group ($-\text{COOH}$) is electron-withdrawing, which deactivates the aromatic ring, making it less reactive towards electrophilic substitution reactions, including Friedel – Crafts reactions.

Step 1: The carboxyl group in benzoic acid deactivates the aromatic ring and prevents the

reaction with electrophiles.

Step 2: The catalyst, AlCl_3 , is unable to bond with the deactivated ring for the Friedel – Crafts reaction to occur.

 Quick Tip

Electron-withdrawing groups such as carboxyl groups deactivate the aromatic ring, preventing Friedel – Crafts reactions.

17. Define the following terms:

(a) Molecularity of reaction

(b) Complex reaction

Solution:

(a) Molecularity of reaction:

Molecularity refers to the number of molecules or ions that must collide in order to result in a chemical reaction. It describes the number of reactant molecules involved in the elementary step of a reaction. For example, in a bimolecular reaction, two reactant molecules collide and react to form products. Molecularity can be classified as follows:

- Unimolecular reaction: Involves one molecule.
- Bimolecular reaction: Involves two molecules.
- Termolecular reaction: Involves three molecules.

(b) Complex reaction:

A complex reaction involves multiple elementary steps, and intermediates may form during the reaction. The rate of the complex reaction is governed by the rate-determining step, which is the slowest elementary step in the sequence. Complex reactions often consist of several steps that must occur in sequence.

Step 1: Molecularity is the number of molecules involved in an elementary reaction.

Step 2: Complex reactions involve multiple steps, with intermediates and a rate-determining step.

 Quick Tip

Molecularity refers to the number of reactant molecules in the elementary step of a reaction. Complex reactions consist of multiple steps, and the overall rate depends on the slowest step.

18. Calculate the molar mass of a compound when 6.3 g of it is dissolved in 27 g of chloroform to form a solution that has a boiling point of 68.04°C . The boiling point of pure chloroform is 61.04°C and K_b for chloroform is $3.63^\circ\text{C kg mol}^{-1}$.

Solution:

The change in boiling point, ΔT_b , is given by:

$$\Delta T_b = T_b - T_{b0} = 68.04^\circ\text{C} - 61.04^\circ\text{C} = 7^\circ\text{C}$$

Now, using the formula for boiling point elevation:

$$\Delta T_b = K_b \times m$$

where m is the molality of the solution. Rewriting the equation for molality:

$$m = \frac{K_b \times w_B \times 1000}{\Delta T_b \times W_A}$$

Here, w_B is the mass of the solute, and W_A is the mass of the solvent. Substituting the given values:

$$m = \frac{3.63 \times 6.3 \times 1000}{7 \times 27}$$

Simplifying:

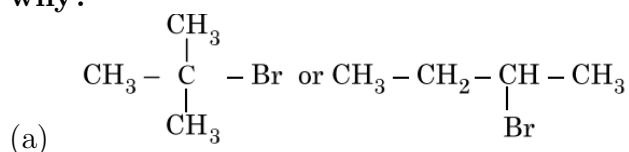
$$m = \frac{22839}{189} = 121 \text{ g mol}^{-1}$$

Thus, the molar mass of the compound is 121 g mol^{-1}

 Quick Tip

Boiling point elevation can be used to calculate the molar mass of a solute. The formula is $\Delta T_b = K_b \times m$, where m is the molality.

19. Which of the following compounds will react more rapidly by S_N2 reaction & why?



Solution:

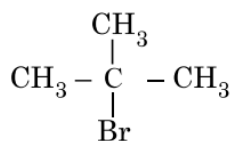
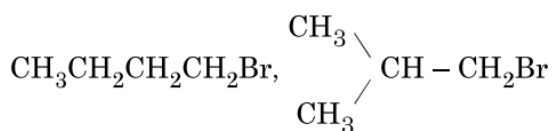
$\text{CH}_3\text{-C-Br}$ will react more rapidly because it is a primary alkyl halide, and primary alkyl halides undergo S_N2 reactions more readily than secondary or tertiary alkyl halides. The size of the alkyl group also affects the rate of the S_N2 reaction, with smaller alkyl groups allowing for easier backside attack by the nucleophile. The bulky secondary alkyl halide in the second compound will be less reactive due to steric hindrance.

In S_N2 reactions, the rate is affected by the steric hindrance around the carbon attached to the leaving group. $\text{CH}_3\text{-C-Br}$ is a primary alkyl halide, and primary halides undergo S_N2 reactions faster than secondary or tertiary halides due to less steric hindrance.

 Quick Tip

In S_N2 reactions, primary alkyl halides are more reactive than secondary or tertiary alkyl halides due to less steric hindrance.

(b) Arrange the following compounds in the increasing order of their boiling points:



Solution: The increasing order of boiling points is:

$\text{CH}_3\text{CH}_2\text{Br} < \text{CH}_3\text{CH}_2\text{CH}_2\text{Br} < \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ This is because the boiling point increases with the size of the molecule and the presence of more carbon atoms, leading to increased London dispersion forces.

The boiling point of a compound is influenced by its molecular weight and intermolecular forces. The larger the alkyl group, the higher the boiling point due to increased van der Waals forces. Thus, the order of boiling points is based on the length of the carbon chain.

💡 Quick Tip

The boiling point of an alkyl halide increases with the length of the carbon chain due to the increased van der Waals forces between the molecules.

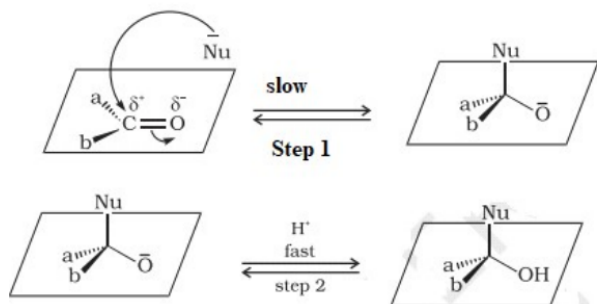
20. (a) Write the stepwise mechanism of nucleophilic addition reactions in the carbonyl compounds.

Solution: Nucleophilic addition reactions occur when a nucleophile attacks the electrophilic carbonyl carbon in aldehydes or ketones. The general mechanism is as follows:

Step 1: The nucleophile (e.g., a hydride ion, alkoxide, or Grignard reagent) attacks the carbonyl carbon of the aldehyde or ketone, breaking the double bond and forming a tetrahedral intermediate.

Step 2: The intermediate is protonated (usually by a water molecule or proton donor) to form the final addition product. For example, if the nucleophile is a hydride (H^-), the product will be an alcohol.

Step 3: The product after protonation is a carbonyl addition product, such as an alcohol.



💡 Quick Tip

In nucleophilic addition reactions, the nucleophile adds to the electrophilic carbonyl carbon, forming a tetrahedral intermediate that is protonated to yield the product.

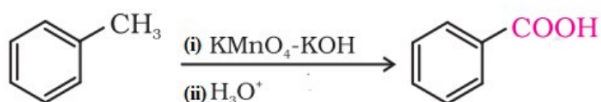
(b) How will you convert the following?

(i) Toluene to benzoic acid.

(ii) Ethanol to 3-Hydroxybutanal.

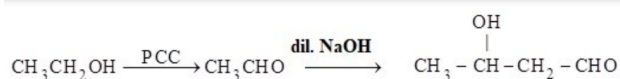
Solution: (i) Toluene to Benzoic acid:

Toluene ($\text{C}_6\text{H}_5\text{CH}_3$) can be oxidized to benzoic acid ($\text{C}_6\text{H}_5\text{COOH}$) using strong oxidizing agents such as potassium permanganate (KMnO_4) or chromic acid (H_2CrO_4). These reagents will oxidize the methyl group ($-\text{CH}_3$) into a carboxyl group ($-\text{COOH}$), converting toluene into benzoic acid.



(ii) Ethanol to 3-Hydroxybutanal:

Ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) can be oxidized to acetaldehyde (CH_3CHO) by using an oxidizing agent like PCC (Pyridinium chlorochromate) or mild oxidizers. The acetaldehyde then undergoes a nucleophilic addition with a Grignard reagent (like CH_3MgBr) to form the intermediate 3-hydroxybutanal.



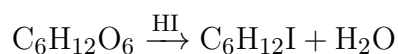
💡 Quick Tip

Toluene can be oxidized using strong oxidizing agents to form benzoic acid, while ethanol can be oxidized to acetaldehyde, which then reacts to form 3-hydroxybutanal.

21. (a) What happens when Glucose reacts with HI? Write the chemical equation.

Solution:

When glucose reacts with HI, the reaction produces an alkyl iodide. The hydroxyl group ($-\text{OH}$) of glucose is replaced by iodine. The reaction mechanism involves the cleavage of the $-\text{OH}$ group and its substitution with iodine.



Thus, glucose undergoes substitution with iodine, forming an alkyl iodide.

💡 Quick Tip

HI reacts with glucose by replacing the hydroxyl group ($-\text{OH}$) with iodine, forming an alkyl iodide.

(b) Which type of bond holds a DNA double helix together?

Solution:

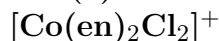
The DNA double helix is held together by hydrogen bonds. These bonds form between the nitrogenous bases of the two complementary strands of DNA. Specifically, adenine (A) pairs

with thymine (T) and guanine (G) pairs with cytosine (C) via hydrogen bonding.

💡 Quick Tip

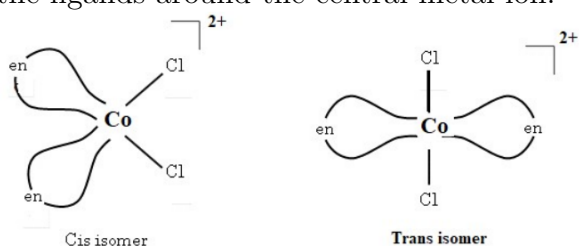
The two strands of DNA are held together by hydrogen bonds between complementary base pairs (A-T and G-C).

22. (a) Draw the geometrical isomers of the given complex:



Solution:

The geometrical isomers of the complex $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ are cis and trans isomers. In the cis isomer, the two chloride ions are adjacent to each other, while in the trans isomer, the chloride ions are opposite each other. These isomers arise due to the spatial arrangement of the ligands around the central metal ion.



Cis Isomer: $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ (chlorides adjacent)

Trans Isomer: $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ (chlorides opposite)

💡 Quick Tip

In coordination complexes, cis and trans isomerism occurs due to different spatial arrangements of ligands around the central metal ion.

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

Solution:

For a d^4 ion with $\Delta_0 > P$, the electronic configuration would be:



This configuration indicates that all six electrons are placed in the lower-energy t_{2g} orbitals, leaving the higher-energy e_g orbitals empty.

💡 Quick Tip

When $\Delta_0 > P$, electrons prefer to pair in the lower-energy t_{2g} orbitals, leading to low-spin configurations.

(c) What is a dentate ligand? Give one example.

Solution:

A dentate ligand is a ligand that can form multiple bonds with a metal center through more than one donor atom. An example of a dentate ligand is ethylenediamine (en), which can form two bonds to a metal ion due to its two nitrogen donor atoms.

 Quick Tip

A dentate ligand can bind to a metal center through multiple donor atoms, like ethylenediamine (en) which is a bidentate ligand.

23. (a) Give chemical tests to distinguish between the following pairs of compounds:

- (i) Phenol and Benzoic acid
- (ii) Propanal and Propanone

Solution:

(i) Phenol gives a violet color when treated with neutral FeCl_3 , forming a complex, while benzoic acid does not react in the same way. The violet coloration is a characteristic test for phenol.

Test for phenol: Add neutral $\text{FeCl}_3 \rightarrow$ Violet color.

Test for benzoic acid: No reaction with FeCl_3 .

(ii) Propanal (an aldehyde) gives a silver mirror when treated with Tollens' reagent, while propanone (a ketone) does not. This is because aldehydes are easily oxidized to carboxylic acids, whereas ketones do not readily undergo oxidation.

Test for propanal: Add Tollens' reagent $\rightarrow$ Silver mirror formation. Test for propanone: No reaction with Tollens' reagent.

 Quick Tip

Phenol reacts with FeCl_3 to form a violet complex, while benzoic acid does not react similarly.

Tollens' reagent gives a silver mirror with aldehydes (propanal), but not with ketones (propanone).

(b) Which one of the given compounds is a stronger acid and why?

$\text{CH}_2\text{FCH}_2\text{CH}_2\text{COOH}$ or $\text{CH}_3\text{CHFCH}_2\text{COOH}$

Solution:

The compound $\text{CH}_2\text{FCH}_2\text{CH}_2\text{COOH}$ is a stronger acid than $\text{CH}_3\text{CHFCH}_2\text{COOH}$. This is due to the presence of the fluorine atom in $\text{CH}_2\text{FCH}_2\text{CH}_2\text{COOH}$, which is highly electronegative and withdraws electron density from the carboxyl group through the inductive effect. This increases the positive character of the hydrogen in the carboxyl group, making it more likely to dissociate as a proton (H^+).

On the other hand, $\text{CH}_3\text{CHFCH}_2\text{COOH}$ contains fluorine attached to a carbon in the alkyl chain, which still has some electron-withdrawing effect, but it is less pronounced than the effect in $\text{CH}_2\text{FCH}_2\text{CH}_2\text{COOH}$ where the fluorine is directly attached to the carbon adjacent to the carboxyl group.

 Quick Tip

Fluorine is a highly electronegative atom and when placed close to a functional group like the carboxyl group, it increases the acidity of the compound by withdrawing electron density via the inductive effect.

24. Show that the time required for 99.9% completion in a first-order reaction is 10 times of half-life ($t_{1/2}$) of the reaction.

Solution: The integrated rate law for a first-order reaction is:

$$\ln \left(\frac{[R_0]}{[R]} \right) = kt$$

Where:

- $[R_0]$ is the initial concentration,
- $[R]$ is the concentration at time t ,
- k is the rate constant,
- t is the time.

Step 1: For 99.9

$$\begin{aligned} \ln \left(\frac{[R_0]}{0.1[R_0]} \right) &= kt_{99.9\%} \\ \ln 10 &= kt_{99.9\%} \\ t_{99.9\%} &= \frac{2.303}{k} \log 10 = \frac{2.303}{k} \end{aligned}$$

Step 2: For half-life $t_{1/2}$, $[R] = 0.5[R_0]$, so:

$$\begin{aligned} \ln \left(\frac{[R_0]}{0.5[R_0]} \right) &= kt_{1/2} \\ \ln 2 &= kt_{1/2} \\ t_{1/2} &= \frac{2.303}{k} \log 2 = \frac{2.303}{k} \times 0.3010 = \frac{2.303}{k} \times 0.3010 \end{aligned}$$

Step 3: Now, dividing the two expressions:

$$\frac{t_{99.9\%}}{t_{1/2}} = \frac{\frac{2.303}{k}}{\frac{2.303 \times 0.3010}{k}} = \frac{1}{0.3010} = 10$$

Final Answer: The time required for 99.9% completion is 10 times the half-life of the reaction.

 Quick Tip

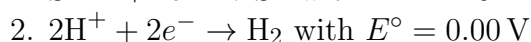
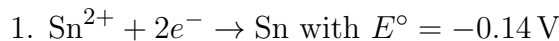
For first-order reactions, the time for 99.9% completion is approximately 10 times the half-life ($t_{1/2}$).

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

Sn/Sn²⁺(0.001 M) — H⁺(0.01 M) — H₂(g)(1 bar) — Pt(s)
 Given: $E^\circ(\text{Sn}^{2+}/\text{Sn}) = -0.14 \text{ V}$, $E^\circ \text{H}^+/\text{H}_2 = 0.00 \text{ V}$ ($\log 10 = 1$)

Solution: We are given the following data:

- The cell consists of two half-reactions:



- Concentration of $\text{Sn}^{2+} = 0.001 \text{ M}$

- Concentration of $\text{H}^+ = 0.01 \text{ M}$

- Standard pressure for $\text{H}_2 = 1 \text{ bar}$

Step 1: Write the Nernst equation for the cell:

$$E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0592}{n} \log Q$$

Where:

- $E_{\text{cell}}^\circ = E_{\text{cathode}}^\circ - E_{\text{anode}}^\circ$

- n is the number of electrons transferred (in this case, $n = 2$).

- Q is the reaction quotient, which is calculated as:

$$Q = \frac{[\text{Sn}^{2+}]}{[\text{H}^+]^2}$$

Substitute the given values:

$$Q = \frac{0.001}{(0.01)^2} = \frac{0.001}{0.0001} = 10$$

Step 2: Calculate the standard cell potential E_{cell}° :

$$E_{\text{cell}}^\circ = E_{\text{cathode}}^\circ - E_{\text{anode}}^\circ = 0.00 \text{ V} - (-0.14 \text{ V}) = 0.14 \text{ V}$$

Step 3: Apply the values to the Nernst equation:

$$E_{\text{cell}} = 0.14 \text{ V} - \frac{0.0592}{2} \log 10$$

Since $\log 10 = 1$, we get:

$$E_{\text{cell}} = 0.14 \text{ V} - \frac{0.0592}{2} \times 1$$

$$E_{\text{cell}} = 0.14 \text{ V} - 0.0296 \text{ V} = 0.1104 \text{ V}$$

Final Answer: The emf of the cell at 25°C is $E_{\text{cell}} = 0.1104 \text{ V}$.

Quick Tip

Use the Nernst equation to calculate the emf of electrochemical cells, considering concentrations and standard electrode potentials.

26. Define the following terms:

(a) Non-essential amino acids.

(b) Monosaccharides.

(c) Anomers.

Solution:

(a) Non-essential amino acids are amino acids that the body can synthesize on its own and thus do not need to be obtained from the diet. These amino acids are part of the metabolic pathways that allow the body to create them as required. Examples of non-essential amino acids include alanine, aspartic acid, and glutamic acid. The body is capable of synthesizing them from other compounds in the body.

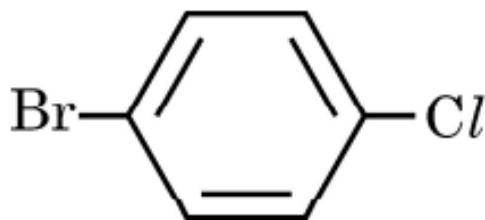
Non-essential amino acids are not needed through the diet because the body can synthesize them on its own from other molecules.

(b) Monosaccharides are the simplest form of carbohydrates. They cannot be hydrolyzed into smaller carbohydrates. They are the building blocks of more complex carbohydrates like disaccharides and polysaccharides. Common monosaccharides include glucose, fructose, and galactose. They have a general formula of $C_nH_{2n}O_n$, where n is typically 3, 4, 5, or 6, corresponding to triose, tetrose, pentose, and hexose sugars, respectively.

Monosaccharides are simple sugars, such as glucose, that cannot be broken down into simpler carbohydrates.

(c) Anomers are a type of stereoisomer that specifically applies to cyclic forms of sugars. Anomers occur when the molecule cyclizes, and the new stereochemistry at the anomeric carbon (the carbon that was part of the carbonyl group) differs. Anomers are of two types: α -anomer and β -anomer, depending on the orientation of the hydroxyl group at the anomeric carbon. For example, in glucose, the anomeric carbon can either have the -OH group pointing down (α -anomer) or up (β -anomer) relative to the plane of the ring. Anomers are isomers that differ in the configuration at the anomeric carbon in cyclic forms of sugars, leading to α - and β -anomer types.

27. (a) Write the IUPAC name of the given compound:



Solution:

The given compound is 1-bromo-2-chlorobenzene. In this compound, the positions of the substituents (bromine and chlorine) are denoted by their respective numbers. The benzene ring is numbered such that the bromo group is at position 1 and the chloro group is at position 2. Therefore, the IUPAC name is 1-bromo-2-chlorobenzene.

IUPAC Name: 1 – bromo-2-chlorobenzene

💡 Quick Tip

When naming substituted benzene rings, the positions of the substituents are indicated by numbers, such as 1-bromo-2-chlorobenzene.

(b) Why are haloalkanes more reactive towards nucleophilic substitution reactions

than haloarenes?

Solution:

Haloalkanes are more reactive towards nucleophilic substitution reactions compared to haloarenes because the carbon-halogen bond in haloalkanes is more polar and weaker than the carbon-halogen bond in haloarenes. In haloalkanes, the halogen (Cl, Br, or I) is attached to a saturated carbon, and the bond is easier to break. In contrast, in haloarenes, the halogen is attached to a carbon in the benzene ring, which has delocalized electrons, making the carbon-halogen bond stronger and less susceptible to nucleophilic attack. This resonance stabilization in haloarenes makes nucleophilic substitution reactions slower.

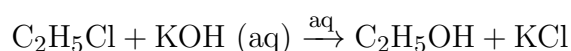
💡 Quick Tip

Haloalkanes undergo nucleophilic substitution more readily than haloarenes because of the weaker carbon-halogen bonds in haloalkanes.

(c) What happens when ethyl chloride is treated with aqueous KOH?

Solution:

When ethyl chloride ($\text{C}_2\text{H}_5\text{Cl}$) is treated with aqueous KOH, a nucleophilic substitution reaction occurs. The hydroxide ion (OH^-) from KOH displaces the chlorine atom, replacing it with a hydroxyl group, forming ethanol ($\text{C}_2\text{H}_5\text{OH}$). The reaction is:



This is an example of an $\text{S}_{\text{N}}2$ reaction.

💡 Quick Tip

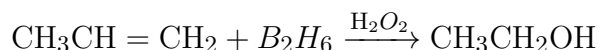
When a haloalkane like ethyl chloride reacts with aqueous KOH, a nucleophilic substitution occurs, resulting in the formation of an alcohol.

28. Write chemical equations for the following reactions: (Do any three)

- (a) Hydroboration – oxidation reaction
- (b) Williamson Synthesis
- (c) Friedel-Crafts Alkylation of Anisole
- (d) Reimer-Tiemann Reaction

Solution: (a) Hydroboration – Oxidation reaction:

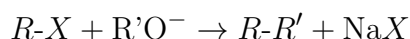
The hydroboration-oxidation of an alkene results in an alcohol. In this reaction, alkene ($\text{CH}_3\text{CH}=\text{CH}_2$) undergoes hydroboration with diborane (B_2H_6), followed by oxidation with hydrogen peroxide to form an alcohol. The reaction is as follows:



Here, the alkene is converted to the alcohol with anti-Markovnikov addition.

(b) Williamson Synthesis:

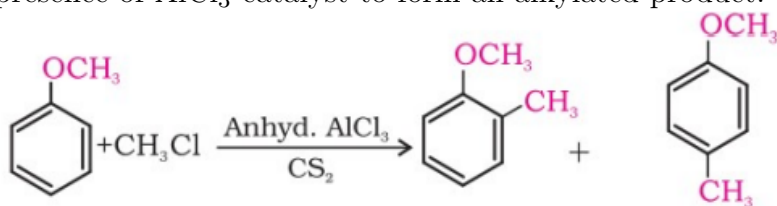
The Williamson synthesis involves the reaction of an alkoxide ion with an alkyl halide to form an ether. The general reaction is:



Where $R-X$ is the alkyl halide, $R'-O^-$ is the alkoxide ion, and $R-R'$ is the ether product.

(c) Friedel-Crafts Alkylation of Anisole:

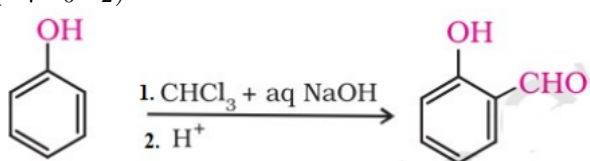
In Friedel-Crafts alkylation, anisole ($C_6H_5OCH_3$) reacts with an alkyl halide (CH_3Cl) in the presence of $AlCl_3$ catalyst to form an alkylated product. The reaction is as follows:



Here, the methyl group is added to the aromatic ring, forming methyl anisole.

(d) Reimer-Tiemann Reaction:

The Reimer-Tiemann reaction involves the reaction of phenol (C_6H_5OH) with chloroform ($CHCl_3$) in the presence of aqueous $NaOH$, followed by acidification to form salicylaldehyde ($C_7H_6O_2$). The reaction is as follows:



Here, the formyl group ($-CHO$) is introduced to the phenol to form salicylaldehyde.

💡 Quick Tip

These reactions are classic organic transformations. Hydroboration-oxidation adds alcohol across alkenes, Williamson synthesis forms ethers, Friedel-Crafts alkylation alkylates aromatic rings, and Reimer-Tiemann introduces a formyl group to phenol.

29. In a galvanic cell, chemical energy of a redox reaction is converted into electrical energy, whereas in an electrolytic cell the redox reaction occurs on passing electricity. The simplest galvanic cell is in which Zn rod is placed in a solution of $ZnSO_4$ and Cu rod is placed in a solution of $CuSO_4$. The two rods are connected by a metallic wire through a voltmeter. The two solutions are joined by a salt bridge. The difference between the two electrode potentials of the two electrodes is known as electromotive force. In the process of electrolysis, the decomposition of a substance takes place by passing an electric current. One mole of electric charge when passed through a cell will discharge half a mole of a divalent metal ion such as Cu^{2+} . This was first formulated by Faraday in the form of laws of electrolysis.

Answer the following questions:

(a) What is the function of a salt bridge in a galvanic cell?

Solution:

(a) **Function of a salt bridge in a galvanic cell:**

The salt bridge allows the flow of ions between the two half-cells, which maintains electrical neutrality. Without the salt bridge, the flow of electrons in the external circuit would stop as the charges would accumulate in the solutions, thus preventing the redox reactions from continuing. It completes the circuit and ensures the flow of charge, allowing the

electrochemical reactions to continue.

💡 Quick Tip

A salt bridge maintains electrical neutrality in the galvanic cell by allowing ions to flow between the two half-cells.

(b) When does a galvanic cell behave like an electrolytic cell?

Solution: A galvanic cell behaves like an electrolytic cell when an external potential greater than the emf (E_{cell}) is applied to the system. This causes the reverse of the natural spontaneous reaction, i.e., a non-spontaneous reaction occurs. In this situation, the cell starts to consume electrical energy rather than produce it. The external voltage must exceed the cell's electromotive force ($E_{\text{ext}} > E_{\text{cell}}$) for the reaction to reverse.

💡 Quick Tip

When $E_{\text{ext}} > E_{\text{cell}}$, a galvanic cell behaves like an electrolytic cell, and the electrochemical reaction is driven in reverse.

(c) Can copper sulphate solution be stored in a pot made of zinc? Explain with the help of the value of E_{cell}° :

Solution: To determine if copper sulphate solution can be stored in a pot made of zinc, we need to calculate the E_{cell}° for the cell. The E_{cell}° is given by:

$$E_{\text{cell}}^{\circ} = E_{\text{Cu}^{2+}/\text{Cu}}^{\circ} - E_{\text{Zn}^{2+}/\text{Zn}}^{\circ}$$

Substituting the given values:

$$E_{\text{cell}}^{\circ} = 0.34 \text{ V} - (-0.76 \text{ V}) = 1.10 \text{ V}$$

Since E_{cell}° is positive (+1.10 V), the reaction will proceed spontaneously, with zinc being oxidized and copper being reduced. This means that copper sulphate solution cannot be stored in a pot made of zinc because zinc will react with the copper ions in the solution, causing zinc to dissolve and copper to deposit on the surface.

💡 Quick Tip

A positive E_{cell}° indicates that the reaction is spontaneous, so zinc will be oxidized in the presence of copper ions, making copper sulphate unsuitable for storage in a zinc pot.

OR

(c) How much charge in terms of Faraday is required for the following reactions:

- (i) 1 mol of MnO_4^- to Mn^{2+}
- (ii) 1 mol of H_2O to O_2

Solution: To calculate the charge required, we use Faraday's first law of electrolysis, which states that one mole of electrons corresponds to 1 Faraday (F) of charge, and the amount of charge required for a reaction depends on the number of moles of electrons involved in the reaction.

(i) 1 mol of MnO_4^- to Mn^{2+} :

The reaction for the reduction of MnO_4^- to Mn^{2+} involves 5 electrons, so the charge required is:

$$\text{Charge} = 5 \times F = 5F$$

(ii) 1 mol of H_2O to O_2 :

The reaction for the oxidation of H_2O to O_2 involves 2 electrons, so the charge required is:

$$\text{Charge} = 2 \times F = 2F$$

💡 Quick Tip

Faraday's law relates the charge passed through a solution to the amount of substance decomposed or deposited. The number of electrons involved in a reaction determines the total charge required.

30. The nature of bonding, structure of the coordination compound can be explained to some extent by valence bond theory. The central metal atom/ion makes available a number of vacant orbitals equal to its coordination number. The appropriate atomic orbitals (s, p and d) of the metal hybridize to give a set of equivalent orbitals of definite geometry such as square planar, tetrahedral, octahedral and so on. A strong covalent bond is formed only when the orbitals overlap to the maximum extent. The d-orbitals involved in the hybridization may be either inner d-orbitals i.e. $(n-1)d$ or outer d-orbitals i.e. nd . The complexes formed are called inner orbital complex (low spin complex) and outer orbital complex (high spin complex) respectively. Further, the complexes can be paramagnetic or diamagnetic in nature. The drawbacks of this theory are that this involves number of assumptions and also does not explain the colour of the complex.

Answer the following questions:

(a) Predict whether $[\text{CoF}_6]^{3-}$ is diamagnetic or paramagnetic and why?

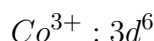
[Atomic number : $\text{Co} = 27$]

Solution:

(a) Paramagnetic or Diamagnetic Nature of $[\text{CoF}_6]^{3-}$:

To predict whether $[\text{CoF}_6]^{3-}$ is paramagnetic or diamagnetic, let's look at the electronic configuration of Co^{3+} . The electronic configuration of Co is $[\text{Ar}] 3d^7 4s^2$. For Co^{3+} , the electrons are removed from the 4s and 3d orbitals, leaving the configuration $3d^6$. In the case of $[\text{CoF}_6]^{3-}$, fluorine is a weak field ligand and does not cause pairing of the electrons. Therefore, the 6 electrons in the 3d orbitals remain unpaired, making $[\text{CoF}_6]^{3-}$ paramagnetic.

Step 1: Determine the electron configuration of Co^{3+}



Step 2: The presence of unpaired electrons in the 3d orbitals means that the complex is paramagnetic.

💡 Quick Tip

A complex is paramagnetic if it contains unpaired electrons in its metal's d-orbitals. If all electrons are paired, it is diamagnetic.

(b) What is the coordination number of Co in $[Co(en)_2Cl_2]^+$?

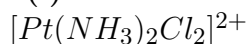
Solution: The coordination number of a metal in a coordination complex is determined by the number of ligand atoms directly bonded to the metal ion. In $[Co(en)_2Cl_2]^+$, ethylenediamine (en) is a bidentate ligand, meaning each en ligand forms two bonds with the metal. Chloride (Cl) is a monodentate ligand, forming one bond with the metal. Therefore, the total coordination number is:

$$\text{Coordination number} = 2 \times 2 (\text{from two en ligands}) + 2 (\text{from two Cl ligands}) = 6$$

💡 Quick Tip

The coordination number is determined by counting the number of bonds formed between the metal and the ligands. Bidentate ligands contribute two bonds.

c(i) Write the IUPAC name of the given complex:



Solution:

In this complex, platinum (Pt) is the central metal ion, and it is surrounded by two ammonia (NH_3) ligands and two chloride (Cl^-) ligands. According to IUPAC nomenclature:

- Ammonia is a neutral ligand and is named as "ammine."
- Chloride is an anionic ligand and is named as "chloro."
- The metal ion (platinum) is named first, followed by the ligands in alphabetical order.

The IUPAC name of the complex is:

Diamminedichloroplatinum(IV) ion

Step 1: Identify the ligands and their names (ammine and chloro).

Step 2: Name the metal and its oxidation state (Pt(II)).

Step 3: Put the ligands and metal together following IUPAC naming rules.

💡 Quick Tip

In IUPAC naming, the ligands are named alphabetically before the metal, and the oxidation state of the metal is indicated in parentheses.

c(ii) Explain $[Co(NH_3)_6]^{3+}$ is an inner orbital or outer orbital complex.

Solution: The complex $[Co(NH_3)_6]^{3+}$ involves the coordination of six ammine (NH_3) ligands to a Co^{3+} ion. For Co^{3+} (with electron configuration $3d^6$), the hybridization occurs using the inner $3d$, $4s$, and $4p$ orbitals, as NH_3 is a weak field ligand and does not cause significant pairing of electrons. Therefore, the complex uses the inner d -orbitals for hybridization and is considered an inner orbital complex.

Step 1: Consider the electron configuration of Co^{3+} and the ligands involved.

Step 2: Since NH_3 is a weak field ligand, Co^{3+} does not undergo pairing, and the metal uses its inner orbitals for hybridization.

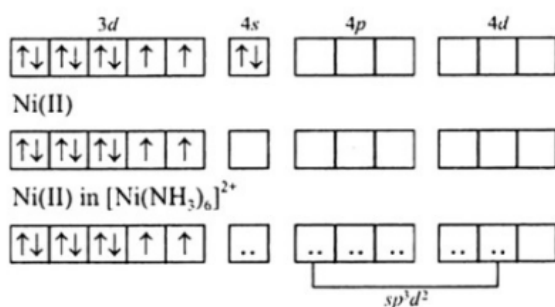
💡 Quick Tip

Inner orbital complexes form when the metal ion uses lower energy d -orbitals for bonding. Outer orbital complexes use higher energy d -orbitals.

OR

(c) Using valence bond theory, deduce the shape and hybridisation of $[Ni(NH_3)_6]^{2+}$
[Atomic number of $Ni = 28$]

Solution: For $[Ni(NH_3)_6]^{2+}$, the coordination number is 6, and the ligand is ammine (NH_3), which is a weak field ligand. Thus, the metal ion, Ni^{2+} , will undergo octahedral hybridization using $3d$, $4s$, and $4p$ orbitals. Since the coordination number is 6, the complex must have an octahedral shape.



Step 1: The Ni^{2+} ion has the electron configuration $3d^8 4s^2$, and upon losing two electrons, it forms Ni^{2+} with $3d^8$.

Step 2: The Ni^{2+} ion uses its $3d$, $4s$, and $4p$ orbitals to form six hybrid orbitals, leading to an octahedral shape.

Step 3: The hybridization of the Ni^{2+} ion is sp^3d^2 , and the complex adopts an octahedral shape.

💡 Quick Tip

For a coordination number of 6, the complex adopts an octahedral shape with sp^3d^2 hybridization.

31. (a) (i) Define reverse osmosis.

Solution:

Step 1: Reverse osmosis is the process in which solvent molecules pass through a

semipermeable membrane from a region of low solute concentration to a region of high solute concentration when pressure greater than the osmotic pressure is applied. The solvent moves against the natural osmotic gradient.

Step 2: This process is widely used in water purification and desalination, where solvent (typically water) is purified by removing solutes like salts and other impurities.

💡 Quick Tip

In reverse osmosis, pressure is applied to push the solvent from low concentration to high concentration across a semipermeable membrane.

(ii) Why are aquatic species more comfortable in cold water in comparison to warm water?

Solution:

Step 1: Cold water has a higher solubility for gases such as oxygen. Since oxygen is crucial for respiration in aquatic species, cold water allows more oxygen to dissolve, making it more available for aquatic species.

Step 2: As temperature increases, the solubility of gases in water decreases. Therefore, warmer water contains less dissolved oxygen, making it less suitable for aquatic life.

💡 Quick Tip

Cold water can hold more dissolved oxygen, making it more suitable for aquatic species, as they rely on dissolved oxygen for respiration.

(iii) A solution containing 2 g of glucose ($M = 180 \text{ g mol}^{-1}$) in 100 g of water is prepared at 303 K. If the vapour pressure of pure water at 303 K is 32.8 mm Hg, what would be the vapour pressure of the solution?

Solution: We can calculate the vapour pressure of the solution using Raoult's Law, which states that the vapour pressure of the solvent in the solution is proportional to the mole fraction of the solvent.

$$P = P_0 \times X_{\text{solvent}}$$

Where: - $P_0 = 32.8 \text{ mm Hg}$ is the vapour pressure of pure water,

- X_{solvent} is the mole fraction of water.

Step 1: Calculate the moles of glucose:

$$\text{Moles of glucose} = \frac{2}{180} = 0.0111 \text{ mol}$$

Step 2: Calculate the moles of water:

$$\text{Moles of water} = \frac{100}{18} = 5.56 \text{ mol}$$

Step 3: Calculate the mole fraction of water:

$$X_{\text{water}} = \frac{\text{moles of water}}{\text{moles of water} + \text{moles of glucose}} = \frac{5.56}{5.56 + 0.0111} = 0.998$$

Step 4: Calculate the vapour pressure of the solution:

$$P = 32.8 \times 0.998 = 32.734 \text{ mm Hg}$$

Thus, the vapour pressure of the solution is 32.734 mm Hg.

 Quick Tip

Raoult's Law states that the vapour pressure of a solvent in a solution is proportional to the mole fraction of the solvent. The presence of a solute lowers the vapour pressure.

OR

(b) (i) Predict whether Van't Hoff factor will be less or greater than one when Ethanoic acid is dissolved in benzene.

Solution: Ethanoic acid (CH_3COOH) is a weak acid and it forms dimers in benzene due to hydrogen bonding between two molecules of ethanoic acid. The formation of dimers reduces the number of particles in the solution. Since Van't Hoff factor i represents the number of particles in solution, for ethanoic acid in benzene, i will be less than 1 due to the dimerization process.

Step 1: Ethanoic acid dissociates into dimers, reducing the total number of particles in the solution.

Step 2: Therefore, the Van't Hoff factor i will be less than 1.

 Quick Tip

Van't Hoff factor (i) is less than 1 when solute molecules form complexes or dimers in solution.

(ii) Define ideal solution.

Solution: An ideal solution is one that obeys Raoult's Law completely over the entire range of concentrations. In an ideal solution, the enthalpy of mixing is zero, and the intermolecular forces between the components (solvent-solvent, solute-solute, and solvent-solute) are similar. There is no excess enthalpy change upon mixing, and the vapor pressure of the solution is proportional to the mole fraction of each component. Real solutions that do not follow Raoult's law due to differences in intermolecular interactions are termed non-ideal solutions.

 Quick Tip

Ideal solutions obey Raoult's law at all concentrations and have no enthalpy change during mixing, implying similar intermolecular forces between components.

(iii) Calculate the mass of CaCl_2 (molar mass = 111 g mol^{-1}) to be dissolved in 500 g of water to lower its freezing point by 2K, assuming that CaCl_2 undergoes complete dissociation.

Solution: We can use the formula for freezing point depression:

$$\Delta T_f = i \times K_f \times m$$

Where:

- $\Delta T_f = 2 \text{ K}$,
- $K_f = 1.86 \text{ K kg mol}^{-1}$ (given),
- $i = 3$ (for CaCl_2 as it dissociates into 3 ions: Ca^{2+} and 2 Cl^-), - m is the molality of the solution.

Step 1: Rearrange the equation to solve for molality:

$$m = \frac{\Delta T_f}{i \times K_f} = \frac{2}{3 \times 1.86} = 0.358 \text{ mol/kg}$$

Step 2: Calculate the moles of CaCl_2 :

$$\text{moles of CaCl}_2 = m \times \text{mass of solvent} = 0.358 \times 0.5 = 0.179 \text{ mol}$$

Step 3: Calculate the mass of CaCl_2 :

$$\text{mass of CaCl}_2 = \text{moles} \times \text{molar mass} = 0.179 \times 111 = 19.89 \text{ g}$$

Thus, the mass of CaCl_2 required is 19.89 g.

 Quick Tip

Freezing point depression depends on the molality and the Van't Hoff factor. For ionic compounds like CaCl_2 , dissociation increases the number of particles and the effect on the freezing point.

32. (a) An amide 'A' with molecular formula $\text{C}_7\text{H}_7\text{ON}$ undergoes Hoffmann Bromamide degradation reaction to give amine 'B'. 'B' on treatment with nitrous acid at 273-278 K forms 'C' and on treatment with chloroform and ethanolic potassium hydroxide forms 'D'. 'C' on treatment with ethanol gives 'E'. Identify 'A', 'B', 'C', 'D' and 'E' and write the sequence of chemical equations.

Solution:

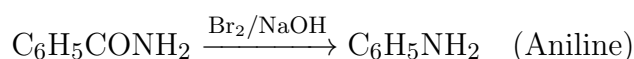
Step 1: Identify the structure of 'A' ($\text{C}_7\text{H}_7\text{ON}$):

The molecular formula $\text{C}_7\text{H}_7\text{ON}$ suggests the compound is a derivative of an amide. A common structure that fits this molecular formula is benzamide ($\text{C}_6\text{H}_5\text{CONH}_2$), which contains a benzene ring attached to a carboxamide group.

Step 2: Hoffmann Bromamide degradation reaction:

In this reaction, benzamide (A) undergoes a degradation when treated with bromine in the presence of alkali (usually NaOH) to give a primary amine. The reaction leads to the loss of one carbon atom from the amide.

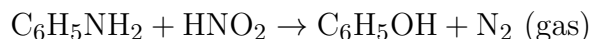
- The product 'B' is aniline ($\text{C}_6\text{H}_5\text{NH}_2$), formed after the elimination of CO_2 from the amide group.



Step 3: Reaction of 'B' with nitrous acid:

When aniline (B) reacts with nitrous acid (HNO_2) at 273-278 K, it undergoes diazotization followed by deamination to form a phenol derivative.

- The product 'C' is phenol ($\text{C}_6\text{H}_5\text{OH}$).



Step 4: Reaction of 'B' with chloroform and ethanolic potassium hydroxide:

When aniline (B) is treated with chloroform (CHCl_3) and ethanolic potassium hydroxide (KOH), it undergoes the Carbylamine reaction, which produces an isocyanide (or isothiocyanate).

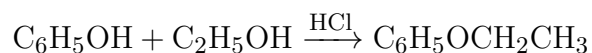
- The product 'D' is phenyl isocyanide ($\text{C}_6\text{H}_5\text{NC}$).



Step 5: Reaction of 'C' with ethanol:

When phenol (C) reacts with ethanol, it undergoes etherification to form an ethoxy group attached to the benzene ring.

- The product 'E' is ethyl phenyl ether ($\text{C}_6\text{H}_5\text{OCH}_2\text{CH}_3$).



 Quick Tip

Hoffmann Bromamide degradation removes the carbonyl group from amides, forming amines. Diazotization of amines with nitrous acid yields phenol derivatives. Carbylamine reaction with chloroform forms isocyanides.

OR

(b) (i) (1) What is Hinsberg's reagent?

Solution: Hinsberg's reagent is benzenesulfonyl chloride ($\text{C}_6\text{H}_5\text{SO}_2\text{Cl}$), which is used to differentiate between primary, secondary, and tertiary amines. The reagent reacts with primary amines to form sulfonamides, with secondary amines to form N-alkyl sulfonamides, and with tertiary amines, no reaction occurs due to the lack of an available hydrogen atom for reaction. This test helps distinguish between the different classes of amines.

 Quick Tip

Hinsberg's reagent is used to differentiate between primary, secondary, and tertiary amines based on their reactions with the sulfonyl chloride group.

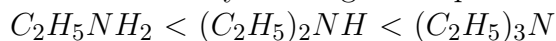
(2) Arrange the following compounds in the increasing order of their basic strength in the gaseous phase:

$\text{C}_2\text{H}_5\text{NH}_2$, $(\text{C}_2\text{H}_5)_3\text{N}$, $(\text{C}_2\text{H}_5)_2\text{NH}$

Solution: Basic strength of amines is influenced by the electron-donating or electron-withdrawing nature of their substituents. Alkyl groups are electron-donating, which

increases the basicity of the amine, whereas an aromatic group (like in aniline) is electron-withdrawing and decreases the basicity.

Order of basicity in the gaseous phase:



- $C_2H_5NH_2$ (Aniline) has the lowest basicity because the phenyl group withdraws electron density from the nitrogen.
- $(C_2H_5)_2NH$ (Diethylamine) has higher basicity because two ethyl groups donate electron density to the nitrogen.
- $(C_2H_5)_3N$ (Triethylamine) has the highest basicity due to the three electron-donating ethyl groups.

 Quick Tip

Aromatic groups withdraw electron density, reducing basicity, while alkyl groups donate electron density, increasing basicity.

(ii) Give reasons for the following:

(1) Methyl amine is more basic than aniline.

Solution: Methylamine (CH_3NH_2) is more basic than aniline ($C_6H_5NH_2$) because the methyl group is an electron-donating group. It increases the electron density on the nitrogen atom, making it more available to accept a proton. In contrast, the phenyl group in aniline is electron-withdrawing through resonance, decreasing the electron density on the nitrogen atom and thus reducing its basicity.

Step 1: Methyl group donates electrons, increasing basicity.

Step 2: Phenyl group withdraws electrons, decreasing basicity.

 Quick Tip

Electron-donating groups (like methyl) increase basicity, while electron-withdrawing groups (like phenyl) decrease basicity.

(2) Aniline readily reacts with bromine water to give 2, 4, 6-tribromoaniline.

Solution: Aniline reacts with bromine water in an electrophilic aromatic substitution reaction. The amino group ($-NH_2$) in aniline is an electron-donating group, which activates the benzene ring towards electrophilic substitution. The bromine molecules attack the ortho and para positions relative to the amino group, resulting in the formation of 2, 4, 6-tribromoaniline.

Step 1: Amino group donates electrons to the ring, making it more reactive.

Step 2: Bromine undergoes electrophilic substitution at the activated positions.

 Quick Tip

Electron-donating groups like $-NH_2$ activate the aromatic ring towards electrophilic substitution, leading to products like 2, 4, 6-tribromoaniline.

(3) Primary amines have higher boiling points than tertiary amines.

Solution: Primary amines have higher boiling points than tertiary amines due to the ability to form hydrogen bonds. In primary amines, the nitrogen atom has a hydrogen atom attached, allowing for hydrogen bonding between molecules. Tertiary amines, on the other hand, do not have a hydrogen atom on the nitrogen, so they cannot form hydrogen bonds as efficiently, leading to lower boiling points.

Step 1: Primary amines form hydrogen bonds, increasing boiling point.

Step 2: Tertiary amines cannot form hydrogen bonds, leading to lower boiling points.

 Quick Tip

Hydrogen bonding increases boiling point. Primary amines have higher boiling points than tertiary amines due to the presence of hydrogen atoms on the nitrogen.

33. Attempt any five of the following:

(a) Why Zinc is not regarded as a transition element?

Solution: Zinc is not regarded as a transition element because it does not have an incomplete d-orbital in its ground state or any of its common oxidation states. The electronic configuration of zinc is $[Ar] 3d^{10}4s^2$, and in its most stable oxidation state of +2, the configuration becomes $[Ar] 3d^{10}$, which is a fully filled d-orbital. For an element to be considered a transition metal, it must have at least one incomplete d-orbital in either its ground state or common oxidation states. Zinc, therefore, does not exhibit the typical characteristics of transition metals such as variable oxidation states and colored complexes.

 Quick Tip

Transition metals typically have an incomplete d-orbital in their ground or common oxidation states, which is not the case for zinc.

(b) What is Lanthanoid contraction?

Solution: Lanthanoid contraction refers to the gradual decrease in the size of the lanthanoid ions (from La^{3+} to Lu^{3+}) across the lanthanide series. Despite the increasing nuclear charge, the addition of electrons occurs mainly in the 4f orbitals, which do not effectively shield the increased positive charge. As a result, the effective nuclear charge experienced by the electrons increases, leading to a gradual contraction of the ionic radius. This contraction is particularly significant between elements such as La and Lu and affects the properties of the elements and their compounds, including the stability of their coordination complexes and their atomic size.

 Quick Tip

Lanthanoid contraction occurs due to poor shielding by the 4f-electrons, causing a decrease in the size of the ions across the series.

(c) Why is first ionization enthalpy of chromium lower than that of Zn?

Solution: The first ionization enthalpy of chromium is lower than that of zinc because of the electron configuration and the stability of the orbitals. Chromium has an electron configuration of $[Ar] 3d^5 4s^1$, where one electron from the 4s orbital is promoted to the 3d orbital, leading to a half-filled stable d-subshell. This arrangement provides extra stability to chromium, making it easier to lose an electron compared to zinc, which has a completely filled $3d^{10} 4s^2$ configuration. The completely filled d-subshell in zinc results in higher stability, which makes it harder to ionize. Hence, chromium's first ionization enthalpy is lower.

 Quick Tip

Half-filled d-subshells, like in chromium, provide extra stability, making ionization easier compared to elements with completely filled orbitals like zinc.

(d) Why are transition elements good catalysts?

Solution: Transition elements are good catalysts due to several reasons:

1. Variable oxidation states: Transition metals can easily change oxidation states, which helps in facilitating redox reactions by acting as both electron donors and acceptors.
2. Ability to form complexes: Transition metals can coordinate with various ligands, forming complexes that are essential intermediates in catalytic processes.
3. Partial filling of d-orbitals: The presence of partially filled d-orbitals allows transition metals to interact with reactant molecules, lowering activation energies.
4. Surface area: Many transition metals have high surface area, providing more active sites for reactions to occur.

These factors combined make transition metals effective in speeding up reactions without being consumed in the process.

 Quick Tip

Transition metals are good catalysts due to their variable oxidation states, ability to form complexes, and partially filled d-orbitals that facilitate reaction mechanisms.

(e) Compounds of transition metals are generally coloured. Give reason.

Solution: Compounds of transition metals are generally colored because of d-d transitions. In these compounds, the d-orbitals are split into two energy levels due to the ligand field. When electrons in the lower energy d-orbitals absorb visible light, they get excited to the higher energy d-orbitals. The wavelength of light absorbed corresponds to the energy difference between the split d-orbitals, and the remaining transmitted light gives the color of the compound. This phenomenon is common in transition metal complexes, particularly when the metal has an incomplete d-orbital configuration. The presence of ligands and the metal's oxidation state also affect the color.

💡 Quick Tip

Transition metal compounds are colored because of d-d transitions, where electrons absorb visible light and move between split d-orbitals.

(f). Out of KMnO_4 and K_2MnO_4 , which one is paramagnetic and why?

Solution: KMnO_4 has Mn in the +7 oxidation state, meaning that there are no unpaired electrons and it is diamagnetic. However, in K_2MnO_4 , Mn is in the +6 oxidation state, and it has unpaired electrons in the d-orbital, making it paramagnetic.

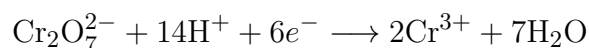
💡 Quick Tip

The magnetic behavior of a compound depends on the number of unpaired electrons. If a compound has unpaired electrons, it is paramagnetic; if all electrons are paired, it is diamagnetic.

(g). Complete the following ionic equation:



Solution: The reaction is a reduction half-reaction, where Cr(VI) is reduced to Cr(III). The complete ionic equation is:



💡 Quick Tip

In redox reactions, always balance the charges and atoms by adding electrons and water molecules when necessary. Here, Cr(VI) is reduced to Cr(III) with water molecules added to balance the oxygens.