CBSE Class XII 2025 Chemistry Set 1 (56/1/1) Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**70	**Total Questions :**33

General Instructions

Read the following instructions very carefully and strictly follow them:

1. This paper consists of 33 questions. All questions are compulsory.
2. This paper is divided into five sections - A, B, C, D and E.
3. Section A Nos. 1 to 16 are Multiple Choice questions. Each carries 1 mark.
4. Section B Nos. 17 to 21 are Very Short Answer type. Each carries 2 marks. Answer to these questions should be in the range of 30 to 50 words.
5. Section C Nos. 22 to 28 are Short Answer (SA) type. Each carries 3 marks. Answer to these questions should be in the range of 50 to 80 words.
6. Section D Nos. 29 and 30 are of 3 source-based/case-based units of assessment carrying 4 marks each with sub-parts.
7. Section E Nos. 31 to 33 are Long Answer type. Each carries 5 marks. Answer to these questions should be in the range of 80 to 120 words.
8. There is no overall choice. However, an internal choice has been provided in some sections. Only one of the alternatives has to be attempted in such s.

Section A

1. In case of association, abnormal molar mass of solute will:

(A) increase

(B) decrease

(C) remain same

(D) first increase and then decrease

Correct Answer: (B) decrease

Solution:

Step 1: Understanding association. In case of association, solute molecules aggregate, resulting in a reduction in the number of particles in the solution. This causes the molar mass to appear lower than the expected value.

Step 2: Conclusion. Thus, the abnormal molar mass decreases in case of association, corresponding to option (B).

> Quick Tip
>
> In case of association, the abnormal molar mass tends to decrease due to the aggregation of solute molecules.

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2. Standard electrode potential for Sn^{4+}/Sn^{2+} couple is +0.15 V and that for the Cr^{3+}/Cr couple is -0.74 V. The two couples in their standard states are connected to make a cell. The cell potential will be:

(A) +1.19 V

(B) +0.89 V

(C) +0.18 V

(D) +1.83 V

Correct Answer: (B) +0.89 V

Solution:

Step 1: Understanding the cell potential. The cell potential is calculated by subtracting the anode potential from the cathode potential. The two given standard electrode potentials are for the Sn^{4+}/Sn^{2+} couple (+0.15 V) and the Cr^{3+}/Cr couple (-0.74 V).

Step 2: Calculation. The cell potential is given by:

$$E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}} = (+0.15\,\text{V}) - (-0.74\,\text{V}) = +0.89\,\text{V}$$

Step 3: Conclusion. Thus, the cell potential is +0.89 V, corresponding to option (B).

Quick Tip

The cell potential is calculated by subtracting the anode potential from the cathode potential.

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3. The magnetic moment is associated with its spin angular momentum and orbital angular momentum. Spin only magnetic moment value of Cr^{3+} ion (Atomic no. : Cr = 24) is:

(A) 2.87 B.M.

(B) 3.87 B.M.

(C) 3.47 B.M.

(D) 3.57 B.M.

Correct Answer: (B) 3.87 B.M.

Solution:

Step 1: Understanding the magnetic moment. The magnetic moment depends on the number of unpaired electrons. For Cr^{3+} (with atomic number 24), the electron configuration is $[Ar]3d^3$, meaning there are 3 unpaired electrons.

Step 2: Calculation. The magnetic moment (μ) is calculated using the formula:

$$\mu = \sqrt{n(n+2)}\,\text{B.M.}$$

Where n is the number of unpaired electrons. For Cr^{3+} (3 unpaired electrons), we get:

$$\mu = \sqrt{3(3+2)} = \sqrt{15} \approx 3.87\,\text{B.M.}$$

Step 3: Conclusion. Thus, the magnetic moment is 3.87 B.M., corresponding to option (B).

Quick Tip

The magnetic moment can be calculated using the formula $\mu = \sqrt{n(n+2)}$, where n is the number of unpaired electrons.

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4. Acidified KMnO$_4$ oxidizes sulphite to:

(A) SO_3^{2-}

(B) SO_4^{2-}

(C) SO_2(g)

(D) $S_2O_8^{2-}$

Correct Answer: (B) SO_4^{2-}

Solution:

Step 1: Understanding the oxidation reaction. In acidic conditions, potassium permanganate ($KMnO_4$) is a strong oxidizing agent that oxidizes sulphite (SO_3^{2-}) to sulfate (SO_4^{2-}).

Step 2: Conclusion. Thus, the oxidation product is SO_4^{2-}, corresponding to option (B).

Quick Tip

$KMnO_4$ in acidic conditions oxidizes sulphite to sulfate.

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5. The correct IUPAC name of [Pt(NH$_3$)$_2$Cl$_2$]$^{2+}$ is:

(A) Diamminedichloridoplatinum (II)

(B) Diamminedichloridoplatinum (IV)

(C) Diamminedichloridoplatinum (O)

(D) Diamminedichloridoplatinate (IV)

Correct Answer: (A) Diamminedichloridoplatinum (II)

Solution:

Step 1: Understanding the IUPAC name. In this compound, platinum is in the +2 oxidation state, and the ligands are ammonia (NH_3) and chloride (Cl^-). The correct IUPAC name is based on the oxidation state of the platinum ion and the ligands attached to it.

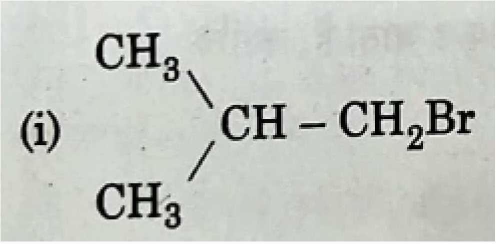
Step 2: Conclusion. Thus, the correct IUPAC name is Diamminedichloridoplatinum (II), corresponding to option (A).

Quick Tip

When naming coordination compounds, ensure the oxidation state of the metal and the ligands are correctly identified.

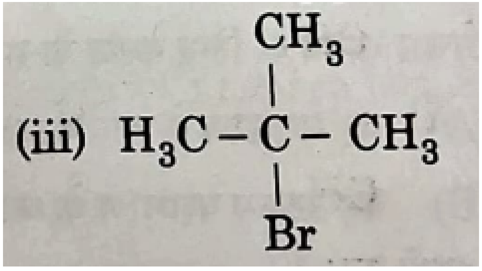
6. Arrange the following compounds in increasing order of their boiling points:

(i)



(ii) $CH_3CH_2CH_2CH_2Br$

(iii)



$H_3C-\overset{\displaystyle CH_3}{\underset{\displaystyle Br}{C}}-CH_3$

(A) (ii) < (i) < (iii)

(B) (i) < (ii) < (iii)

(C) (iii) < (i) < (ii)

(D) (iii) < (ii) < (i)

Correct Answer: (B) (i) < (ii) < (iii)

Solution:

Step 1: Understanding boiling points. Boiling points are affected by molecular size and the type of intermolecular forces. The more carbon atoms and longer the chain, the higher the boiling point.

Step 2: Analysis of the compounds. - Compound (i) CH_3CH_2Br has a relatively small chain, resulting in a lower boiling point.
- Compound (ii) $CH_3CH_2CH_2Br$ has a longer chain, leading to higher boiling point.
- Compound (iii) $CH_3CH_2CH_2Br$, with the largest size, has the highest boiling point.

Step 3: Conclusion. Thus, the correct order of boiling points is (i) $<$ (ii) $<$ (iii), corresponding to option (B).

Quick Tip

Boiling point increases with chain length and molecular size due to stronger London dispersion forces.

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7. Alkyl halides undergoing nucleophilic bimolecular substitution reaction involve:

(A) retention of configuration

(B) formation of racemic mixture

(C) inversion of configuration

(D) formation of carbocation

Correct Answer: (C) inversion of configuration

Solution:

Step 1: Understanding nucleophilic bimolecular substitution (SN2). In an SN2 reaction, the nucleophile attacks the carbon opposite to the leaving group, leading to the inversion of configuration.

Step 2: Conclusion. Thus, SN2 reactions involve inversion of configuration, corresponding to option (C).

Quick Tip

In SN2 reactions, the configuration of the carbon center is inverted due to backside attack by the nucleophile.

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8. Which is the correct order of acid strength from the following?

(A) $C_6H_5OH > H_2O > ROH$

(B) $C_6H_5OH > ROH > H_2O$

(C) $ROH > C_6H_5OH > H_2O$

(D) $H_2O > C_6H_5OH > ROH$

Correct Answer: (D) $H_2O > C_6H_5OH > ROH$

Solution:

Step 1: Understanding acidity. The acid strength depends on the ability to donate a proton. Alcohols and phenols are weaker acids than water, and phenols are generally stronger acids than alcohols.

Step 2: Conclusion. Thus, the correct order of acid strength is $H_2O > C_6H_5OH > ROH$, corresponding to option (D).

Quick Tip

The acidity of alcohols, phenols, and water is governed by their ability to stabilize the negative charge after deprotonation.

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9. The acid formed when propyl magnesium bromide is treated with CO_2 followed by acid hydrolysis is:

(A) C_3H_7COOH

(B) C_2H_5COOH

(C) CH_3COOH

(D) C_3H_7OH

Correct Answer: (A) C_3H_7COOH

Solution:

Step 1: Understanding the reaction. Propyl magnesium bromide is a Grignard reagent that reacts with CO_2 to form a carboxylate anion, which is then hydrolyzed to form a carboxylic acid.

Step 2: Conclusion. Thus, the acid formed is propionic acid (C_3H_7COOH), corresponding to option (A).

Quick Tip

Grignard reagents react with CO_2 to form carboxylates, which can be hydrolyzed to yield carboxylic acids.

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10. The best reagent for converting propanamide into propanamine is:

(A) excess H_2

(B) Br_2 in aqueous NaOH

(C) iodine in the presence of red phosphorus

(D) $LiAlH_4$ in ether

Correct Answer: (D) $LiAlH_4$ in ether

Solution:

Step 1: Understanding the reduction process. To reduce an amide to an amine, lithium aluminum hydride ($LiAlH_4$) is the most commonly used reagent, as it is capable of reducing the carbonyl group in amides to an amine group.

Step 2: Conclusion. Thus, the best reagent for converting propanamide to propanamine is $LiAlH_4$ in ether, corresponding to option (D).

Quick Tip

$LiAlH_4$ is a strong reducing agent that can reduce amides to amines.

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11. Which of the following statements is not true about glucose?

(A) It is an aldose.

(B) On heating with HI it forms n-hexane.

(C) It exists in furanose form.

(D) It does not give Schiff's test.

Correct Answer: (D) It does not give Schiff's test.

Solution:

Step 1: Understanding glucose's properties. Glucose is an aldose (option A) and forms n-hexane on heating with HI (option B). It can exist in the furanose form (option C) as well.
Step 2: Schiff's test. Glucose, being an aldehyde, will give a positive Schiff's test, which detects aldehydes.
Step 3: Conclusion. Thus, the statement that glucose does not give Schiff's test is incorrect, corresponding to option (D).

Quick Tip

Schiff's reagent tests for aldehydes, and glucose, being an aldose, will give a positive result.

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12. An unripe mango placed in a concentrated salt solution to prepare pickle, shrivels because

(A) it gains water due to osmosis

(B) it loses water due to reverse osmosis

(C) it gains water due to reverse osmosis

(D) it loses water due to osmosis

Correct Answer: (D) it loses water due to osmosis

Solution:
Step 1: Understanding osmosis. When the mango is placed in a concentrated salt solution, water from the mango moves out to dilute the external solution due to osmosis, as water moves from low solute concentration to high solute concentration.
Step 2: Conclusion. Thus, the mango loses water due to osmosis, corresponding to option (D).

Quick Tip

Osmosis involves the movement of water from a region of lower solute concentration to a region of higher solute concentration.

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13. Assertion (A): [Cr(H_2O)$_6$]Cl$_2$ and [Fe(H_2O)$_6$]Cl$_2$ are examples of homoleptic complexes.

Reason (R): All the ligands attached to the metal are the same.

(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:

Step 1: Understanding homoleptic complexes. Homoleptic complexes are those in which all the ligands attached to the central metal atom are the same. Both $[Cr(H_2O)_6]Cl_2$ and $[Fe(H_2O)_6]Cl_2$ are examples of homoleptic complexes, as all the ligands in each complex are water molecules.

Step 2: Conclusion. Since Assertion (A) is true, and Reason (R) correctly explains it, the correct answer is option (A).

Quick Tip

Homoleptic complexes contain only one type of ligand bound to the central metal atom.

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14. Assertion (A): The boiling points of alkyl halides decrease in the order: RI $>$ RBr $>$ RCl $>$ RF.

Reason (R): The boiling points of alkyl chlorides, bromides and iodides are considerably higher than that of the hydrocarbon of comparable molecular mass.

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

Solution:
Step 1: Understanding the boiling point order. The boiling points of alkyl halides decrease in the order: RI $>$ RBr $>$ RCl $>$ RF because the iodine atom is the largest halogen, leading to stronger dispersion forces and, consequently, higher boiling points.
Step 2: Reason for the boiling point order. While Reason (R) is true in stating that alkyl halides have higher boiling points compared to hydrocarbons of comparable molecular mass, it does not directly explain the order in which boiling points decrease. The reason for this specific order lies more in the halogen size and the resultant intermolecular forces.
Step 3: Conclusion. Thus, both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A). The correct answer is option (B).

Quick Tip

Boiling points of alkyl halides are influenced by the size of the halogen and the intermolecular forces present.

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15. Assertion (A): The boiling point of ethanol is higher than that of methoxymethane.
Reason (R): There is intramolecular hydrogen bonding in ethanol.

(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:

Step 1: Understanding boiling point comparison. Ethanol has a higher boiling point than methoxymethane due to the presence of hydrogen bonding between ethanol molecules, which requires more energy to break these interactions.

Step 2: Reason for the boiling point difference. The intramolecular hydrogen bonding in ethanol is the reason for its higher boiling point compared to methoxymethane, as methoxymethane lacks such hydrogen bonding.

Step 3: Conclusion. Since both Assertion (A) and Reason (R) are true, and Reason (R) correctly explains Assertion (A), the correct answer is option (A).

Quick Tip

Hydrogen bonding increases the boiling point of compounds as it requires more energy to break these bonds.

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16. Assertion (A): All naturally occurring α-amino acids except glycine are optically active.

Reason (R): Most naturally occurring amino acids have L-configuration.

(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:

Step 1: Understanding optical activity of amino acids. All naturally occurring α-amino acids, except for glycine, are optically active because they contain a chiral carbon atom (except glycine which has two hydrogen atoms on the chiral center, making it achiral).

Step 2: L-configuration of amino acids. Most naturally occurring amino acids are in the L-configuration, which is why they are optically active (except glycine).

Step 3: Conclusion. Thus, both Assertion (A) and Reason (R) are true, and Reason (R) correctly explains Assertion (A), making option (A) the correct answer.

Quick Tip

The L-configuration of amino acids contributes to their optical activity, except for glycine, which is achiral.

Section B

17. (A) Give reasons:

(a) Cooking is faster in a pressure cooker than in an open pan.

(b) On mixing liquid X and liquid Y, volume of the resulting solution decreases. What type of deviation from Raoult's law is shown by the resulting solution? What change in temperature would you observe after mixing liquids X and Y?

Solution:

(a) Cooking is faster in a pressure cooker than in an open pan: Cooking is faster in a pressure cooker because the pressure inside the cooker is higher than atmospheric pressure. This leads to an increase in the boiling point of water. As a result, the water in the cooker can reach a higher temperature before it boils, which speeds up the cooking process. In an open pan, the water boils at a lower temperature, so the food takes longer to cook.

(b) On mixing liquid X and liquid Y, volume of the resulting solution decreases: When mixing two liquids and the volume decreases, it indicates that there is an interaction between the molecules of liquid X and Y that causes them to pack more closely together, resulting in a decrease in the overall volume. This type of behavior shows a negative deviation from Raoult's law, which occurs when the intermolecular forces between the components of the mixture are stronger than the forces in the pure components.

Change in temperature after mixing liquids X and Y: When a negative deviation occurs, the mixing of the liquids is usually exothermic, meaning it releases heat. As a result, the temperature of the solution would increase. This happens because the interaction between the molecules in the mixture is stronger than in the individual pure liquids, and energy is released when these interactions are formed.

Quick Tip

Negative deviation from Raoult's law occurs when the intermolecular forces between the components of the solution are stronger than in the pure state, leading to a decrease in volume and an exothermic mixing process.

OR

(B) Define Azeotrope. What type of Azeotrope is formed by negative deviation from Raoult's law? Give an example.

Solution:

Azeotrope: An azeotrope is a mixture of two or more liquids that behaves as a single substance when boiled. This means that the composition of the vapor produced during boiling is the same as the composition of the liquid, and thus it cannot be separated by simple distillation. Azeotropes occur because of the specific interactions between the components in the mixture.

Azeotrope formed by negative deviation from Raoult's law: In mixtures that show a negative deviation from Raoult's law, the intermolecular forces between the components are stronger than those in the individual pure components. This leads to a lower vapor pressure than expected, and the mixture boils at a lower temperature than either of the pure liquids. This behavior often leads to the formation of an azeotrope.

An example of an azeotrope formed by a negative deviation is the water and hydrochloric acid (HCl) mixture. The HCl solution in water forms an azeotrope at around 20.2

Quick Tip

Azeotropes form when the vapor pressure of the mixture is either higher or lower than expected, preventing the components from separating by distillation. Negative deviations occur when stronger interactions exist between the molecules of the mixture.

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18. Complete and balance the following chemical equations:

(a)

$$2MnO_4^-(aq) + 10I^-(aq) + 16H^+(aq) \rightarrow$$

(b)

$$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow$$

Solution:

(a) Reaction of permanganate with iodide ions: In an acidic solution, permanganate ions (MnO_4^-) act as an oxidizing agent and oxidize iodide ions (I^-) to iodine (I_2). The balanced equation shows the reduction of permanganate to Mn^{2+} and the oxidation of iodide to iodine.

$$2MnO_4^-(aq) + 10I^-(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5I_2(aq) + 8H_2O(l)$$

(b) Reaction of dichromate with iron(II) ions: In an acidic solution, dichromate ions ($Cr_2O_7^{2-}$) are reduced to chromium(III) ions (Cr^{3+}), while iron(II) ions (Fe^{2+}) are oxidized to iron(III) ions (Fe^{3+}).

$$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O(l)$$

Quick Tip

In redox reactions, the oxidizing agent is reduced, and the reducing agent is oxidized. Pay attention to the stoichiometric coefficients when balancing the equation.

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19. Would you expect benzaldehyde to be more reactive or less reactive in nucleophilic addition reactions than propanal? Justify your answer.

Solution: Benzaldehyde would be less reactive in nucleophilic addition reactions compared to propanal. This is because in benzaldehyde, the carbonyl group is attached to a benzene ring, which provides some resonance stabilization. The lone pairs of electrons on the oxygen of the carbonyl group can delocalize into the benzene ring, reducing the partial positive charge on the carbonyl carbon. This makes the carbonyl carbon less electrophilic and less reactive to nucleophilic attack.

On the other hand, in propanal, the carbonyl group is attached to a simple alkyl chain, and there is no resonance effect to stabilize the carbonyl carbon. Therefore, the carbonyl carbon in propanal is more electrophilic and more reactive to nucleophilic addition.

Quick Tip

Resonance effects in aromatic aldehydes like benzaldehyde reduce the electrophilicity of the carbonyl carbon, making them less reactive in nucleophilic addition reactions.

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20. Identify A and B in each of the following reaction sequence:

(a)

$$CH_3CH_2Cl \xrightarrow{NaCN} A \xrightarrow{H_2/Ni} B$$

(b)

$$C_6H_5NH_2 \xrightarrow{NaNO_2/HCl} A \xrightarrow{C_6H_5NH_2} B$$

Solution:

(a) Reaction Sequence: 1. The reaction of CH_3CH_2Cl with $NaCN$ results in the formation of ethyl cyanide (A) through nucleophilic substitution, where the chlorine is replaced by the cyanide ion.

$$A = CH_3CH_2CN$$

2. The hydrogenation of ethyl cyanide (CH_3CH_2CN) in the presence of H_2 and a nickel catalyst leads to the reduction of the nitrile group to an amine, yielding ethylamine (B).

$$B = CH_3CH_2NH_2$$

(b) Reaction Sequence: 1. The reaction of aniline ($C_6H_5NH_2$) with sodium nitrite ($NaNO_2$) and hydrochloric acid (HCl) forms a diazonium salt, $C_6H_5N_2^+Cl^-$ (A).
2. The treatment of $C_6H_5N_2^+Cl^-$ with an acid (e.g., H^+) causes the diazonium ion to undergo hydrolysis, leading to the formation of phenol (B).

$$B = C_6H_5OH$$

Quick Tip

Nucleophilic substitution with cyanide forms nitriles, which can be reduced to amines. Diazonium salts are highly reactive intermediates that can be converted to phenols by hydrolysis.

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21. Write the reactions involved when D-glucose is treated with the following reagents: (a) HCN (b) Br$_2$ water

Solution:

(a) Reaction of D-glucose with HCN: When D-glucose is treated with hydrogen cyanide (HCN), it undergoes cyanohydration to form a cyanohydrin, specifically D-glucose cyanohydrin.

$$\text{D-glucose} + HCN \rightarrow \text{D-glucose cyanohydrin}$$

(b) Reaction of D-glucose with Br$_2$ water: When D-glucose is treated with bromine water, it undergoes oxidation at the aldehyde group. This converts the aldehyde group to a carboxylic acid group, and the product is gluconic acid.

$$\text{D-glucose} + Br_2(\text{water}) \rightarrow \text{Gluconic acid}$$

Quick Tip

Cyanohydrin formation is a typical nucleophilic addition reaction, and oxidation with bromine water converts aldehydes to carboxylic acids.

Section C

22. A solution of glucose (molar mass = 180 g mol^{-1}) in water has a boiling point of 100.20°C. Calculate the freezing point of the same solution. Molal constants for water K_f and K_b are 1.86 K kg mol^{-1} and 0.512 K kg mol^{-1} respectively.

Solution:

Step 1: Understanding the problem. We are given that the solution is made with glucose, which is a non-volatile, non-electrolyte solute, and its molar mass is 180 g mol^{-1}. We need to calculate the freezing point of this solution, given the boiling point elevation.

The boiling point elevation formula is:

$$\Delta T_b = K_b \cdot m$$

Where: ΔT_b = Boiling point elevation K_b = ebullioscopic constant (given as 0.512 K kg mol^{-1}) m = molality of the solution

Step 2: Calculate the molality of the solution. The solution's boiling point is given as 100.20°C. The normal boiling point of water is 100°C, so:

$$\Delta T_b = 100.20C - 100C = 0.20C$$

Using the boiling point elevation formula:

$$\Delta T_b = K_b \cdot m$$

$$0.20 = 0.512 \cdot m$$

Solving for molality:

$$m = \frac{0.20}{0.512} = 0.3906\,\text{mol/kg}$$

Step 3: Calculate the freezing point depression. The freezing point depression formula is:

$$\Delta T_f = K_f \cdot m$$

Where: ΔT_f = Freezing point depression K_f = cryoscopic constant (given as 1.86 K kg mol^{-1}) m = molality of the solution (calculated as 0.3906 mol/kg)

Substituting the values:

$$\Delta T_f = 1.86 \cdot 0.3906 = 0.726\,°\text{C}$$

Step 4: Calculate the freezing point. The normal freezing point of water is 0°C. Since the solution has a freezing point depression, the freezing point of the solution will be:

$$\text{Freezing point} = 0C - 0.726C = -0.726C$$

Thus, the freezing point of the solution is -0.726°C.

Quick Tip

Freezing point depression and boiling point elevation are both colligative properties that depend on the molality of the solute and the solvent's cryoscopic and ebullioscopic constants.

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23. (a) State the following:

(i) Kohlrausch law of independent migration of ions

Solution: The Kohlrausch law of independent migration of ions states that the molar conductivity of an electrolyte at infinite dilution is the sum of the contributions from the individual ions. This means that the contribution of each ion to the total conductivity can be considered independently of the other ions.

$$\Lambda_m^\infty = \lambda_+^\infty + \lambda_-^\infty$$

Where: Λ_m^∞ is the molar conductivity at infinite dilution, λ_+^∞ is the conductivity of the cation at infinite dilution, and λ_-^∞ is the conductivity of the anion at infinite dilution.

Quick Tip

Kohlrausch's law helps in understanding the individual contributions of ions to the overall conductivity in solutions, especially at infinite dilution.

(ii) Faraday's first law of electrolysis

Solution: Faraday's first law of electrolysis states that the amount of substance deposited or liberated at each electrode during electrolysis is directly proportional to the quantity of electricity passed through the electrolyte.

$$m = \frac{M \cdot I \cdot t}{F}$$

Where: m is the mass of the substance deposited or liberated, M is the molar mass of the substance, I is the current, t is the time, and F is Faraday's constant (96500 C mol^{-1}).

Quick Tip

Faraday's first law quantifies the relationship between the quantity of electricity and the amount of material involved in electrolysis.

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

Given: $E^\circ_{X^{2+}/X} = -2.36\,\text{V}$ $E^\circ_{Y^{2+}/Y} = -0.14\,\text{V}$ $E^\circ_{Fe^{2+}/Fe} = -0.44\,\text{V}$

Solution:

To prevent corrosion of iron, we must consider the electrode potentials of the metal to be used for coating. A metal that has a higher (less negative) reduction potential will be more easily reduced and less likely to corrode.

The metal with the more negative reduction potential will act as a sacrificial anode, corroding in place of the iron.

1. For metal X: The reduction potential of X^{2+}/X is $-2.36\,\text{V}$, which is very negative. This means that metal X is more easily oxidized and will corrode easily, making it unsuitable for coating the surface of iron.

2. For metal Y: The reduction potential of Y^{2+}/Y is $-0.14\,\text{V}$, which is less negative than metal X. This means metal Y is more stable and less likely to corrode than metal X.
3. For iron (Fe): The reduction potential of Fe^{2+}/Fe is $-0.44\,\text{V}$, which is less negative than X but more negative than Y. Iron itself will corrode over time if left unprotected.
Conclusion: Metal Y is the better choice for coating the surface of iron to prevent corrosion because it has a less negative reduction potential compared to iron and X. As a result, it will be more stable and less likely to corrode, offering better protection to the iron surface.

Quick Tip

To prevent corrosion, the coating material should have a reduction potential that is less negative than that of the metal being protected, so it will be more stable and less likely to corrode.

---

24. A certain reaction is 50 complete in 20 minutes at 300 K and the same reaction is 50 complete in 5 minutes at 350 K. Calculate the activation energy if it is a first order reaction.

Given:

$$R = 8.314\,\text{J K}^{-1}\,\text{mol}^{-1}, \quad \log 4 = 0.602$$

Solution:

For a first-order reaction, the rate constant k is related to the time taken for a certain fraction of the reaction to be completed. The equation for the rate constant k for a first-order reaction is:

$$\ln\left(\frac{[A_0]}{[A]}\right) = kt$$

Where: - $[A_0]$ is the initial concentration,
- $[A]$ is the concentration after time t, and
- k is the rate constant.

However, for this problem, we will use the Arrhenius equation to relate the rate constants at two different temperatures. The Arrhenius equation is:

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Where: - k_1 and k_2 are the rate constants at temperatures T_1 and T_2,

- E_a is the activation energy,

- R is the universal gas constant (8.314 J mol^{-1} K^{-1}),

- T_1 and T_2 are the temperatures in Kelvin.

Step 1: Determine the rate constants k_1 and k_2.

The reaction is 50 complete at both temperatures. For a first-order reaction, the time taken to reach 50 completion is related to the rate constant by the equation:

$$t_{1/2} = \frac{0.693}{k}$$

This equation relates the half-life ($t_{1/2}$) to the rate constant (k) for a first-order reaction. Thus:

$$k_1 = \frac{0.693}{t_{1/2,1}} = \frac{0.693}{20\,\text{min}} = 0.03465\,\text{min}^{-1}$$

$$k_2 = \frac{0.693}{t_{1/2,2}} = \frac{0.693}{5\,\text{min}} = 0.1386\,\text{min}^{-1}$$

Step 2: Use the Arrhenius equation.

Now we can use the Arrhenius equation to solve for the activation energy (E_a):

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Substitute the known values into the equation:

$$\ln\left(\frac{0.1386}{0.03465}\right) = \frac{E_a}{8.314}\left(\frac{1}{300} - \frac{1}{350}\right)$$

Simplify the logarithm:

$$\ln(4.0) = \frac{E_a}{8.314}\left(\frac{1}{300} - \frac{1}{350}\right)$$

$$0.602 = \frac{E_a}{8.314} \times \left(\frac{50}{300 \times 350}\right)$$

Simplifying further:

$$0.602 = \frac{E_a}{8.314} \times 0.0004762$$

Solving for E_a:

$$E_a = \frac{0.602 \times 8.314}{0.0004762} = 10,574.7\,\text{J/mol} = 10.57\,\text{kJ/mol}$$

Thus, the activation energy for the reaction is approximately 10.57 kJ/mol.

Quick Tip

The Arrhenius equation relates the rate constant of a reaction to the activation energy, allowing us to calculate activation energy when rate constants are known at different temperatures.

---

25. The elements of 3d transition series are given as: Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn Answer the following:

(a) Copper has an exceptionally positive $E^\circ_{\mathbf{M^{2+}/M}}$ value, why?

Solution:

Copper has an exceptionally positive $E^\circ_{\mathrm{M^{2+}/M}}$ value because copper's $3d^{10}4s^1$ electron configuration makes its Cu^{2+} ion highly stable compared to the other transition metal ions. When copper undergoes oxidation from Cu to Cu^{2+}, it loses electrons, and the reaction becomes more favorable due to the relatively low tendency of copper to lose electrons. Additionally, the stable $3d^{10}$ configuration of Cu^{+} gives it a strong tendency to stay in the +1 oxidation state, making copper less likely to oxidize further to +2.

Thus, the positive $E^\circ_{\mathrm{M^{2+}/M}}$ value reflects the fact that the copper ion is more stable in its lower oxidation state, giving it a tendency to resist further oxidation.

Quick Tip

Copper's positive standard electrode potential indicates that it is less likely to undergo oxidation to Cu^{2+} due to its stable $3d^{10}$ electron configuration.

(b) Which element is a strong reducing agent in +2 oxidation state and why?

Solution:

The element that is a strong reducing agent in the +2 oxidation state is Zinc (Zn). Zinc has a relatively low $E^\circ_{\text{Zn}^{2+}/\text{Zn}}$ value of $-0.76\,\text{V}$, which means it readily loses electrons to form Zn^{2+}. The more negative the E° value, the stronger the reducing agent, because it indicates a greater tendency to donate electrons.

In the +2 oxidation state, zinc acts as a strong reducing agent, easily donating electrons to reduce other species.

Quick Tip

A strong reducing agent has a more negative electrode potential, as it easily loses electrons and undergoes oxidation.

(c) Zn^{2+} salts are colourless. Why?

Solution:

Zinc $^{2+}$ salts are colorless because the Zn^{2+} ion has a completely filled $3d^{10}$ electron configuration. The lack of any unpaired electrons in the $3d$ orbitals prevents the absorption of visible light, which is required for color. As a result, zinc salts do not absorb visible wavelengths of light, leading to the colorless appearance of Zn^{2+} solutions.

In other transition metal ions, the unfilled d-orbitals allow electronic transitions that absorb specific wavelengths of visible light, giving the solution a color. Since Zn^{2+} does not have such transitions, it remains colorless.

Quick Tip

The color of transition metal salts depends on the presence of unpaired electrons in the d-orbitals that can absorb visible light.

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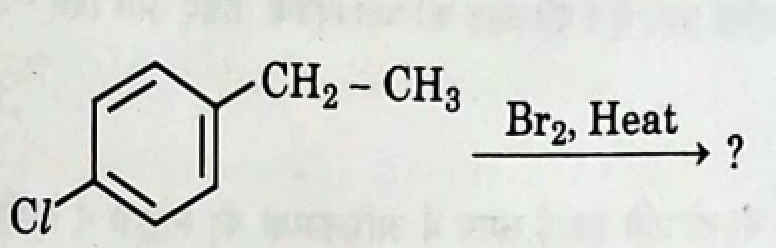
26. (A) Draw the structure of the major monohalo product for each of the following reactions:

(a)



Solution:

The reaction involves a bromination in the presence of heat, which typically leads to the formation of a benzylic bromination product. In this case, the hydrogen at the benzylic position (the carbon adjacent to the benzene ring) will be replaced by a bromine atom, forming 1-bromo-2-phenylethane as the major product.

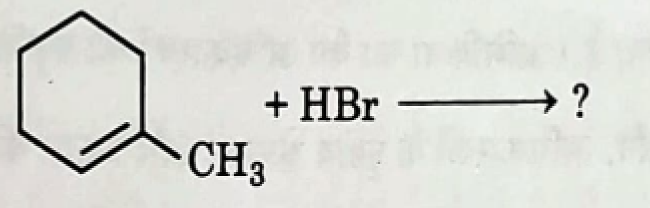
The structure of the product is:

$$C_6H_5CH_2CH_2Br$$

Quick Tip

In the presence of heat, bromination occurs at the benzylic position, replacing a hydrogen atom with a bromine atom.

(b)



Solution:

The reaction of toluene (methylbenzene) with HBr leads to the alkyl group (methyl) being substituted with a bromine atom at the benzylic position, forming 1-bromo-2-methylbenzene as the major product.

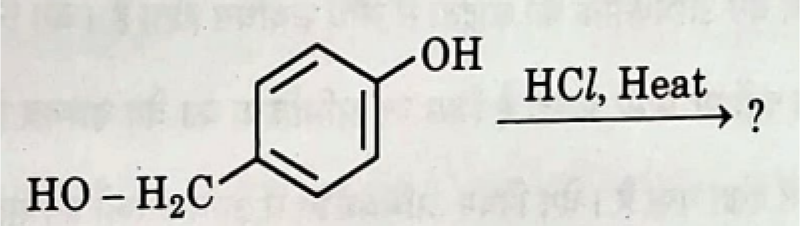
The structure of the product is:

$$C_6H_4CH_2Br$$

Quick Tip

The reaction of an alkylbenzene with HBr typically results in benzylic substitution, where the alkyl group is replaced by a bromine atom.

(c)



Solution:

In this reaction, phenol (C_6H_5OH) reacts with hydrochloric acid (HCl) in the presence of heat to form chlorobenzene. The hydroxyl group on the phenol is replaced by a chlorine atom through electrophilic aromatic substitution.

The structure of the product is:

$$C_6H_5Cl$$

Quick Tip

When phenol reacts with HCl, the hydroxyl group is substituted by a chlorine atom, yielding chlorobenzene.

(B) How do you convert:

(a) Chlorobenzene to biphenyl

Solution: To convert chlorobenzene to biphenyl, you can use the Wurtz-Fittig reaction. In this reaction, chlorobenzene undergoes a coupling reaction with another molecule of chlorobenzene in the presence of sodium metal in dry ether, resulting in biphenyl.

$$2\,C_6H_5Cl \xrightarrow{\text{Na, Ether}} C_6H_5C_6H_5$$

Quick Tip

The Wurtz-Fittig reaction is used for coupling two aromatic rings to form biphenyl.

(b) Propene to 1-Iodopropane

Solution: To convert propene to 1-iodopropane, you can use hydroiodic acid (HI). The alkene undergoes electrophilic addition with HI, where the iodine atom adds to the carbon of the double bond with the most hydrogen atoms (Markovnikov's rule).

$$CH_2CHCH_3 + HI \rightarrow CH_3CH_2I$$

Quick Tip

Hydroiodic acid (HI) adds to alkenes following Markovnikov's rule, with the iodine adding to the more substituted carbon.

(c) 2-Bromobutane to but-2-ene

Solution: To convert 2-bromobutane to but-2-ene, you can use a strong base like potassium hydroxide (KOH) in an elimination reaction (E2 mechanism). This will remove the hydrogen atom from the carbon adjacent to the one bearing the bromine, resulting in the formation of the alkene.

$$CH_3CHBrCH_3 \xrightarrow{\text{KOH}} CH_3CH{=}CH_2$$

Quick Tip

An E2 elimination mechanism involves the simultaneous removal of a proton and a leaving group, resulting in the formation of an alkene.

---

27. (a) Arrange the following compounds in increasing order of their boiling point:

$$(CH_3)_2NH,\ CH_3CH_2NH_2,\ CH_3CH_2OH$$

Solution:

To arrange the compounds in increasing order of their boiling points, we need to consider the type and strength of intermolecular forces. The compounds are:

1. Dimethylamine $(CH_3)_2NH$: This compound is a simple amine with weak hydrogen bonding. It will have a lower boiling point compared to alcohols but higher than alkyl amines due to the possibility of dipole-dipole interactions.

2. Ethylamine $CH_3CH_2NH_2$: Similar to dimethylamine, but it has a slightly higher boiling point because the ethyl group is larger than the methyl group, which introduces slightly stronger van der Waals forces.

3. Ethanol CH_3CH_2OH: Ethanol has hydrogen bonding due to the presence of the hydroxyl group, which significantly increases its boiling point compared to the amines.

Thus, the order of boiling points from lowest to highest is:

$$(CH_3)_2NH < CH_3CH_2NH_2 < CH_3CH_2OH$$

Quick Tip

Boiling points increase with the strength of intermolecular forces. Alcohols have stronger hydrogen bonding than amines, which leads to higher boiling points.

(b)Give plausible explanation for each of the following:

(i) Aromatic primary amines cannot be prepared by Gabriel Phthalimide synthesis.

Solution: Gabriel Phthalimide synthesis involves the reaction of phthalimide with an alkyl halide to form an amine. This method works well for aliphatic amines but fails for aromatic primary amines because the reaction does not readily occur with aryl halides. Aromatic rings are generally less reactive in nucleophilic substitution reactions due to the resonance stabilization of the ring, which makes it harder for the nucleophile (amide ion) to attack. Hence, Gabriel's synthesis does not work efficiently for preparing aromatic primary amines.

Quick Tip

Aromatic rings are less reactive in nucleophilic substitution reactions due to the resonance stabilization of the ring.

(ii) Amides are less basic than amines.

Solution: Amides are less basic than amines because the lone pair of electrons on the nitrogen atom in amides is delocalized into the carbonyl group through resonance. This reduces the availability of the lone pair for protonation, making the nitrogen less basic. In contrast, amines do not have such resonance and their lone pair is more available for protonation, making them more basic than amides.

Quick Tip

The basicity of amines is higher than amides because the lone pair on the nitrogen in amides is less available due to resonance with the carbonyl group.

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28. (a) What is the difference between native protein and denatured protein?

Solution: Native proteins are proteins that have their functional three-dimensional structure, which is necessary for their biological activity. They are in their natural, folded state with specific secondary, tertiary, and quaternary structures that are stabilized by various forces such as hydrogen bonding, hydrophobic interactions, and disulfide bonds.

Denatured proteins, on the other hand, are proteins that have lost their natural structure due to the disruption of these stabilizing forces, often due to changes in temperature, pH, or chemical treatment. Denaturation results in the unfolding of the protein, causing it to lose its biological function.

Quick Tip

Denaturation does not affect the primary structure (sequence of amino acids) but causes a loss of the functional three-dimensional structure of the protein.

(b) Which one of the following is a disaccharide?

Glucose, Lactose, Amylose, Fructose

Solution: A disaccharide is a carbohydrate composed of two monosaccharide units joined by a glycosidic bond. Out of the options given:

- Glucose is a monosaccharide.
- Lactose is a disaccharide made up of glucose and galactose.
- Amylose is a polysaccharide made up of glucose units.
- Fructose is a monosaccharide.

Thus, Lactose is the disaccharide.

Quick Tip

Disaccharides are made up of two monosaccharides joined by a glycosidic bond. Lactose is an example of a disaccharide.

(c) Which vitamin is responsible for the coagulation of blood?

Solution: The vitamin responsible for blood coagulation is Vitamin K. Vitamin K plays a crucial role in the synthesis of clotting factors in the liver, which are essential for the coagulation of blood.

Quick Tip

Vitamin K is necessary for the synthesis of clotting factors that help in the coagulation of blood.

Section D

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

Passage: The rate of a chemical reaction is expressed either in terms of decrease in the concentration of reactants or increase in the concentration of a product per unit time. Rate of the reaction depends upon the nature of reactants, concentration of reactants, temperature, presence of catalyst, surface area of the reactants and presence of light. Rate of reaction is directly related to the concentration of reactant. Rate law states that the rate of reaction depends upon the concentration terms on which the rate of reaction actually depends, as observed experimentally. The sum of powers of the concentration of the reactants in the Rate law expression is called order of reaction while the number of reacting species taking part in an elementary reaction which must collide simultaneously in order to bring about a chemical reaction is called molecularity of the reaction.

Answer the following questions:

(a) (i) What is a rate determining step?

Solution: The rate-determining step is the slowest step in a reaction mechanism. It limits the overall rate of the reaction because the rate of the entire reaction is governed by the rate of this step. In a multi-step reaction, the rate-determining step is the step with the highest activation energy or the slowest rate.

Quick Tip

In a reaction mechanism, the rate-determining step controls the speed of the overall reaction because it is the slowest step in the process.

(a) (ii) Define complex reaction.

Solution: A complex reaction involves more than one elementary reaction step. These reactions occur through a sequence of individual reactions, each involving the collision and interaction of reactants. A complex reaction can have multiple intermediates and may involve different molecular species at various stages.

Quick Tip

Complex reactions involve multiple elementary steps, each with its own reaction rate, leading to the overall reaction.

(b) What is the effect of temperature on the rate constant of a reaction?

Solution: The rate constant of a reaction generally increases with temperature. This is explained by the Arrhenius equation, which shows that the rate constant k increases exponentially with an increase in temperature. As the temperature rises, the number of molecules having sufficient energy to overcome the activation energy barrier increases, leading to an increase in the rate constant.

$$k = A \cdot e^{-\frac{E_a}{RT}}$$

Where: - k is the rate constant, - A is the frequency factor, - E_a is the activation energy, - R is the gas constant, - T is the temperature in Kelvin.

Quick Tip

An increase in temperature results in an increase in the rate constant, accelerating the reaction.

OR

(b) Why is molecularity applicable only for elementary reactions whereas order is applicable for elementary as well as complex reactions?

Solution: Molecularity refers to the number of reacting species involved in an elementary reaction and is a property of that specific step. It applies only to elementary reactions because these reactions occur in a single step and involve a fixed number of reacting molecules. On the other hand, the order of a reaction is determined experimentally and refers to the relationship between the concentration of reactants and the rate of the overall reaction, which can apply to both elementary and complex reactions.

Quick Tip

Molecularity applies only to elementary reactions, while order applies to the overall reaction, regardless of whether it is elementary or complex.

(c) The conversion of molecule X to Y follows second-order kinetics. If the concentration of X is increased 3 times, how will it affect the rate of formation of Y?

Solution: For a second-order reaction, the rate of the reaction is proportional to the square of the concentration of reactant X:

$$\text{Rate} = k \cdot [X]^2$$

If the concentration of X is increased 3 times, the rate of formation of Y will increase by a factor of:

$$(3)^2 = 9$$

Thus, the rate of formation of Y will increase by a factor of 9 when the concentration of X is increased 3 times.

Quick Tip

In a second-order reaction, the rate of the reaction is proportional to the square of the concentration of the reactant.

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30. Phenols undergo electrophilic substitution reactions readily due to the strong activating effect of the OH group attached to the benzene ring. Since the OH group increases the electron density more to the ortho- and para- positions, one of the examples of the aldehyde group being introduced on the aromatic ring of phenol, ortho to the hydroxyl group. This is a general method used for the ortho-formylation of phenols.

Answer the following questions:

(a)What happens when phenol reacts with:

(i) Br_2/CS_2

Solution: When phenol reacts with bromine in carbon disulfide (CS_2), an electrophilic substitution reaction occurs, where the hydroxyl group (OH) activates the ring towards substitution at the ortho and para positions. The major product is 2,4,6-Tribromophenol, as bromine atoms are added at the ortho and para positions relative to the hydroxyl group.

$$C_6H_5OH + 3Br_2 \xrightarrow{CS_2} C_6H_2Br_3OH$$

Quick Tip

The presence of the hydroxyl group makes phenol highly reactive to electrophilic substitution, resulting in tribromination in the ortho and para positions.

(ii) Conc. HNO_3

Solution: When phenol reacts with concentrated nitric acid (HNO_3), it undergoes nitration at the ortho and para positions relative to the hydroxyl group. The major product is 2,4,6-Trinitrophenol (picric acid), which is highly reactive due to the electron-donating effect of the hydroxyl group, activating the ring for nitration.

$$C_6H_5OH + 3HNO_3 \rightarrow C_6H_2NO_3OH$$

Quick Tip

Concentrated nitric acid causes electrophilic nitration of phenol, predominantly at the ortho and para positions, leading to trinitrophenol (picric acid).

(b) Why phenol does not undergo protonation readily?

Solution: Phenol does not undergo protonation readily because the lone pair of electrons on the oxygen of the hydroxyl group is delocalized into the benzene ring through resonance. This reduces the electron density on the oxygen atom, making it less available to accept a proton. As a result, phenol is less basic than alcohols and does not readily undergo protonation.

Quick Tip

The resonance of the lone pair on the oxygen in phenol with the benzene ring decreases its availability to accept a proton, making protonation less likely.

(c) Which is a stronger acid – phenol or cresol? Give reason.

Solution: Phenol is a stronger acid than cresol because cresol has a methyl group ($-CH_3$) attached to the aromatic ring. The methyl group is an electron-donating group, which increases the electron density on the ring and on the oxygen atom of the hydroxyl group. This reduces the ability of the oxygen atom to lose a proton, making cresol less acidic than phenol. In contrast, phenol's hydroxyl group is less stabilized and more likely to lose a proton, making it more acidic.

Quick Tip

Electron-donating groups like the methyl group in cresol reduce the acidity of phenols by stabilizing the negative charge on the oxygen less effectively.

OR

(c) Write the IUPAC name of the product formed in the Reimer-Tiemann reaction.

Solution: The Reimer-Tiemann reaction involves the formylation of phenol, where the hydroxyl group is activated to form an ortho-formylated product. In the presence of chloroform ($CHCl_3$) and a base like NaOH, the major product is 2-formylphenol (also known as ortho-hydroxybenzaldehyde).
The IUPAC name of the product is 2-formylphenol.

Quick Tip

The Reimer-Tiemann reaction introduces an aldehyde group ortho to the hydroxyl group on the benzene ring of phenol.

Section D

31. (A) (a) Write the cell reaction and calculate the e.m.f. of the following cell at 298 K:

$$\text{Sn}(s) \mid \text{Sn}^{2+}(0.004\text{ M}) \parallel \text{H}^{+}(0.02\text{ M}) \mid \text{H}_2(1\text{ Bar}) \mid \text{Pt}(s)$$

(Given: $E^\circ_{\text{Sn}^{2+}/\text{Sn}} = -0.14\,\text{V}, E^\circ_{\text{H}^+/\text{H}_2} = 0.00\,\text{V}$)

Solution:

The cell reaction is written as:

$$\text{Sn}(s) \mid \text{Sn}^{2+}(0.004\text{ M}) \parallel \text{H}^{+}(0.02\text{ M}) \mid \text{H}_2(1\text{ Bar}) \mid \text{Pt}(s)$$

The cell potential E_{cell} can be calculated using the Nernst equation:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0591}{n} \log \frac{[\text{products}]}{[\text{reactants}]}$$

Where: - $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$, - $E^\circ_{\text{cathode}} = E^\circ_{\text{H}^+/\text{H}_2} = 0.00\,\text{V}$, - $E^\circ_{\text{anode}} = E^\circ_{\text{Sn}^{2+}/\text{Sn}} = -0.14\,\text{V}$, - $n = 2$ (since the reaction involves the transfer of 2 electrons). Now, calculate the cell potential:

$$E_{\text{cell}} = 0.00 - (-0.14) - \frac{0.0591}{2} \log \frac{[\text{H}^+]^2}{[\text{Sn}^{2+}]}$$

Substitute the given concentrations:

$$E_{\text{cell}} = 0.14 - \frac{0.0591}{2} \log \frac{(0.02)^2}{0.004}$$

Simplifying the logarithmic term:

$$E_{\text{cell}} = 0.14 - \frac{0.0591}{2} \log \frac{0.0004}{0.004}$$

$$E_{\text{cell}} = 0.14 - \frac{0.0591}{2} \log 0.1$$

Since $\log 0.1 = -1$:

$$E_{\text{cell}} = 0.14 - \frac{0.0591}{2}(-1)$$

$$E_{\text{cell}} = 0.14 + 0.02955$$

$$E_{\text{cell}} = 0.16955\,\text{V}$$

Thus, the e.m.f. of the cell is 0.170 V.

Quick Tip

The Nernst equation allows for the calculation of the cell potential by taking into account the concentrations of the ions involved in the electrochemical reaction.

(b) Account for the following:

(i) On the basis of E° values, O_2 gas should be liberated at anode but it is Cl_2 gas which is liberated in the electrolysis of aqueous NaCl.

Solution: The standard electrode potential for the reduction of oxygen to water is $E^\circ_{\text{O}_2/\text{H}_2\text{O}} = +1.23\,\text{V}$, while for chloride to chlorine gas, $E^\circ_{\text{Cl}^-/\text{Cl}_2} = +1.36\,\text{V}$. In the electrolysis of aqueous NaCl, chloride ions are more readily oxidized to chlorine gas because the chloride ions are present in much higher concentration compared to oxygen in the solution. Therefore, despite the more positive potential for oxygen reduction, chlorine is liberated at the anode due to the high concentration of chloride ions.

Quick Tip

Even though oxygen has a more positive reduction potential, chlorine is preferentially produced at the anode due to the high concentration of chloride ions.

(ii) Conductivity of CH_3COOH decreases on dilution.

Solution: The conductivity of acetic acid (CH_3COOH) decreases on dilution because it is a weak electrolyte that ionizes only partially in solution. As the solution is diluted, the number of ions in the solution decreases, reducing the overall conductivity. In the case of weak electrolytes like acetic acid, dilution reduces the concentration of dissociated ions, leading to a decrease in electrical conductivity.

Quick Tip

Weak electrolytes like acetic acid dissociate partially, and dilution reduces the number of ions in solution, causing a decrease in conductivity.

OR

31(B) (a.)Write the anode and cathode reactions and the overall cell reaction occurring in a lead storage battery during its use.

Solution:

In a lead storage battery (also known as a lead-acid battery), during discharge:

- Anode reaction:

$$\text{Pb}(s) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{PbSO}_4(s) + 2\text{e}^-$$

- Cathode reaction:

$$\text{PbO}_2(s) + 4\text{H}^+(aq) + 2\text{e}^- \rightarrow \text{PbSO}_4(s) + 2\text{H}_2\text{O}(l)$$

- Overall reaction:

$$\text{Pb}(s) + \text{PbO}_2(s) + 2\text{H}_2\text{SO}_4(aq) \rightarrow 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l)$$

Quick Tip

In a lead-acid battery, lead sulfate is formed at both electrodes during discharge, and the reaction is reversible during charging.

31(B) (b.)Calculate the potential for half-cell containing 0.01 M $K_2Cr_2O_7$(aq), 0.01 M Cr^{3+}(aq), and 1.0 x 10^{-4} M H^+(aq).

Solution:

The half-cell reaction is:

$$\text{Cr}_2\text{O}_7^{2-}(aq) + 14\text{H}^+(aq) + 6e^- \rightarrow 2\text{Cr}^{3+}(aq) + 7\text{H}_2\text{O}(l)$$

The standard electrode potential for this half-cell reaction is $E^\circ = 1.33\,\text{V}$.

Using the Nernst equation:

$$E = E^\circ - \frac{0.0591}{n} \log \left(\frac{[\text{products}]}{[\text{reactants}]} \right)$$

Substituting values:

$$E = 1.33 - \frac{0.0591}{6} \log \left(\frac{[\text{Cr}^{3+}]^2 \times [\text{H}_2\text{O}]^7}{[\text{Cr}_2\text{O}_7^{2-}] \times [\text{H}^+]^{14}} \right)$$

$$E = 1.33 - \frac{0.0591}{6} \log \left(\frac{(0.01)^2 \times 1}{(0.01) \times (1.0 \times 10^{-4})^{14}} \right)$$

After simplification, calculate the final E.

Quick Tip

Use the Nernst equation to adjust the standard potential based on the concentration of the species involved in the reaction.

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32. (A) Answer the following:

(a) Low spin tetrahedral complexes are not known.

Solution: Low spin tetrahedral complexes are not known because tetrahedral complexes typically have a weaker ligand field splitting energy compared to octahedral complexes. In a tetrahedral field, the splitting energy (Δ_T) is smaller, which does not create a significant enough energy difference between the d-orbitals to cause pairing of electrons. Therefore, in a tetrahedral complex, the electrons tend to occupy all available orbitals singly (high-spin state), and low-spin tetrahedral complexes are not stable.

Quick Tip

Low-spin complexes are more commonly seen in octahedral geometries where the ligand field splitting is stronger.

(b) Co^{2+} is easily oxidized to Co^{3+} in the presence of a strong ligand (At. No. of Co = 27).

Solution: Cobalt in the +2 oxidation state (Co^{2+}) has a relatively low stability due to the presence of a higher number of electrons in its d-orbitals, leading to higher repulsion between them. When a strong ligand, such as ammonia (NH) or cyanide (CN), is present, it can create a strong ligand field that stabilizes Co^{3+} by lowering the energy of the d-orbitals. As a result, Co^{2+} is easily oxidized to Co^{3+}, which is more stable due to the lower electron-electron repulsion in the 3d configuration.

Quick Tip

Strong field ligands can stabilize high oxidation states, like Co^{3+}, by creating a strong ligand field.

(c) What type of isomerism is shown by the complex [Co(NH)][Cr(CN)]?

Solution: The complex [Co(NH)][Cr(CN)] exhibits ionization isomerism. In ionization isomerism, two different compounds have the same molecular formula but differ in the way the ions are arranged. One of the isomers will have the ion [Cr(CN)] as the anion, while the other will have the ion [Co(NH)] as the anion. The difference in the arrangement of ions leads to the formation of different ions in the solution, which are responsible for the isomerism.

Quick Tip

Ionization isomerism occurs when two compounds have the same molecular formula but differ in the arrangement of ions.

(d) Why is a solution of Ni(HO)^2 green while a solution of Ni(CN)^2 is colourless? (At. No. of Ni = 28)

Solution: The color of a coordination compound is largely influenced by the ligand field and the d-electron transitions of the metal ion. In the case of Ni(HO)^2, water is a weak field ligand that causes a small splitting of the d-orbitals in Ni^2. This allows the absorption of light in the visible spectrum, giving the solution a green color.
In contrast, in Ni(CN)^2, cyanide is a strong field ligand that causes a large splitting of the

d-orbitals in Ni^{2}, leading to no available electronic transitions in the visible region. As a result, the solution of $Ni(CN)^{2}$ is colorless because no visible light is absorbed.

Quick Tip

The color of a complex is influenced by the strength of the ligand and the extent of splitting of the metal's d-orbitals.

(e) Write the IUPAC name of the following complex: [Co(NH)(CO)]Cl.

Solution: The IUPAC name of the complex [Co(NH)(CO)]Cl is Pentaamminecarbonato cobalt(III) chloride. Explanation: - "Pentaammine" refers to the five ammonia (NH) ligands.
- "Carbonato" refers to the carbonate (CO) ligand.
- "Cobalt(III)" indicates that cobalt is in the +3 oxidation state.
- "Chloride" is the anion that balances the charge of the complex.

Quick Tip

The IUPAC naming system for coordination compounds includes the names of the ligands, the metal, its oxidation state, and the counter-ion.

33. (A) (a) Carry out the following conversions:

(i) Ethanal to But-2-enal

Solution: The conversion of Ethanal (Acetaldehyde) to But-2-enal involves an aldol condensation reaction. The steps are:
1. Aldol condensation: Ethanal undergoes aldol condensation in the presence of a base like NaOH to form But-3-en-2-al (crotonaldehyde).

$$CH_3CHO + CH_3CHO \xrightarrow{NaOH} CH_3CH{=}CHCHO \quad \text{(But-3-en-2-al)}$$

2. The final product is But-2-enal, which is the desired compound.

Quick Tip

Aldol condensation is used to form conjugated enals, and here, it is used to synthesize But-2-enal from Ethanal.

(ii) Propanoic acid to Ethane

Solution: To convert propanoic acid to ethane, we perform a reduction reaction using a strong reducing agent like LiAlH. The steps are:

1. Reduction of Propanoic acid: Propanoic acid is reduced by lithium aluminum hydride (LiAlH) to ethanol.

$$CH_3CH_2COOH \xrightarrow{LiAlH_4} CH_3CH_2OH$$

2. Reduction of Ethanol to Ethane: Ethanol is then reduced further by a reducing agent like zinc in the presence of hydrochloric acid (Zn/HCl) to ethane.

$$CH_3CH_2OH \xrightarrow{Zn/HCl} CH_3CH_3$$

Thus, Propanoic acid is first converted to ethanol and then ethanol to ethane.

Quick Tip

Reduction of carboxylic acids can yield alcohols, and further reduction of alcohols can yield alkanes.

(b) An alkene A with molecular formula C_6H_{10} on ozonolysis gives a mixture of two compounds B and C. Compound B gives positive Fehling test and also reacts with iodine and NaOH solution. Compound C does not give Fehling solution test but forms iodoform. Identify the compounds A, B, and C.

Solution: The molecular formula of the alkene is C_6H_{10}. The ozonolysis of this alkene would break it into two carbonyl compounds. Let's break down the reaction:

1. Ozonolysis of Alkene A: Ozonolysis of C_6H_{10} gives two products, B and C. The alkene is likely 1,5-hexadiene, which splits into acetaldehyde (B) and butan-2-one (C) after

ozonolysis.
- Compound B (Acetaldehyde): Acetaldehyde is an aldehyde, which gives a positive Fehling's test (as it reduces Cu^2 to Cu). It also reacts with iodine and NaOH, forming iodoform (CHCOOH).
- Compound C (Butan-2-one): Butan-2-one is a methyl ketone, which reacts with iodine and NaOH to form iodoform (CHCOOH), but does not give a Fehling's test (as ketones are generally resistant to oxidation by Fehling's solution).

Thus, - Alkene A is 1,5-hexadiene. - Compound B is acetaldehyde (CHCHO). - Compound C is butan-2-one (CHCOCH).

Quick Tip

Ozonolysis of alkenes cleaves the double bond, producing carbonyl compounds such as aldehydes and ketones.

OR

(B) An organic compound (A) (molecular formula $C_8H_{16}O_2$) was hydrolyzed with dilute sulphuric acid to get a carboxylic acid (B) and an alcohol (C). Oxidation of (C) with chromic acid produced (B). On dehydration, (C) gives But-1-ene. Identify (A), (B), and (C) and write chemical equations for the reactions involved.

Solution: The compound A has the molecular formula $C_8H_{16}O_2$, which suggests it is an ester. The reactions involved indicate the formation of a carboxylic acid (B) and an alcohol (C), followed by oxidation and dehydration.

1. Identification of A: Since A undergoes hydrolysis to form a carboxylic acid (B) and alcohol (C), compound A is likely ethyl butanoate (C_6H_5COOCHCH).

2. Hydrolysis of A:

$$C_6H_5COOCH_2CH_3 + H_2O \xrightarrow{\text{dilute } H_2SO_4} C_5H_10COOH\ (B) + C_2H_5OH\ (C)$$

3. Oxidation of C: The alcohol C (ethanol) can be oxidized with chromic acid to produce acetic acid (B).

$$C_2H_5OH \xrightarrow{CrO_3} CH_3COOH$$

4. Dehydration of C: On dehydration, ethanol (C) undergoes elimination to form But-1-ene (CH).

$$C_2H_5OH \xrightarrow{H_2SO_4} CH_2 = CH_2$$

Thus, - A is ethyl butanoate. - B is acetic acid (CHCOOH). - C is ethanol (CHCHOH).

Quick Tip

Hydrolysis of esters produces carboxylic acids and alcohols, oxidation of alcohols produces acids, and dehydration of alcohols can form alkenes.

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(i) Ethanal to But-2-enal

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$$CH_3CHO + CH_3CHO \xrightarrow{NaOH} CH_3CH{=}CHCHO \quad \text{(But-3-en-2-al)}$$

2. The final product is But-2-enal, which is the desired compound.

Quick Tip

Aldol condensation is used to form conjugated enals, and here, it is used to synthesize But-2-enal from Ethanal.

(ii) Propanoic acid to Ethane

Solution: To convert propanoic acid to ethane, we perform a reduction reaction using a strong reducing agent like LiAlH. The steps are:
1. Reduction of Propanoic acid: Propanoic acid is reduced by lithium aluminum hydride (LiAlH) to ethanol.

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$$CH_3CH_2OH \xrightarrow{Zn/HCl} CH_3CH_3$$

Thus, Propanoic acid is first converted to ethanol and then ethanol to ethane.

Quick Tip

Reduction of carboxylic acids can yield alcohols, and further reduction of alcohols can yield alkanes.

(b) An alkene A with molecular formula CH on ozonolysis gives a mixture of two compounds B and C. Compound B gives positive Fehling test and also reacts with iodine and NaOH solution. Compound C does not give Fehling solution test but forms iodoform. Identify the compounds A, B, and C.

Solution: The molecular formula of the alkene is CH. The ozonolysis of this alkene would break it into two carbonyl compounds. Let's break down the reaction:

1. Ozonolysis of Alkene A: Ozonolysis of CH gives two products, B and C. The alkene is likely 1,5-hexadiene, which splits into acetaldehyde (B) and butan-2-one (C) after ozonolysis.

- Compound B (Acetaldehyde): Acetaldehyde is an aldehyde, which gives a positive Fehling's test (as it reduces Cu^2 to Cu). It also reacts with iodine and NaOH, forming iodoform (CHCOOH).
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Thus, - Alkene A is 1,5-hexadiene. - Compound B is acetaldehyde (CHCHO). - Compound C is butan-2-one (CHCOCH).

Quick Tip

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