CBSE 12 2025 Chemistry Set 2 (56/2/2) 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 :

(i) This question paper contains 33 questions. All questions are compulsory.

(ii) This question paper is divided into five sections — Section A, B, C, D and E.

(iii) Section A - questions number 1 to 16 are multiple choice type questions. Each question carries 1 mark.

(iv) Section B - questions number 17 to 21 are very short answer type questions. Each question carries 2 marks.

(v) Section C - questions number 22 to 28 are short answer type questions. Each q ype q question carries 8 marks.

(vi) Section D - questions number 29 and 30 are case-based questions. Each question carries 4 marks.

(vii) Section E - questions number 31 to 33 are long answer type questions. Each question carries 5 marks.

(viii) 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.

(ix) Kindly note that there is a separate question paper for Visually Impaired candidates.

(x) Use of calculators is not allowed.

SECTION A

Questions no. 1 to 16 are Multiple Choice type Questions, carrying 1 mark each

1. Assertion (A): Vitamin D cannot be stored in our body. Reason (R): Vitamin D is fat-soluble vitamin and is not excreted from the body in urine.

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

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

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

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

Correct Answer: (3) Assertion (A) is true, but Reason (R) is false.

Solution: Vitamin D is a fat-soluble vitamin and gets stored in the body, unlike water-soluble vitamins. Hence, Assertion (A) is correct. However, Vitamin D is not excreted from the body in urine; instead, it is stored in fat and liver. This makes Reason (R) false.

Step 2: Thus, the correct answer is option (3).

Quick Tip

Remember that fat-soluble vitamins like Vitamin D, A, E, and K are stored in the liver and fatty tissues, whereas water-soluble vitamins are not stored and are excreted in urine.

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2. Assertion (A): Aromatic primary amines cannot be prepared by Gabriel Phthalimide synthesis. Reason (R): Aryl halides do not undergo nucleophilic substitution reaction with the anion formed by phthalimide.

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

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

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

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

Correct Answer: (2) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Solution: Gabriel Phthalimide synthesis is a method used to prepare primary amines, but it does not work with aromatic amines. Aryl halides do not undergo nucleophilic substitution with the anion formed by phthalimide due to the absence of a good leaving group in aryl halides, but this is not the reason for aromatic primary amines not being prepared.

Step 2: Thus, both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation for Assertion (A).

Quick Tip

The Gabriel synthesis is a way of synthesizing primary amines from alkyl halides, but does not work effectively with aryl halides due to their poor reactivity in nucleophilic substitution reactions.

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3. Assertion (A): Cu cannot liberate H_2 on reaction with dilute mineral acids. Reason (R): Cu has positive electrode potential.

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

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

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

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

Correct Answer: (4) Assertion (A) is false, but Reason (R) is true.

Solution: Cu does not liberate hydrogen gas when it reacts with dilute mineral acids because copper is less reactive and cannot displace hydrogen from dilute acids. However, copper has a positive electrode potential, which means it is less likely to lose electrons and participate in such reactions, but this does not directly explain the inability to liberate hydrogen gas.

Step 2: Thus, Assertion (A) is false, and Reason (R) is true, but they are not logically connected.

Quick Tip

Metals like copper, with a positive electrode potential, are less reactive and do not readily release hydrogen when reacting with dilute acids.

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4. Assertion (A): In a first order reaction, if the concentration of the reactant is doubled, its half-life is also doubled. Reason (R): The half-life of a reaction does not depend upon the initial concentration of the reactant in a first order reaction.

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

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

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

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

Correct Answer: (4) Assertion (A) is false, but Reason (R) is true.

Solution: For a first-order reaction, the half-life is independent of the initial concentration of the reactant, and it remains constant regardless of how the concentration changes. Thus, Assertion (A) is false, but Reason (R) is true.

Step 2: Thus, Assertion (A) is false, and Reason (R) is true.

Quick Tip

For first-order reactions, the half-life remains constant regardless of the concentration of reactants, which is a key feature of such reactions.

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5. Scurvy is caused due to deficiency of

(1) Vitamin B1

(2) Vitamin B2

(3) Ascorbic acid

(4) Glutamic acid

Correct Answer: (3) Ascorbic acid

Solution: Scurvy is a disease caused due to the deficiency of Vitamin C, also known as ascorbic acid. It is essential for the synthesis of collagen in the body.

Step 2: Thus, the correct answer is option (3).

Quick Tip

Vitamin C (ascorbic acid) is crucial for the health of connective tissues and collagen formation. Its deficiency leads to scurvy.

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6. Nucleotides are joined together by

(1) Glycosidic linkage

(2) Peptide linkage

(3) Hydrogen bonding

(4) Phosphodiester linkage

Correct Answer: (4) Phosphodiester linkage

Solution: Nucleotides in nucleic acids (DNA and RNA) are joined by phosphodiester bonds, where a phosphate group connects the 3' carbon atom of one sugar molecule to the 5' carbon of another.

Step 2: Thus, the correct answer is option (4).

Quick Tip

In nucleic acids, phosphodiester bonds form the backbone of the structure by connecting the sugar and phosphate groups of adjacent nucleotides.

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7. Which of the following is/are examples of denaturation of protein?

(1) Coagulation of egg white

(2) Curdling of milk

(3) Clotting of blood

(4) Both (1) and (2)

Correct Answer: (4) Both (1) and (2)

Solution: Denaturation of proteins refers to the process in which proteins lose their natural structure due to external factors like temperature or pH. Both coagulation of egg white and curdling of milk involve protein denaturation.

Step 2: Thus, the correct answer is option (4).

Quick Tip

Denaturation of proteins can be caused by heat, acid, or mechanical agitation. This leads to a loss of their functional structure.

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8. The conversion of phenol to salicylic acid can be accomplished by

(1) Reimer-Tiemann reaction

(2) Friedel-Crafts reaction

(3) Kolbe reaction

(4) Coupling reaction

Correct Answer: (1) Reimer-Tiemann reaction

Solution: The Reimer-Tiemann reaction is used to convert phenols to salicylic acid. In this reaction, phenol is treated with chloroform and a base to form salicylic acid.

Step 2: Thus, the correct answer is option (1).

Quick Tip

The Reimer-Tiemann reaction involves the chlorination of phenol followed by hydrolysis, which yields salicylic acid, a precursor of aspirin.

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9. What will be formed after oxidation of secondary alcohol with chromic anhydride (CrO3)?

(1) Aldehyde

(2) Ketone

(3) Carboxylic acid

(4) Ester

Correct Answer: (2) Ketone

Solution: When a secondary alcohol is oxidized with chromic anhydride (CrO3), it undergoes oxidation to form a ketone. Secondary alcohols do not oxidize to aldehydes or carboxylic acids.

Step 2: Thus, the correct answer is option (2).

Quick Tip

Chromic anhydride is a strong oxidizing agent that selectively oxidizes secondary alcohols to ketones without affecting aldehydes or carboxylic acids.

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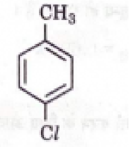
10. Which is the correct IUPAC name for



(1) Methylchlorobenzene

(2) Toluene

(3) 1-Chloro-4-Methylbenzene

(4) 1-Methyl-4-Chlorobenzene

Correct Answer: (3) 1-Chloro-4-Methylbenzene

Solution: The compound consists of a methyl group and a chlorine atom attached to a benzene ring. The correct IUPAC name is 1-Chloro-4-Methylbenzene, where the numbering starts from the position of the chlorine atom, followed by the methyl group.

Step 2: Thus, the correct answer is option (3).

Quick Tip

In aromatic compounds with more than one substituent, the substituents are numbered to give the lowest possible locants, with the substituent listed first in alphabetical order.

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11. The diamagnetic species is :

At. No. Co = 27, Fe =26, Ni= 28]

(1) $[Ni(CN)_4]^{2-}$

(2) $[NiCl_4]^{2-}$

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

(4) $[CoF_6]^{3-}$

Correct Answer: (1) $[Ni(CN)_4]^{2-}$

Solution: Diamagnetic species are those that do not have any unpaired electrons. Among the given options, $[Ni(CN)_4]^{2-}$ is diamagnetic because the Ni^{2+} ion in this complex has no unpaired electrons.

Step 2: Thus, the correct answer is option (1).

Quick Tip

Diamagnetic species have all their electrons paired and are repelled by a magnetic field, unlike paramagnetic species, which have unpaired electrons.

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12. The complex ions $[Co(NH_3)_5(NO_2)]^{2+}$ **and** $[Co(NH_3)_5(ONO)]^{2+}$ **are called**

(1) Ionization isomers

(2) Linkage isomers

(3) Co-ordination isomers

(4) Geometrical isomers

Correct Answer: (2) Linkage isomers

Solution: Linkage isomerism occurs when a ligand can bind to the metal ion in two different ways. Here, NO_2 and ONO are two forms of the same ligand, leading to linkage isomerism.

Step 2: Thus, the correct answer is option (2).

Quick Tip

In linkage isomerism, a ligand can attach to a metal through different atoms, resulting in isomers with the same formula but different structures.

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13. The element having $[Ar]3d^{10}4s^1$ electronic configuration is

(1) Cu

(2) Zn

(3) Cr

(4) Mn

Correct Answer: (1) Cu

Solution: The electron configuration $[Ar]3d^{10}4s^1$ corresponds to Copper (Cu), which has an atomic number of 29.

Step 2: Thus, the correct answer is option (1).

Quick Tip

Copper (Cu) has an electron configuration of $[Ar]3d^{10}4s^1$, which is an exception to the general electron configuration rule due to stability gained by a filled 3d subshell.

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14. The number of molecules that react with each other in an elementary reaction is a measure of the:

(1) activation energy of the reaction

(2) stoichiometry of the reaction

(3) molecularity of the reaction

(4) order of the reaction

Correct Answer: (3) molecularity of the reaction

Solution: Molecularity of a reaction refers to the number of molecules involved in an elementary reaction. It is a fundamental concept used to determine the mechanism of a reaction.

Step 2: Thus, the correct answer is option (3).

Quick Tip

Molecularity is the number of reactant molecules that collide in an elementary step to undergo a reaction.

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15. Which among the following is a false statement?

(1) Rate of zero order reaction is independent of initial concentration of reactant.

(2) Half-life of a zero order reaction is inversely proportional to the rate constant.

(3) Molecularity of a reaction may be zero.

(4) For a first order reaction, $t_{1/2} = 0.693/k$.

Correct Answer: (3) Molecularity of a reaction may be zero.

Solution: Molecularity refers to the number of reacting species in an elementary reaction, and it cannot be zero. A reaction cannot occur with zero reacting molecules.

Step 2: Thus, the correct answer is option (3).

Quick Tip

Molecularity is always a positive integer, representing the number of molecules involved in an elementary reaction step.

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16. The charge required for the reduction of 1 mol of MnO_4^- to MnO_2 is

(1) 1 F

(2) 3 F

(3) 5 F

(4) 6 F

Correct Answer: (3) 5 F

Solution: In the reduction of MnO_4^- to MnO_2, the manganese ion undergoes a change in oxidation state from +7 to +4, which requires 5 moles of electrons. Hence, the charge required is 5 F (Faradays).

Step 2: Thus, the correct answer is option (3).

Quick Tip

The number of Faradays required for a redox reaction corresponds to the total number of electrons involved in the oxidation or reduction of the species.

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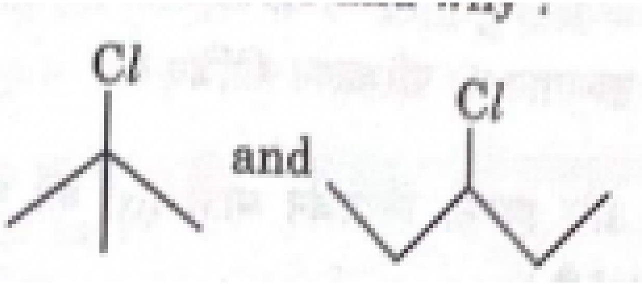
17. (a) In the following pair of halogen compounds, which compound undergoes S_N1 reaction faster and why?



Solution: Step 1: Understanding the S_N1 Mechanism.

The S_N1 reaction proceeds via a two-step mechanism:

1. Formation of a carbocation (rate-determining step).

2. Nucleophilic attack on the carbocation.

The rate of the S_N1 reaction depends on the stability of the carbocation. Tertiary carbocations are more stable due to greater alkyl group substitution which provides better electron donation through hyperconjugation and inductive effects. This stability accelerates the formation of the carbocation, thus enhancing the reaction rate.

Given two halogen compounds, the one with the tertiary halogenated carbon (i.e., more substituted carbon) will form a more stable carbocation and thus undergoes the S_N1 reaction faster.

Quick Tip

Remember, in S_N1 reactions, the stability of the carbocation intermediate is crucial. More substituted carbocations are generally more stable and form faster, leading to a quicker overall reaction.

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17. (b) Arrange the following compounds in increasing order of their reactivity towards S_N2 displacement: 2-Bromo-2-methylbutane, 1-Bromopentane, 2-Bromopentane.

Solution: Step 1: Understanding S_N2 Mechanism. The S_N2 mechanism involves a single step where the nucleophile attacks the electrophilic carbon, displacing the leaving group, all happening simultaneously. This mechanism is highly sensitive to steric hindrance; thus, less substituted carbons are more reactive due to easier accessibility for the nucleophile.

2-Bromo-2-methylbutane: This is a tertiary bromide and thus highly hindered, making S_N2 reactions extremely slow.

2-Bromopentane: As a secondary bromide, it is less hindered than the tertiary but more so than the primary, placing it in the middle for reactivity.

1-Bromopentane: This is a primary bromide with the least steric hindrance, facilitating the fastest S_N2 reaction.

Therefore, the order of increasing reactivity towards S_N2 displacement is:

$$\text{2-Bromo-2-methylbutane} < \text{2-Bromopentane} < \text{1-Bromopentane}.$$

Quick Tip

For S_N2 reactions, remember that less steric hindrance at the reactive center increases the reaction rate. Primary halides are typically more reactive than secondary and tertiary halides.

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18. A reaction is of second order with respect to a reactant. How is the rate of reaction affected if the concentration of the reactant is (i) doubled, (ii) reduced to half?

Solution: Step 1: Understanding Second-Order Reactions. For a second-order reaction, the rate law is given by:

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

where $[A]$ is the concentration of the reactant and k is the rate constant.

Step 2: Effect of Concentration Change. (i) If the concentration of A is doubled, the rate will increase by a factor of $2^2 = 4$. This is because the rate is proportional to the square of the concentration.

$$\text{New Rate} = k(2[A])^2 = 4k[A]^2$$

(ii) If the concentration of A is reduced to half, the rate will decrease by a factor of $\left(\frac{1}{2}\right)^2 = \frac{1}{4}$.

$$\text{New Rate} = k\left(\frac{1}{2}[A]\right)^2 = \frac{1}{4}k[A]^2$$

Thus, doubling the concentration quadruples the rate, while halving the concentration reduces the rate to one-quarter.

Quick Tip

For second-order reactions, the rate is proportional to the square of the concentration. Doubling the concentration increases the rate by a factor of 4, while halving it decreases the rate by a factor of 4.

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19. When $FeCr_2O_4$ is fused with Na_2CO_3 in the presence of air, it gives a yellow solution of compound (A). Compound (A) on acidification gives compound (B). Compound (B) on reaction with KCl forms an orange-colored compound (C). An acidified solution of compound (C) oxidizes Na_2SO_3 to (D). Identify (A), (B), (C), and (D).

Solution: Step 1: Identifying Compound (A). When $FeCr_2O_4$ is fused with Na_2CO_3 in the presence of air, it forms a yellow solution of sodium chromate (Na_2CrO_4). Thus, $A = Na_2CrO_4$.

Step 2: Identifying Compound (B). Upon acidification, Na_2CrO_4 is converted to potassium dichromate ($K_2Cr_2O_7$), which is orange in color. Thus, $B = K_2Cr_2O_7$.

Step 3: Identifying Compound (C). The reaction of $K_2Cr_2O_7$ with KCl leads to the formation of orange-colored $Cr_2O_7^{2-}$ ions. Thus, C is an orange-colored chromium compound. Thus, $C = K_2Cr_2O_7$.

Step 4: Identifying Compound (D). An acidified solution of C oxidizes sodium sulfite (Na_2SO_3) to sodium sulfate (Na_2SO_4). This is a typical redox reaction where chromium compounds act as oxidizing agents. Thus, $D = Na_2SO_4$.

So, the identities are:

$A = Na_2CrO_4$

$B = K_2Cr_2O_7$

$C = K_2Cr_2O_7$

$D = Na_2SO_4$

Quick Tip

Chromates and dichromates are strong oxidizing agents. Chromates are yellow in alkaline conditions, while dichromates are orange in acidic conditions.

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20. Explain $[Co(NH_3)_6]^{3+}$ is an inner orbital complex whereas $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex. [At. No. Co = 27, Ni = 28]

Solution: Step 1: Understanding Inner and Outer Orbital Complexes. Inner orbital complexes involve the use of d-orbitals from the inner shell (typically the $3d$-orbitals in transition metals). This type of hybridization leads to low-spin complexes, where ligands coordinate using these inner d-orbitals.

Outer orbital complexes involve the use of d-orbitals from the outer shell (typically $4d$-orbitals for transition metals in higher oxidation states). This type of hybridization leads to high-spin complexes, where ligands coordinate using these outer d-orbitals.

Step 2: Identifying the Hybridization in $[Co(NH_3)_6]^{3+}$. Cobalt in the $+3$ oxidation state has an electronic configuration of $3d^6$, and the complex $[Co(NH_3)_6]^{3+}$ uses inner $3d$-orbitals for bonding with the ligands. The $3d^2sp^3$ hybridization results in an inner orbital complex.

Step 3: Identifying the Hybridization in $[Ni(NH_3)_6]^{2+}$. Nickel in the $+2$ oxidation state has an electronic configuration of $3d^8$, and the complex $[Ni(NH_3)_6]^{2+}$ uses outer $4d$-orbitals for bonding. The sp^3d^2 hybridization results in an outer orbital complex.

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

Quick Tip

For inner orbital complexes, low-spin configurations are typical with d^2sp^3 hybridization. For outer orbital complexes, high-spin configurations are typical with sp^3d^2 hybridization.

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21. (A) The rate constant for a zero-order reaction $A \to P$ is 0.0030 mol L^{-1} s^{-1}. How long will it take for the initial concentration of A to fall from 0.10 M to 0.075 M?

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

$$[A] = [A_0] - kt$$

where: - $[A]$ is the concentration of A at time t, - $[A_0]$ is the initial concentration, - k is the rate constant, and - t is the time taken.

We are given: - $[A_0] = 0.10\,\text{M}$, - $[A] = 0.075\,\text{M}$, - $k = 0.0030\,\text{mol L}^{-1}\,\text{s}^{-1}$.

Substituting these values into the rate law equation:

$$0.075 = 0.10 - (0.0030)(t)$$

Rearranging to solve for t:

$$0.0030t = 0.10 - 0.075 = 0.025$$

$$t = \frac{0.025}{0.0030} = 8.33\,\text{seconds}$$

Thus, it will take approximately $8.33\,\text{seconds}$ for the concentration of A to fall from 0.10 M to 0.075 M.

Quick Tip

For zero-order reactions, the concentration decreases linearly with time. The time for a certain concentration change can be calculated using the integrated rate law.

OR

21. (B) The decomposition of NH_3 on a platinum surface is a zero-order reaction. What are the rates of production of N_2 and H_2 if $k = 2.5 \times 10^{-4}\,\text{mol L}^{-1}\,\text{s}^{-1}$?

Solution: For a zero-order reaction, the rate of reaction is constant and equal to the rate constant k. The rate of production of products is the same as the rate constant. In this case, the rate constant $k = 2.5 \times 10^{-4}\,\text{mol L}^{-1}\,\text{s}^{-1}$.

The decomposition of NH_3 on the platinum surface produces N_2 and H_2 in a 1:3 molar ratio. Therefore, the rates of production of both N_2 and H_2 will be equal to k.

Thus, the rates of production of N_2 and H_2 are both:

$$\text{Rate of production of } N_2 = \text{Rate of production of } H_2 = 2.5 \times 10^{-4}\,\text{mol L}^{-1}\,\text{s}^{-1}.$$

Quick Tip

For zero-order reactions, the rate of product formation is constant and equal to the rate constant. This applies regardless of the concentration of reactants.

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22. A solution containing 15 g urea (molar mass = 60 g mol^{-1}) per litre of solution in water has the same osmotic pressure (isotonic) as a solution of glucose (molar mass = 180 g mol^{-1}) in water. Calculate the mass of glucose present in one litre of its solution.

Solution: Osmotic pressure (π) is given by the formula:

$$\pi = \frac{nRT}{V}$$

where:

n is the number of moles of solute,

R is the gas constant,

T is the temperature,

V is the volume of the solution.

Since both solutions have the same osmotic pressure, the number of moles of solute in both solutions must be the same. For urea, the number of moles n_1 is calculated as:

$$n_1 = \frac{15\,\text{g}}{60\,\text{g/mol}} = 0.25\,\text{mol}.$$

Let the mass of glucose be m_2. The number of moles of glucose n_2 is:

$$n_2 = \frac{m_2}{180\,\text{g/mol}}.$$

Since the osmotic pressures are the same, the number of moles of urea must equal the number of moles of glucose:

$$0.25 = \frac{m_2}{180}.$$

Solving for m_2:

$$m_2 = 0.25 \times 180 = 45\,\text{g}.$$

Thus, the mass of glucose present in one litre of its solution is $45\,\text{g}$.

Quick Tip

When two solutions have the same osmotic pressure, the number of moles of solute is proportional to the molar mass of the solute.

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23. Calculate Λ_m^0 for acetic acid and its degree of dissociation (α) if its molar conductivity is 48.1 Ω^{-1} cm^2 mol^{-1}.

Given that

Λ_m^0(**HC**) $= 426\,\Omega^{-1}$ **cm^2 mol^{-1},**

Λ_m^0(**NaCl**) $= 126\,\Omega^{-1}$ **cm^2 mol^{-1},**

Λ_m^0(**CH$_3$COONa**) $= 91\,\Omega^{-1}$ **cm^2 mol^{-1}.**

Solution: First, we need to calculate the molar conductivity at infinite dilution, Λ_m^0, for acetic acid, which is the sum of the conductivity contributions from the ions of acetic acid and sodium acetate:

$$\Lambda_m^0(\text{Acetic acid}) = \Lambda_m^0(\text{HC}) - \Lambda_m^0(\text{NaCl}) = 426 - 126 = 300\,\Omega^{-1}\,\text{cm}^2\,\text{mol}^{-1}.$$

Next, we can calculate the degree of dissociation α by comparing the observed molar conductivity of acetic acid to the expected conductivity at infinite dilution:

$$\alpha = \frac{\Lambda_m}{\Lambda_m^0}.$$

Substitute the given values:

$$\alpha = \frac{48.1}{300} \approx 0.16.$$

Thus, the degree of dissociation α is 0.16, and the molar conductivity at infinite dilution for acetic acid is 300 $\Omega^{-1}\,\text{cm}^2\,\text{mol}^{-1}$.

Quick Tip

The degree of dissociation α indicates the fraction of the total molecules that dissociate into ions in a solution.

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24. (a) Why is Cr^{2+} strongly reducing while Mn^{3+} is strongly oxidizing?

Solution: Chromium in the Cr^{2+} state has an electronic configuration of $[Ar]3d^4$, which is relatively unstable and easily oxidizes to the more stable Cr^{3+} configuration, $[Ar]3d^5$. This makes Cr^{2+} a strong reducing agent because it readily loses electrons.

On the other hand, Mn^{3+} has an electronic configuration of $[Ar]3d^4$, which is also unstable. It is prone to gaining electrons to become Mn^{2+}, which has a more stable $[Ar]3d^5$ configuration. Thus, Mn^{3+} is a strong oxidizing agent because it readily accepts electrons.

Step 2: Thus, the differences in the electronic configurations of Cr^{2+} and Mn^{3+} explain why Cr^{2+} is a strong reducing agent and Mn^{3+} is a strong oxidizing agent.

Quick Tip

Elements with an electronic configuration that leads to an unstable oxidation state (such as Cr^{2+} or Mn^{3+}) are more likely to undergo reduction or oxidation to attain more stable states.

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24. (b) Write two consequences of lanthanide contraction.

Solution: Lanthanide contraction refers to the gradual decrease in the ionic radius of the lanthanide series as the atomic number increases, caused by the poor shielding effect of the 4f-electrons. Two important consequences of lanthanide contraction are:

1. Decreasing ionic radii: As the atomic number increases from La^{3+} to Lu^{3+}, the size of the ions decreases, leading to an increase in the effective nuclear charge experienced by the electrons. This results in a decrease in the ionic radii.

2. Similarity between the 3d and 4d/5d elements: The lanthanide contraction leads to similarities in the properties of the lanthanide elements and the d-block elements in the same period. For example, Zr (a 4d element) and Hf (a 5d element) have very similar ionic radii due to the lanthanide contraction.

Step 2: Thus, the lanthanide contraction results in smaller ionic radii and increased similarities between the properties of lanthanides and d-block elements.

Quick Tip

The lanthanide contraction explains many similarities between the properties of d-block and f-block elements, particularly in terms of ionic radii and chemical behavior.

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24. (c) Which element of the 3d series has the lowest enthalpy of atomisation and why?

Solution: The element of the 3d series with the lowest enthalpy of atomisation is copper (Cu). Copper has a completely filled $3d^{10}$ configuration, which makes it highly stable. The stability of the $3d^{10}$ configuration reduces the energy required to break the metallic bonds during atomisation, hence lowering the enthalpy of atomisation.

In contrast, elements like zinc (Zn) and manganese (Mn) have less stable electron configurations and require more energy to break the bonds during atomisation.

Step 2: Thus, copper (Cu) has the lowest enthalpy of atomisation due to the stability provided by its filled $3d^{10}$ configuration.

Quick Tip

The enthalpy of atomisation is lower for elements with stable electron configurations, such as copper's $3d^{10}$, as less energy is required to break the bonds.

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25. Write IUPAC names of the following coordination entities:

(a) $[Fe(en)_2Cl_2]^+$

(b) $[Co(NH_3)_4(H_2O)Br]SO_4$

(c) $[Ni(CN)_4]^{2-}$

Solution: (a) $[Fe(en)_2Cl_2]^+$

In this complex: - The metal ion is Fe^{3+}, which is iron in the +3 oxidation state. - en refers to ethylenediamine, which is a bidentate ligand. - Chlorine (Cl) is the monodentate ligand. - The overall charge of the complex is +1.

The IUPAC name for this complex is:

$$\text{bis(ethylenediamine)(chlorido)iron(III)}^+$$

(b) $[Co(NH_3)_4(H_2O)Br]SO_4$

In this complex: - The metal ion is Co^{3+}, which is cobalt in the +3 oxidation state. - NH_3 is ammonia, a monodentate ligand. - H_2O is water, also a monodentate ligand. - Br is bromide, a monodentate ligand. - The anion SO_4^{2-} balances the charge.

The IUPAC name for this complex is:

$$\text{tetraammin(aqua)bromidocobalt(III) sulfate}$$

(c) $[Ni(CN)_4]^{2-}$

In this complex:

The metal ion is Ni^{2+}, which is nickel in the +2 oxidation state.

CN^- is cyanide, a monodentate ligand.

The overall charge of the complex is -2.

The IUPAC name for this complex is:

$$\text{tetra(cyanido)nickelate(II)}^{2-}$$

Quick Tip

When naming coordination complexes, remember to follow these key steps:

Name the ligands first, in alphabetical order. Use prefixes like ”di-”, ”tri-” to indicate the number of identical ligands.

The metal follows the ligands, with its oxidation state in parentheses in Roman numerals.

For anionic complexes, the metal name ends in ”-ate” (e.g., nickel becomes ”nickelate”).

For neutral ligands, use their common names (e.g., ammonia for NH_3, water for H_2O).

---

26. (A) Explain the following reactions and write chemical equations involved:

(a) Wolff-Kishner reduction

(b) Etard reaction

(c) Cannizzaro reaction

Solution:

(a) Wolff-Kishner Reduction The Wolff-Kishner reduction is a method of reducing a carbonyl group (C=O) to a methylene group (CH_2) using hydrazine (H_2NNH_2) in the presence of a strong base like potassium hydroxide (KOH) and heating the mixture. This reduction removes the oxygen atom from the carbonyl group, yielding a hydrocarbon.

Reaction:

$$\text{R-CO-R'} + H_2NNH_2 \xrightarrow{\text{KOH, heat}} \text{R-CH}_2\text{R'}$$

In this reaction, aldehydes or ketones are reduced to alkanes.

(b) Etard Reaction The Etard reaction is the oxidation of toluene (methylbenzene) to benzaldehyde using chromium-based reagents such as chromium trioxide (CrO_3) or pyridinium chlorochromate (PCC). This reaction adds an aldehyde group to the methyl group of toluene.

Reaction:

$$C_6H_5CH_3 + CrO_3 \rightarrow C_6H_5CHO$$

In this reaction, toluene is oxidized to benzaldehyde.

(c) Cannizzaro Reaction The Cannizzaro reaction is a redox disproportionation reaction that occurs with aldehydes that do not have an alpha hydrogen. In the presence of a strong base, one molecule of the aldehyde is reduced to an alcohol, and the other is oxidized to a carboxylate anion.

Reaction:

$$\text{2R-CHO} \xrightarrow{\text{strong base}} \text{R-CH}_2\text{OH} + \text{R-COO}^-$$

In this reaction, two molecules of aldehyde react, with one being reduced to alcohol and the other oxidized to a carboxylate.

Quick Tip

In the Wolff-Kishner reduction, remember that hydrazine and strong base under heat are used to reduce carbonyl compounds, whereas in the Cannizzaro reaction, aldehydes without alpha hydrogens undergo disproportionation.

OR

26. (B) Write the structures of A, B, and C in the following sequence of reactions:

(a) $$CH_3COOH \xrightarrow{SOCl_2} A \xrightarrow{H_2,\ Pd\text{-}BaSO_4} B \xrightarrow{H_2N\text{-}NH_2} C$$

(b) $$CH_3CN \xrightarrow[2.\ H_2O]{1.(DIBAL\text{-}H)} A \xrightarrow{\text{Dil. NaOH}} B \xrightarrow{\Delta} C$$

Solution:

(a) Reaction Sequence: 1. $CH_3COOH \xrightarrow{SOCl_2} CH_3COCl$: Acetic acid ($CH_3COOH$) reacts with thionyl chloride ($SOCl_2$) to form acetyl chloride (CH_3COCl), which is an acyl chloride.

2. $CH_3COCl \xrightarrow{H_2,\text{Pd-BaSO}_4} CH_3CH_2NH_2$: The acetyl chloride undergoes a reduction reaction using hydrogen (H_2) in the presence of a palladium catalyst on barium sulfate (Pd-$BaSO_4$) to form ethylamine ($CH_3CH_2NH_2$).

3. $CH_3CH_2NH_2 \xrightarrow{H_2\text{N-NH}_2} C$: The ethylamine ($CH_3CH_2NH_2$) reacts with hydrazine ($H_2N\text{-}NH_2$) to form a product C, which is likely a hydrazone or another nitrogen-containing

compound.

(b) Reaction Sequence: 1. $CH_3CN \xrightarrow{\text{1.DIBAL-H,2.}H}_2$ O A: Methyl cyanide (CH_3CN) reacts with DIBAL-H (diisobutylaluminum hydride) to reduce the nitrile group (CN) to an aldehyde (CH_3CHO), which is compound A.
2. A $\xrightarrow{\text{NaOH, heat}}$ B: The aldehyde A undergoes an aldol condensation in the presence of sodium hydroxide (NaOH) and heat, forming a product B, which is likely a -hydroxy aldehyde or ketone.
3. B $\xrightarrow{C}$ C: The compound B undergoes further reactions, likely a dehydration or other transformation to form the final product C.

Quick Tip

In this reaction sequence, DIBAL-H is used to reduce nitriles to aldehydes, and aldol condensation with NaOH under heat leads to the formation of -hydroxy aldehydes or ketones, which can undergo further transformations to form the final product.

27. (a) Define the following:
(i) Enantiomers
(ii) Racemic mixture
Solution:
(i) Enantiomers: Enantiomers are pairs of molecules that are non-superimposable mirror images of each other. They have identical physical properties but differ in their interaction with plane-polarized light and in the way they interact with other chiral substances. For example, the right- and left-handed forms of a chiral molecule are enantiomers.
(ii) Racemic mixture: A racemic mixture is a mixture containing equal amounts of two enantiomers of a chiral compound. In a racemic mixture, the optical activities of the enantiomers cancel each other out, resulting in no net optical rotation.

Quick Tip

Enantiomers can be separated by chiral chromatography, and racemic mixtures can be resolved into their constituent enantiomers using techniques like recrystallization or enzymatic methods.

---

27. (b) Why is chlorobenzene resistant to nucleophilic substitution reactions?

Solution: Chlorobenzene is resistant to nucleophilic substitution due to the electron-withdrawing effect of the chlorine atom, which decreases the electron density on the benzene ring. This makes the carbon attached to the chlorine less electrophilic, which reduces its ability to undergo nucleophilic attack. Additionally, the resonance stabilization of the chlorine atom with the aromatic ring further makes the carbon-chlorine bond stronger, thus making nucleophilic substitution less favorable.

Quick Tip

The electron-withdrawing effect of the chlorine atom and the resonance stabilization in chlorobenzene make it resistant to nucleophilic substitution reactions, unlike alkyl halides where such substitution is easier.

---

28. (a) Write the product obtained when D-glucose reacts with $H_2N - OH$.

Solution: When D-glucose reacts with hydroxylamine ($H_2N - OH$), it forms an oxime. The aldehyde group of D-glucose reacts with hydroxylamine to form a stable oxime, with the general formula $R - C = N - OH$, where R is the remainder of the glucose molecule. In this reaction, the glucose aldehyde undergoes nucleophilic addition to form the corresponding oxime.

Quick Tip

Hydroxylamine reacts with aldehydes and ketones to form oximes, which are useful intermediates in organic synthesis.

---

28. (b) Amino acids show amphoteric behaviour, why?

Solution: Amino acids show amphoteric behavior because they have both acidic and basic functional groups. The amino group ($-NH_2$) can act as a base and accept protons, while the carboxyl group ($-COOH$) can donate protons, acting as an acid. This dual capability allows amino acids to react both as acids and bases, depending on the pH of the solution, demonstrating amphoteric behavior.

Quick Tip

Amino acids can exist in different ionic forms (zwitterions) depending on the pH, where the amino group is protonated (NH_3^+) and the carboxyl group is deprotonated (COO^-).

---

28. (c) Why can't vitamin C be stored in our body?

Solution: Vitamin C (ascorbic acid) cannot be stored in the body because it is water-soluble, and the body lacks the necessary mechanisms to store water-soluble vitamins. Instead, vitamin C is excreted in the urine when consumed in excess. Therefore, it is essential to consume vitamin C regularly through diet to maintain adequate levels, as the body cannot store it for long periods.

Quick Tip

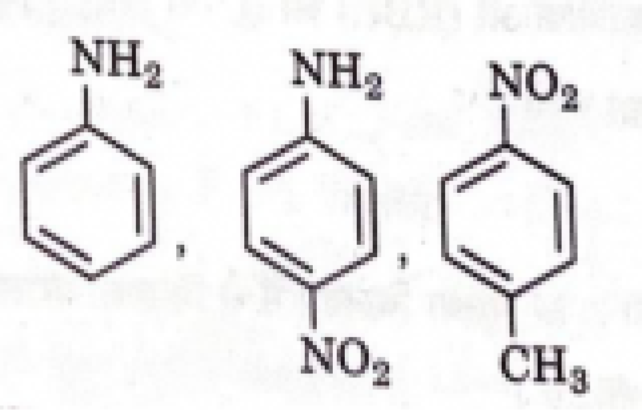
Vitamin C must be consumed regularly since it is not stored in the body. Good dietary sources include citrus fruits, tomatoes, and green leafy vegetables.

SECTION -D

29. Amines have a lone pair of electrons on nitrogen atom due to which they behave as Lewis base. Greater the value of K_b or smaller the value of pK_b, stronger is the base. Amines are more basic than alcohols, ethers, esters, etc. The basic character of aliphatic amines should increase with the increase of alkyl substitution. But it does not occur in a regular manner as a secondary aliphatic amine is unexpectedly more basic than a tertiary amine in aqueous solutions. Aromatic amines are weaker bases than

ammonia and aliphatic amines. Electron releasing groups such as $–CH_3$, $–NH_2$, etc., increase the basicity while electron-withdrawing substituents such as $–NO_2$, –CN, halogens, etc., decrease the basicity of amines. The effect of these substituents is more at the p than at m position.

(a) Arrange the following in the increasing order of their basic character. Give reason:



Solution:

Step 1: Understanding the Factors Affecting Basicity The basicity of amines is primarily determined by the electron density on the nitrogen atom. The more electron-donating the substituents, the more basic the amine will be, as they increase the availability of the lone pair on nitrogen for protonation. Conversely, electron-withdrawing groups decrease the electron density on nitrogen and thus reduce its basicity.

Electron-donating groups (such as $–NH_2$ and $–CH_3$) increase the basicity because they increase the electron density on nitrogen.

Electron-withdrawing groups (such as $–NO_2$ and –CN) decrease the basicity because they pull electron density away from nitrogen, making the lone pair less available to accept a proton.

Step 2: Analyzing the Substituents Let's break down the substituents attached to the nitrogen atoms in the given compounds:

$–NH_2$ is an amine group, which is an electron-donating group. Thus, it will increase the electron density on nitrogen, making the amine more basic.

$–NO_2$ is a strong electron-withdrawing group. It pulls electron density away from the nitrogen, thus decreasing the availability of the nitrogen's lone pair and reducing the basicity.

$–CH_3$ is an electron-donating group, but not as strongly as $–NH_2$. Therefore, it increases basicity, though to a lesser extent compared to $-NH_2$.

Step 3: Arranging in Order Now, let's arrange the compounds in the order of increasing basicity, considering the strength of electron-donating or electron-withdrawing effects:
$-NO_2$ (electron-withdrawing) will have the lowest basicity.
$-NO_2$ (with $-NO_2$ at the para position) is less basic than NH due to the electron-withdrawing nature of $-NO_2$.
$-NH_2$ will be more basic than both $-NO_2$ and $-CH_3$, as it is a strong electron-donating group. $-CH_3$ is a mild electron-donating group, so it will be more basic than $-NO_2$ but less basic than $-NH_2$.
Thus, the increasing order of basicity is:

$$\mathrm{NO_2} < \mathrm{NO_2} < \mathrm{NH_2} < \mathrm{NH_2} < \mathrm{CH_3}$$

Quick Tip

The basicity of amines is determined by the electron-donating or electron-withdrawing effect of the substituents attached to the nitrogen. Electron-donating groups increase basicity, while electron-withdrawing groups decrease it.

---

29. (b) Why pK of aniline is more than that of methylamine?

Solution:

Step 1: Understanding the Concept of Basicity Basicity of amines is defined as the tendency of the nitrogen atom to donate its lone pair of electrons to a proton. The basicity is higher when the lone pair of electrons on nitrogen is more available for protonation.
In aniline (CHNH), the lone pair of electrons on the nitrogen atom can interact with the benzene ring via resonance, making the nitrogen's lone pair less available for protonation. This reduces the electron density on nitrogen, making aniline a weaker base than methylamine (CHNH), where the methyl group is an electron-donating group, increasing the electron density on nitrogen and making its lone pair more available for protonation.

Step 2: Resonance Effect in Aniline In aniline, the nitrogen's lone pair of electrons can be delocalized into the aromatic ring, creating a resonance structure where the nitrogen's lone pair is not as available for protonation. This is called the resonance effect, and it reduces the basicity of aniline compared to methylamine.

Step 3: Methylamine and the Inductive Effect Methylamine, on the other hand, has a methyl group (–CH) attached to nitrogen. The methyl group is an electron-donating group via the inductive effect, which pushes electron density towards the nitrogen, making the nitrogen's lone pair more available to accept a proton, thereby increasing its basicity.
Thus, the basicity of methylamine is greater than that of aniline, and consequently, the pK of aniline is more than that of methylamine.

Quick Tip

The basicity of aromatic amines like aniline is reduced due to resonance with the aromatic ring, while aliphatic amines like methylamine are more basic due to the electron-donating inductive effect of the alkyl group.

---

29. (c) (i) Arrange the following in the increasing order of their basic character in an aqueous solution:

$(CH_3)_3N$, $(CH_3)_2NH$, NH_3, CH_3NH_2

Solution:

Step 1: Understanding the Effect of Alkyl Groups on Basicity The basicity of amines in aqueous solutions increases with the number of alkyl groups attached to the nitrogen atom. Alkyl groups are electron-donating groups, and they increase the electron density on nitrogen, making the lone pair more available to accept a proton.
Trimethylamine $(CH_3)_3N$ has three methyl groups attached to nitrogen, making it highly electron-donating and thus the most basic.
Dimethylamine $(CH_3)_2$NH has two methyl groups, so it is also basic, but not as basic as trimethylamine.
Methylamine (CH_3NH_2) has one methyl group, which donates less electron density than two or three groups.
Ammonia (NH_3) has no alkyl groups, so it is the least basic.

Step 2: Arranging in Order of Basicity The increasing order of basicity is:

$$(NH_3) < (CH_3NH_2) < (CH_3)_2NH < (CH_3)_3N$$

Quick Tip

The basicity of amines increases as the number of electron-donating alkyl groups attached to nitrogen increases. Alkyl groups push electron density towards the nitrogen, enhancing the availability of its lone pair for protonation.

OR

29. (c) (ii) Why ammonolysis of alkyl halides is not a good method to prepare pure amines?

Solution:

Step 1: The Ammonolysis Process Ammonolysis of alkyl halides involves reacting an alkyl halide with ammonia (NH), where the nucleophilic nitrogen from ammonia attacks the electrophilic carbon in the alkyl halide, displacing the halide ion and forming a primary amine.

However, this reaction suffers from a major drawback: the product amine can further react with excess alkyl halide, leading to the formation of secondary and tertiary amines.

Step 2: Multiple Reactions The alkyl groups attached to the nitrogen of the amines formed during ammonolysis can make the reaction progress further to form secondary and tertiary amines. This leads to a mixture of amines, rather than a pure primary amine. For example, if methylamine (CHNH) is formed in the first step, it can then react with another molecule of alkyl halide to form dimethylamine (CHNHCH), and further to trimethylamine (CHN(CH)).

Step 3: Alternative Methods To obtain pure primary amines, other methods, such as reductive amination or Gabriel synthesis, are preferred as they avoid the formation of secondary and tertiary amines.

Quick Tip

Ammonolysis of alkyl halides often leads to a mixture of primary, secondary, and tertiary amines. To avoid this, alternative synthetic methods, like Gabriel synthesis, can be used to obtain pure primary amines.

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30. The spontaneous flow of the solvent through a semipermeable membrane from a pure solvent to a solution or from a dilute solution to a concentrated solution is called osmosis. The phenomenon of osmosis can be demonstrated by taking two eggs of the same size. In an egg, the membrane below the shell and around the egg material is semipermeable. The outer hard shell can be removed by putting the egg in dilute hydrochloric acid. After removing the hard shell, one egg is placed in distilled water and the other in a saturated salt solution. After some time, the egg placed in distilled water swells up while the egg placed in salt solution shrinks. The external pressure applied to stop the osmosis is termed as osmotic pressure (a colligative property). Reverse osmosis takes place when the applied external pressure becomes larger than the osmotic pressure.

(a) Define reverse osmosis. Name one SPM which can be used in the process of reverse osmosis.

Solution: Reverse osmosis is a process in which solvent moves from a solution with higher concentration to a solution with lower concentration through a semipermeable membrane, but this process occurs when external pressure is applied that exceeds the osmotic pressure. This reverses the natural osmotic flow.

An example of a semi-permeable membrane (SPM) used in reverse osmosis is cellulose acetate.

Quick Tip

Reverse osmosis is the process of forcing solvent through a semipermeable membrane from a concentrated solution to a diluted one, by applying pressure greater than the osmotic pressure. It's widely used in water purification.

---

30. (b) (i) What do you expect to happen when red blood corpuscles (RBC's) are placed in 0.5% NaCl solution?

Solution: When red blood cells (RBCs) are placed in a 0.5% NaCl solution, which is hypotonic relative to the intracellular fluid, water will move into the RBCs due to osmosis. This causes the cells to swell as water enters. If too much water enters, the RBCs may burst, a process known as hemolysis.

Quick Tip

Hypotonic solutions cause water to flow into RBCs by osmosis, leading to swelling and potential bursting (hemolysis).

OR

30. (b) (ii) Which one of the following will have higher osmotic pressure in 1 M KCl or 1 M urea solution? Justify your answer.

Solution: Osmotic pressure is directly proportional to the number of solute particles in solution. Since KCl dissociates into two ions (K^+ and Cl^-) in solution, a 1 M KCl solution will have a higher osmotic pressure than a 1 M urea solution, which does not dissociate into ions. Therefore, the 1 M KCl solution will have a higher osmotic pressure.

Quick Tip

Osmotic pressure depends on the number of particles in solution. Ionic compounds like KCl dissociate into more particles, increasing osmotic pressure compared to non-ionic compounds like urea.

---

30. (c) Why osmotic pressure is a colligative property?

Solution: Osmotic pressure is a colligative property because it depends only on the number of solute particles in a solution, not on their nature or identity. The greater the number of solute particles, the higher the osmotic pressure, regardless of whether the solute is ionic or non-ionic.

Quick Tip

Osmotic pressure is a colligative property because it depends on the concentration of solute particles in a solution, not their chemical nature.

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31. (A) An organic compound A, molecular formula C_2H_6O, oxidises with Cr_2O_7 to form a compound B. Compound B on warming with iodine and aqueous solution of NaOH gives a yellow precipitate of compound C. When compound A is heated with conc. H_2SO_4 at 413 K, it gives a compound D, which on reaction with excess HI gives compound E. Identify compounds A, B, C, D, and E and write chemical equations involved.

Solution:

Compound A has the molecular formula C_2H_6O, which suggests it is ethanol.

When ethanol is oxidized by Cr_2O_7, it forms acetic acid, CH_3COOH, which is compound B.

When acetic acid reacts with iodine and NaOH, it forms a yellow precipitate of iodoform (CHI_3), which is compound C.

When ethanol is heated with conc. H_2SO_4 at 413 K, it undergoes dehydration to form ethene (C_2H_4), which is compound D.

When ethene reacts with excess HI, it forms iodoethane (C_2H_5I), which is compound E.

The chemical equations involved are as follows:

1. $C_2H_5OH + Cr_2O_7^{2-} \rightarrow CH_3COOH$
2. $CH_3COOH + I_2 + NaOH \rightarrow CHI_3$ (yellow precipitate)
3. $C_2H_5OH \xrightarrow{H_2SO_4, 413K} C_2H_4 + H_2O$
4. $C_2H_4 + I_2 \rightarrow C_2H_5I$

Quick Tip

The iodoform test (formation of yellow precipitate) is used to detect compounds with a structure CH_3CO or CH_3CH, such as aldehydes and alcohols.

OR

31. (B) (a) Write chemical equations of the following reactions: (i) Phenol is treated with conc. HNO_3.

(ii) Propene is treated with B_2H_6 followed by oxidation by H_2O_2/OH^-.

(iii) Sodium t-butoxide is treated with CH_3Cl.

Solution:

1. Phenol treated with conc. HNO_3: Phenol reacts with concentrated nitric acid (HNO_3) to form a mixture of nitrophenols. The reaction is as follows:

$$C_6H_5OH + HNO_3 \rightarrow 2,4,6-\text{Nitrophenol} + H_2O$$

2. Propene treated with B_2H_6 followed by oxidation by H_2O_2/OH^-: The hydroboration-oxidation reaction of propene results in the formation of an alcohol:

$$C_3H_6 + B_2H_6 \rightarrow C_3H_7B \quad \text{(Hydroboration)}$$

Followed by oxidation:

$$C_3H_7B + H_2O_2/OH^- \rightarrow C_3H_7OH \quad \text{(Propan-2-ol)}$$

3. Sodium t-butoxide treated with CH_3Cl: Sodium t-butoxide undergoes nucleophilic substitution with methyl chloride to form t-butyl methyl ether:

$$(CH_3)_3CO^- + CH_3Cl \rightarrow (CH_3)_3COCH_3$$

Quick Tip

The hydroboration-oxidation of alkenes adds water in a syn fashion, which is different from the anti-addition in acid-catalyzed hydration.

---

31. (B) (b) Give a simple chemical test to distinguish between butan-1-ol and butan-2-ol.

Solution: A simple chemical test to distinguish between butan-1-ol and butan-2-ol is the oxidation test using potassium dichromate ($K_2Cr_2O_7$) in acidic medium. Butan-1-ol will oxidize to butanoic acid, while butan-2-ol will oxidize to acetone.

Butan-1-ol: On oxidation, it gives a carboxylic acid, butanoic acid.

Butan-2-ol: On oxidation, it gives a ketone, acetone.

Another test is the reaction with iodine and NaOH:

Butan-1-ol gives a yellow precipitate of iodoform when treated with iodine and NaOH.

Butan-2-ol also gives a yellow precipitate of iodoform, but this reaction can differentiate based on the intensity of the reaction.

Quick Tip

The oxidation test and iodoform test can help distinguish between primary and secondary alcohols. Primary alcohols are oxidized to carboxylic acids, while secondary alcohols form ketones.

---

31. (c) Arrange the following in increasing order of acid strength: phenol, ethanol, water.

Solution: To arrange these compounds in increasing order of acid strength, we consider the ability of these compounds to donate a proton. The stronger the ability to donate a proton (H^+), the stronger the acid.

1. Ethanol (CH_3CH_2OH): Ethanol has a hydroxyl group (-OH) but it is a very weak acid compared to water or phenol. 2. Water (H_2O): Water is neutral but can act as a weak acid, donating a proton to form OH^-. 3. Phenol (C_6H_5OH): Phenol is a stronger acid than both ethanol and water due to the resonance stabilization of the phenoxide ion ($C_6H_5O^-$) after proton donation.

Thus, the increasing order of acid strength is:

$$\text{Ethanol} < \text{Water} < \text{Phenol}$$

Quick Tip

The acidity of alcohols and phenols increases with the ability to stabilize the conjugate base. Phenols are more acidic due to the resonance stabilization of the phenoxide ion.

---

32. (A) (a) Give IUPAC name of $CH_3 = CH - CH = CH - CHO$.

Solution: The IUPAC name of the compound $CH_3 = CH - CH = CH - CHO$ is pent-2,4-enal.

The compound consists of a 5-carbon chain with two double bonds at positions 2 and 4.

The aldehyde group ($-CHO$) is located at the end of the chain, and the suffix "-al" is used to indicate the aldehyde functional group.

Thus, the IUPAC name is pent-2,4-enal.

Quick Tip

When naming compounds with multiple functional groups, the highest-priority functional group is given the lowest possible number, and double bonds are numbered to ensure the lowest positions.

---

32. (b) Give a simple chemical test to distinguish between propanal and propanone.

Solution: A simple chemical test to distinguish between propanal (an aldehyde) and propanone (a ketone) is the Tollens' test.

Propanal (Aldehyde): On treatment with Tollens' reagent (ammoniacal silver nitrate), aldehydes reduce the silver ions to metallic silver, forming a silver mirror on the inner surface of the test tube.

Propanone (Ketone): Ketones do not react with Tollens' reagent and hence do not produce the silver mirror.

Thus, the Tollens' test can distinguish between an aldehyde and a ketone.

Quick Tip

The Tollens' test is a classic test to identify aldehydes. Aldehydes reduce silver ions to form a silver mirror, while ketones do not react.

---

32. (c) How will you convert the following:

(i) Toluene to benzoic acid.

(ii) Ethanol to propan-2-ol.

(iii) Propanal to 2-hydroxy propanoic acid.

Solution:

1. Toluene to benzoic acid: Toluene can be oxidized to benzoic acid by treating it with potassium permanganate ($KMnO_4$).

$$C_6H_5CH_3 + KMnO_4 \to C_6H_5COOH$$

This is a typical oxidation reaction where the methyl group ($-CH_3$) is oxidized to a carboxyl group (-COOH).

2. Ethanol to propan-2-ol: Ethanol can be converted to propan-2-ol by using a suitable catalyst for a reduction reaction. For example, it can be oxidized to acetaldehyde (CH_3CHO), which is then reduced to propan-2-ol using a reducing agent like lithium aluminum hydride ($LiAlH_4$).

$$C_2H_5OH \xrightarrow{[O]} C_2H_4O \xrightarrow{LiAlH_4} C_3H_7OH$$

Alternatively, it can be directly hydrated from propene.

3. Propanal to 2-hydroxy propanoic acid: Propanal can be converted to 2-hydroxy propanoic acid by the hydroxylation reaction, specifically by adding a hydroxyl group to the alpha-carbon of the aldehyde. A suitable reagent for this transformation is hydroxylamine or a mild oxidizing agent.

$$C_3H_7CHO + OH^- \to C_3H_6(OH)COOH$$

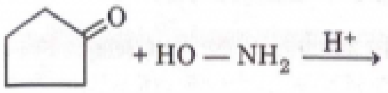
Quick Tip

The oxidation of toluene with potassium permanganate is a strong method to obtain benzoic acid. Hydration of propene and reduction of aldehydes are common transformations in organic synthesis.

OR

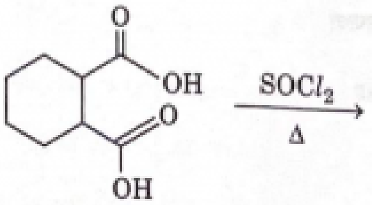
32. (B) Complete each synthesis by giving missing starting material, reagent, or products:

(a)

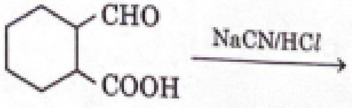


(b)

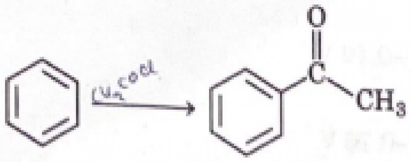
(c)



(d)



(e)



Solution:

(a)

$$O + HO - NH2 \xrightarrow{H+} NH2OH$$

The reaction involves the formation of hydroxylamine ($NH2OH$) from an aldehyde (O) and hydroxylamine ($HO - NH2$) in the presence of an acid catalyst ($H+$).

(b)

$$CH2 = CH2 \xrightarrow{\text{(i) } O_3 \text{ (ii) } Zn{-}H_2O} 2HCHO \xrightarrow{\Delta} \text{No further change}$$

The reaction involves ozonolysis of ethene ($CH2 = CH2$) followed by reductive workup to form formaldehyde ($HCHO$). Heating (Δ) does not change the product further.

(c)

$$OH \xrightarrow{SOCl2} Cl$$

The reaction involves the conversion of an alcohol (OH) to an alkyl chloride (Cl) using thionyl chloride ($SOCl2$) under heating (Δ).

(d)

$$CHO \xrightarrow{NaCN/HCl} COOH$$

The reaction involves the conversion of an aldehyde (CHO) to a carboxylic acid ($COOH$) using sodium cyanide ($NaCN$) and hydrochloric acid (HCl).

(e)

$$Cl2C6H5 \xrightarrow{CH3} Cl2C6H4CH3$$

The reaction involves the methylation of chlorobenzene ($Cl2C6H5$) to form a methylated chlorobenzene derivative ($Cl2C6H4CH3$).

Quick Tip

Quick Tips for Organic Synthesis:

- **(a)** Aldehydes react with hydroxylamine ($HO - NH2$) in the presence of an acid to form oximes, which are useful intermediates in organic synthesis.
- **(b)** Ozonolysis cleaves double bonds in alkenes, producing carbonyl compounds (aldehydes or ketones) depending on the structure of the starting alkene.
- **(c)** Thionyl chloride ($SOCl2$) is a common reagent for converting alcohols to alkyl chlorides, with gaseous byproducts ($SO2$ and HCl) that are easy to remove.
- **(d)** Aldehydes can be converted to carboxylic acids using sodium cyanide ($NaCN$) and hydrochloric acid (HCl) via cyanohydrin formation and hydrolysis.
- **(e)** Electrophilic aromatic substitution reactions, such as methylation, introduce substituents like $CH3$ onto the benzene ring, commonly seen in aromatic compounds.

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33. (A) (a) Calculate the standard Gibbs energy (ΔG°) of the following reaction at 25°C:

$$\text{Au}(s) + \text{Ca}^{2+}(1M) \rightarrow \text{Au}^{3+}(1M) + \text{Ca}(s)$$

$$E^\circ_{\text{Au}^{3+}/\text{Au}} = +1.5\,\text{V}, \quad E^\circ_{\text{Ca}^{2+}/\text{Ca}} = -2.87\,\text{V}$$

Predict whether the reaction will be spontaneous or not at 25°C. [1 F = 96500 C mol^{-1}]

Solution: The standard Gibbs free energy change (ΔG°) is related to the standard electrode potential change (ΔE°) by the formula:

$$\Delta G^\circ = -nF\Delta E^\circ$$

Where: - n is the number of moles of electrons transferred in the reaction (which is 3 for this reaction). - F is the Faraday constant ($96500\,\text{C mol}^{-1}$). - ΔE° is the cell potential, which is calculated as:

$$\Delta E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = 1.5 - (-2.87) = 4.37\,\text{V}.$$

Now, calculating ΔG°:

$$\Delta G^\circ = -3 \times 96500 \times 4.37 = -1.26 \times 10^6\,\text{J/mol}.$$

Since ΔG° is negative, the reaction is **spontaneous**.

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A negative value for ΔG° indicates that the reaction is spontaneous. The magnitude of ΔG° is related to the cell potential, which can be calculated using the Nernst equation.

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33. (b) Tarnished silver contains Ag_2S. Can this tarnish be removed by placing tarnished silverware in an aluminium pan containing an inert electrolytic solution such as NaCl? The standard electrode potential for the half reaction:

$$\mathbf{Ag_2S}(s) + 2e^- \rightarrow 2\mathbf{Ag}(s) + S^{2-}(aq)\ (\mathbf{E}^\circ = -0.71\,\mathbf{V})$$

$$\mathbf{Al}^{3+}(aq) + 3e^- \rightarrow \mathbf{Al}(s)\ (\mathbf{E}^\circ = -1.66\,\mathbf{V})$$

Solution: The reaction involves the reduction of Ag_2S to silver, and the oxidation of aluminium to aluminium ion. The cell potential for this reaction is the difference between the reduction potential of silver and aluminium:

$$\Delta E^\circ = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = (-0.71) - (-1.66) = 0.95\,\text{V}.$$

Since the cell potential is positive, the reaction is spontaneous, meaning that tarnish can be removed by using an aluminium pan containing NaCl.

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In electrochemical reactions, the substance with the more positive reduction potential (cathode) will be reduced, and the one with the more negative reduction potential (anode) will be oxidized.

OR

33. (B) (a) (i) Define the following:

(i) Cell potential

Solution: Cell potential is the difference in the electric potential between two electrodes in an electrochemical cell. It is a measure of the ability of a redox reaction to occur spontaneously. The cell potential is typically measured in volts (V) and is denoted by E_{cell}. The higher the cell potential, the greater the driving force for the reaction.

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The cell potential is calculated as the difference between the reduction potentials of the cathode and anode, and it indicates the direction of electron flow in an electrochemical cell.

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33. (a) (ii) Fuel cell

Solution: A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (such as hydrogen or methanol) into electrical energy through a redox reaction. The reactants are continuously supplied to the cell, and the products are continuously removed. The most common example is the hydrogen fuel cell, where hydrogen reacts with oxygen to produce water and electricity.

Quick Tip

Fuel cells are environmentally friendly because their only byproduct is usually water, making them an important alternative to traditional power sources.

33. (b) Calculate emf of the following cell at 25°C:

$$\text{Zn}(s)\,|\,\text{Zn}^{2+}(0.1M)\,||\,\text{Cd}^{2+}(0.01M)\,|\,\text{Cd}(s)$$

Given:

$$E^\circ_{\text{Zn}^{2+}/\text{Zn}} = -0.40\,\text{V}, \quad E^\circ_{\text{Cd}^{2+}/\text{Cd}} = -0.76\,\text{V}.$$

Solution: The emf of the cell is given by the Nernst equation:

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{0.0592}{n}\log\left(\frac{[\text{products}]}{[\text{reactants}]}\right)$$

Where: - $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$. - $n = 2$ (the number of electrons transferred).

The standard cell potential is:

$$E^\circ_{\text{cell}} = (-0.76) - (-0.40) = -0.36\,\text{V}.$$

Now, substitute into the Nernst equation:

$$E_{\text{cell}} = -0.36 - \frac{0.0592}{2}\log\left(\frac{0.01}{0.1}\right)$$

$$E_{\text{cell}} = -0.36 - \frac{0.0592}{2}\log(0.1)$$

$$E_{\text{cell}} = -0.36 - \frac{0.0592}{2}\times(-1) = -0.36 + 0.0296 = -0.33\,\text{V}.$$

Thus, the emf of the cell at 25°C is $-0.33\,\text{V}$.

Quick Tip

The Nernst equation is used to calculate the emf of an electrochemical cell under non-standard conditions by considering the concentrations of the ions involved.