UP Board Class 12 Chemistry - 347 (JZ) - 2025 Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**100	**Total questions :**9

General Instructions

1. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. Section A is of multiple choice type and each question carries 1 mark.
4. Section B is of very short answer type and each question carries 1 mark.
5. Section C is of short answer type-I and carries 2 marks each.
6. Section D is of short answer type-II and carries 3 marks each.
7. Section E is of long answer type. Each question carries 5 marks. In all four questions of this section with internal choices have been given. You have to do only one question from the choices given in the question.
8. The symbols used in the question paper have usual meaning.

Section - A

Q.1 (a) Give an example of such solid solution in which solute is gas.

(A) Oxygen dissolved in water.

(B) Solution of camphor in nitrogen.

(C) Solution of hydrogen in palladium.

(D) Glucose dissolved in water.

Correct Answer: (C) Solution of hydrogen in palladium.

Solution:

Step 1: Deconstructing the Question

The question asks for an example of a ”solid solution” where the ”solute” is a ”gas”. Let’s break down these terms:

- **Solvent:** The substance present in the larger amount, which determines the final phase (state) of the solution. For a ”solid solution,” the solvent must be a solid.
- **Solute:** The substance present in the smaller amount, which is dissolved in the solvent. The question specifies that the solute must be a gas.

Therefore, we are looking for an example where a gas is dissolved in a solid.

Step 2: Evaluating the Options Against the Criteria

Let’s analyze each option to see if it fits the ”gas in solid” model.

- **(A) Oxygen dissolved in water:** This is a **gas (solute)** dissolved in a **liquid (solvent)**. The result is a liquid solution. This does not fit the criteria.
- **(B) Solution of camphor in nitrogen:** This describes camphor (a solid that sublimes) as a vapor (solute) mixed with nitrogen **(gas, solvent)**. The result is a gaseous solution. This does not fit the criteria.
- **(C) Solution of hydrogen in palladium:** This describes hydrogen **(gas, solute)** being absorbed into the crystal structure of palladium **(solid, solvent)**. The resulting material is a solid solution (an interstitial alloy). This perfectly matches the criteria.
- **(D) Glucose dissolved in water:** This is a **solid (solute)** dissolved in a **liquid (solvent)**. The result is a liquid solution. This does not fit the criteria.

Step 3: Final Conclusion

Based on the analysis, the only option that represents a gas dissolved in a solid to form a solid solution is the solution of hydrogen in palladium.

Thus, the correct answer is option (C).

> Quick Tip
>
> Solid solutions in which gases are dissolved typically involve metals like palladium, which can absorb gases like hydrogen.

(b) Magnetic moment of a bivalent ion in aqueous solution will be, if its atomic number is 25:

(A) 1.73 BM

(B) 2.83 BM

(C) 4.96 BM

(D) 5.92 BM

Correct Answer: (D) 5.92 BM

Solution:

Step 1: Determine the Electronic Configuration of the Ion

First, identify the neutral element. An atomic number (Z) of 25 corresponds to Manganese (Mn).

The ground-state electronic configuration of a neutral Manganese atom is:

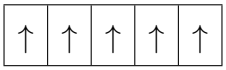
$$\text{Mn} : 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5 \quad \text{or} \quad [\text{Ar}] 4s^2 3d^5$$

A "bivalent ion" has a charge of +2. To form the Mn^{2+} ion, the atom loses two electrons. Electrons are always removed from the outermost shell first, which is the $n = 4$ shell in this case.

$$\text{Mn}^{2+} : [\text{Ar}] 3d^5$$

Step 2: Count the Number of Unpaired Electrons (n)

Next, we examine the $3d$ subshell of the Mn^{2+} ion. The d subshell has 5 orbitals. According to Hund's rule of maximum multiplicity, electrons will occupy separate orbitals with parallel spins before they start pairing up. For a $3d^5$ configuration, the orbital diagram is:



Each of the five d orbitals contains one electron, and all of them are unpaired. Therefore, the number of unpaired electrons is $n = 5$.

Step 3: Calculate the Magnetic Moment (μ)

The "spin-only" magnetic moment is calculated using the formula:

$$\mu = \sqrt{n(n+2)}\,\text{Bohr Magnetons (BM)}$$

Substitute the value $n = 5$ into the formula:

$$\mu = \sqrt{5(5+2)}$$

$$\mu = \sqrt{5 \times 7}$$

$$\mu = \sqrt{35}$$

Calculating the square root:

$$\mu \approx 5.916\,\text{BM}$$

Step 4: Conclusion

The calculated magnetic moment is approximately 5.92 BM. This matches option (D).

> Quick Tip
>
> The magnetic moment is calculated using $\mu = \sqrt{n(n+2)}$, where n is the number of unpaired electrons. For Mn^{2+}, $n = 5$, leading to a magnetic moment of 2.83 BM.

(c) How many ions will be generated from the solution of the complex $[Co(NH_3)_6]Cl_2$?

(A) 6

(B) 4

(C) 3

(D) 2

Correct Answer: (C) 3

Solution:

Step 1: Identify the Components of the Coordination Compound

A coordination compound consists of two main parts:

- **The Coordination Sphere:** This is the central metal ion and its attached ligands, written inside square brackets. In this case, it is $[Co(NH_3)_6]$.
- **The Counter-ions:** These are the ions located outside the square brackets, which balance the charge of the coordination sphere. In this case, they are the two chloride atoms, Cl_2.

Step 2: Understand the Bonding and Dissociation

The bond between the coordination sphere and the counter-ions is ionic. When the compound is dissolved in a polar solvent like water, this ionic bond breaks, and the compound dissociates. The ligands (NH_3) are attached to the central metal (Co) by coordinate covalent bonds, which are strong and do not break upon dissolution.

Step 3: Write the Dissociation Equation

The entire coordination sphere acts as a single, indivisible polyatomic ion. The counter-ions separate individually. Since there are two chloride ions (Cl^-), each with a -1 charge, the coordination sphere must have a charge of +2 to maintain electrical neutrality. The dissociation is as follows:

$$[Co(NH_3)_6]Cl_2 \xrightarrow{\text{water}} [Co(NH_3)_6]^{2+}(aq) + 2Cl^-(aq)$$

Step 4: Count the Total Number of Ions

By examining the products of the dissociation, we can count the number of distinct ions produced from one formula unit of the complex:

- One complex cation: $[Co(NH_3)_6]^{2+}$
- Two simple anions: $2 \times Cl^-$

Total number of ions = $1 + 2 = 3$ ions.

Therefore, the correct answer is option (C).

> Quick Tip
>
> When a coordination compound dissociates in water, the number of ions formed is equal to the sum of the charge on the complex and the number of counter ions.

(d) Reagent, which do not react with acetone and benzaldehyde:

(A) Sodium hydrogen sulphite

(B) Phenyl hydrazine

(C) Fehling's solution

(D) Grignard reagent

Correct Answer: (C) Fehling's solution

Solution:

Step 1: Analyze the Target Molecules

The two molecules we are testing are:

- **Acetone (CH_3COCH_3):** An aliphatic ketone.
- **Benzaldehyde (C_6H_5CHO):** An aromatic aldehyde.

The question asks which of the given reagents will react with *neither* of these two compounds.

Step 2: Evaluate the Reactivity of Each Reagent

Let's consider each option's reactivity towards ketones and aldehydes.

- **(A) Sodium hydrogen sulphite ($NaHSO_3$):** This reagent undergoes a characteristic nucleophilic addition reaction with most aldehydes and many ketones (especially methyl ketones like acetone) to form crystalline bisulfite adducts. Therefore, it reacts with both acetone and benzaldehyde.
- **(B) Phenyl hydrazine ($C_6H_5NHNH_2$):** This is a derivative of ammonia that reacts with the carbonyl group of both aldehydes and ketones to form phenylhydrazones. It will react with both acetone and benzaldehyde.

- **(C) Fehling's solution:** This is a mild oxidizing agent (containing Cu^{2+} ions) used specifically to test for **aliphatic aldehydes**.
  - It does **not** react with ketones, so it will not react with acetone.
  - It does **not** react with aromatic aldehydes like benzaldehyde, as they are not easily oxidized by this mild reagent.

  Therefore, Fehling's solution reacts with neither acetone nor benzaldehyde.
- **(D) Grignard reagent ($RMgX$):** This is a very strong nucleophile. It readily attacks the electrophilic carbonyl carbon of both aldehydes and ketones in a nucleophilic addition reaction, which upon hydrolysis yields alcohols. Therefore, it reacts with both acetone and benzaldehyde.

Step 3: Conclusion

Based on the analysis, Fehling's solution is the only reagent on the list that does not react with either acetone (a ketone) or benzaldehyde (an aromatic aldehyde).
Therefore, the correct answer is option (C).

> Quick Tip
>
> Grignard reagents do not react directly with acetone and benzaldehyde to form addition products like other reagents (e.g., phenyl hydrazine or sodium bisulfite).

(e) Sweetest sugar is:

(A) Glucose
(B) Lactose
(C) Sucrose
(D) Fructose

Correct Answer: (D) Fructose

Solution:

Fructose is considered the sweetest of all the common sugars. It is a monosaccharide that is sweeter than glucose, sucrose, and lactose. Fructose is found in honey, fruits, and root vegetables, and is often used as a sweetener in foods and beverages.

- Glucose is sweet but not as sweet as fructose.
- Lactose is a disaccharide found in milk and has a less sweet taste than fructose.
- Sucrose (table sugar) is a disaccharide consisting of glucose and fructose but is not as sweet as fructose alone.

Thus, the correct answer is option (D) Fructose.

Quick Tip

Fructose is the sweetest sugar among common sugars and is often used as a sweetener in foods and beverages.

(f) The correct IUPAC name for $CH_2 = CHCH_2NHCH_3$ is:

(A) Allylmethylamine

(B) 1-amine-4-pentene

(C) 4-aminopent-1-ene

(D) N-methylprop-2-ene-1-amine

Correct Answer: (C) 4-aminopent-1-ene

Solution:

The given compound is $CH_2 = CHCH_2NHCH_3$. To assign the correct IUPAC name, we need to:

1. Identify the longest carbon chain that includes the double bond, which is 5 carbon atoms long. This gives the base name ”pentene.”
2. Number the chain from the end nearest the double bond, which is at position 1, so the compound is pent-1-ene.
3. Identify the substituents. The amino group (-NH2) is located at position 4 on the chain.
4. The methyl group (-CH3) is attached to the nitrogen atom, which is implied in the name ”N-methyl” (indicating the methyl group is attached to the nitrogen atom).

Thus, the correct IUPAC name is 4-aminopent-1-ene.

Therefore, the correct answer is option (C) 4-aminopent-1-ene.

> Quick Tip
>
> The IUPAC name for compounds with multiple functional groups involves identifying the longest chain, numbering the chain to give the functional groups the lowest possible numbers, and naming each substituent.

Section - B

2.(a) Calculate molality of a solution of 5.0 g of ethanoic acid (CH_3COOH) in 150.0 g of benzene.

Solution:

Molality is a measure of the concentration of a solute in a solution, defined as the number of moles of solute per kilogram of solvent. The formula for molality m is:

$$m = \frac{n_{\text{solute}}}{m_{\text{solvent}}}$$

Where: - m_{solute} is the number of moles of solute (in this case, ethanoic acid),

- m_{solvent} is the mass of the solvent (benzene) in kilograms.

We are given:

- Mass of ethanoic acid $= 5.0\,\text{g}$,

- Mass of benzene $= 150.0\,\text{g} = 0.150\,\text{kg}$,

- Molar mass of ethanoic acid $(CH_3COOH) = 60.0\,\text{g/mol}$.

Step 1: Calculate the number of moles of ethanoic acid (solute).

The number of moles n_{solute} is calculated by the formula:

$$n_{\text{solute}} = \frac{\text{Mass of solute}}{\text{Molar mass}} = \frac{5.0\,\text{g}}{60.0\,\text{g/mol}} = 0.0833\,\text{mol}$$

Step 2: Calculate molality using the formula.

Now, we can use the formula for molality:

$$m = \frac{0.0833\,\text{mol}}{0.1500\,\text{kg}} = 0.5567\,\text{mol/kg}$$

Thus, the molality of the solution is 0.5567 mol/kg.

> **Quick Tip**
>
> Molality is particularly useful for temperature-dependent solutions because it does not change with temperature, unlike molarity, which can change due to volume expansion or contraction. Always ensure that the mass of the solvent is converted to kilograms when calculating molality.

(b) Why is there always a decreasing tendency of solubility of gases in liquid on rising temperature?

Solution:

The solubility of gases in liquids is generally inversely proportional to temperature, meaning that as the temperature of the liquid increases, the solubility of the gas decreases. This can be explained through the following points:

1. Increased Kinetic Energy of Gas Molecules

As the temperature increases, the kinetic energy of the gas molecules also increases. The molecules move faster, and as a result, they are more likely to overcome the intermolecular forces that hold them in the liquid. This leads to a higher tendency for the gas molecules to escape from the liquid into the gas phase. Therefore, the gas becomes less soluble in the liquid.

2. Le Chatelier's Principle

Le Chatelier's principle states that if a system at equilibrium is disturbed, the equilibrium shifts in the direction that minimizes the effect of the disturbance. For gas solubility, when temperature increases, the equilibrium shifts in such a way that more gas molecules escape the liquid phase, reducing the solubility. This is because the dissolution of gas is an exothermic process, and according to Le Chatelier's principle, increasing the temperature causes the system to favor the gas phase, thus decreasing solubility.

3. Vapor Pressure of the Gas

At higher temperatures, the vapor pressure of the gas increases. This means that the gas is more likely to escape from the liquid to the surface and enter the gas phase. Thus, with an increase in temperature, the solubility of gases decreases because more gas molecules are found in the vapor phase.

4. Entropy Considerations

As temperature increases, the disorder or entropy of the system increases. At higher temperatures, the gas molecules have more freedom of motion and are less likely to stay dissolved in the liquid. This also leads to a decrease in solubility.

In conclusion, at higher temperatures, gas molecules gain enough energy to escape from the liquid, and the solubility decreases.

Quick Tip

Gases generally become less soluble in liquids as temperature increases because the increased kinetic energy of the gas molecules allows them to escape the liquid phase. Always remember that temperature increases cause gas molecules to move more energetically and tend to leave the solution.

(c) How many oxidation states are exhibited by lanthanides?

Solution:

Lanthanides, which consist of the 14 elements from atomic numbers 58 (Cerium) to 71 (Lutetium), exhibit a wide range of oxidation states. These oxidation states arise from the loss of electrons from the 4f, 5s, and 5p orbitals. The oxidation states of lanthanides are generally determined by the availability of the 4f electrons for bonding.

Common Oxidation States: 1. +3 Oxidation State (Most Common):

The most common and stable oxidation state for lanthanides is +3. In this state, the three 4f electrons are lost, leaving the lanthanide in a stable, highly charged state. This is the predominant oxidation state for the majority of the lanthanides. For example, the most common ion in lanthanide chemistry is La^{3+}, Ce^{3+}, and Nd^{3+}.

2. +2 Oxidation State:

Some lanthanides like europium (Eu) and ytterbium (Yb) can also exist in the +2 oxidation state. The +2 state is observed when the lanthanide loses two 4f electrons. The lanthanide ions in this state tend to be more stable in an environment that provides additional stabilization, such as when they are complexed with ligands.

3. +4 Oxidation State:

A few lanthanides, such as cerium (Ce) and thorium (Th), can exhibit the +4 oxidation state. In this state, they lose all of their 4f electrons and can bond with more electronegative species such as oxygen or halides. The +4 state is less stable compared to the +3 state and is generally observed in rare cases, usually when the lanthanide is in a more oxidizing environment.

Rare Oxidation States: - +5 and +6 Oxidation States: These are very rare and unstable oxidation states for lanthanides. Some lanthanides like praseodymium (Pr) and neodymium (Nd) can exhibit the +5 oxidation state under special conditions, but they are rarely encountered in nature.

Summary:

- Lanthanides predominantly exhibit the +3 oxidation state.
- The +2 and +4 oxidation states are observed in some lanthanides but are less stable.
- The +5 and +6 oxidation states are very rare and highly unstable.

> Quick Tip
>
> Remember, lanthanides predominantly show the +3 oxidation state. The +2 and +4 states are less common but can be observed under specific conditions.

(d) Show the geometrical isomers of $[Fe(NH_3)_2(CN)_4]$.

Solution:

In this question, we are dealing with the complex $[Fe(NH_3)_2(CN)_4]$, which is an octahedral coordination complex. The central metal ion is iron (Fe), surrounded by two ammonia (NH_3) molecules and four cyanide (CN^-) ions. The coordination number of the metal ion is 6, forming an octahedral geometry.

Geometrical Isomerism in Octahedral Complexes:

Geometrical isomerism arises in octahedral complexes when there are different possible spatial arrangements of ligands. In this case, the complex $[Fe(NH_3)_2(CN)_4]$ can have cis and trans isomers based on the arrangement of the ligands.

1. Cis-Isomer: In the cis configuration, the two NH_3 molecules are placed next to each other, i.e., they occupy adjacent positions (90° apart) in the octahedral arrangement. The four cyanide ions are placed at the remaining positions, opposite each other. This creates a symmetrical arrangement of the ligands in the octahedral complex. The formula for this isomer can be represented as:

$$[Fe(NH_3)_2(CN)_4]_{\text{cis}}$$

2. Trans-Isomer: In the trans configuration, the two NH_3 molecules are placed opposite each other, i.e., they occupy opposite positions (180° apart) in the octahedral arrangement. The four cyanide ions occupy the remaining positions. This arrangement is different from the cis-isomer and results in a distinct geometric shape. The formula for this isomer is:

$$[Fe(NH_3)_2(CN)_4]_{\text{trans}}$$

Conclusion: - The cis-isomer has the two NH_3 molecules adjacent to each other, while in the trans-isomer, the NH_3 molecules are opposite each other. These two different spatial arrangements of the ligands lead to geometrical isomerism in the complex.

> Quick Tip
>
> In octahedral complexes with two different types of ligands, geometrical isomerism can occur, resulting in cis and trans isomers depending on the relative positions of the ligands.

3.(a) Explain the following reactions with suitable chemical equations:

(i) Wurtz reaction

(ii) Wurtz-Fittig reaction

Solution:

(i) Wurtz Reaction:

The Wurtz reaction is a coupling reaction in which two alkyl halides react with sodium metal in dry ether to form a higher alkane. This reaction proceeds through the formation of free radicals, and the general reaction is as follows:

$$2R - \text{X} + 2\text{Na} \rightarrow R - R + 2\text{NaX}$$

Where: - $R - \text{X}$ is an alkyl halide (for example, ethyl chloride C_2H_5Cl), - $R - R$ is the resulting alkane (for example, ethane C_2H_6), - NaX is the sodium halide (for example, sodium chloride NaCl).

In this reaction, sodium (Na) donates electrons to the alkyl halide, generating free radicals. These free radicals combine to form a new alkane. The Wurtz reaction is primarily used to synthesize symmetrical alkanes.

(ii) Wurtz-Fittig Reaction:

The Wurtz-Fittig reaction is a coupling reaction that involves the reaction of an alkyl halide with an aryl halide in the presence of sodium metal, forming a biphenyl derivative or an alkyl-aromatic compound. It is a combination of the Wurtz reaction and the Fittig reaction. The general reaction is:

$$R - \text{X} + C_6H_5 - \text{Y} + \text{Na} \rightarrow R - C_6H_5 + \text{NaXY}$$

Where: - $R - \text{X}$ is an alkyl halide, - $C_6H_5 - \text{Y}$ is an aryl halide, - $R - C_6H_5$ is the resulting alkyl-aromatic compound (for example, toluene, C_7H_8).

This reaction is used to form substituted benzene derivatives. Sodium metal reacts with the halides, resulting in the formation of free radicals that couple to produce the alkyl-aromatic compound.

Quick Tip

In the Wurtz reaction, two alkyl halides react in the presence of sodium to form a symmetrical alkane. The Wurtz-Fittig reaction involves one alkyl halide and one aryl halide, resulting in an alkyl-aromatic compound.

(b) Alcohols are more soluble in water in comparison to hydrocarbons of comparable molecular weight. Explain.

Solution:

Alcohols are more soluble in water compared to hydrocarbons of similar molecular weight due to the presence of the hydroxyl group (-OH), which allows alcohols to form hydrogen bonds with water molecules. The following points explain this in detail:

1. Hydrogen Bonding:

Alcohols contain a hydroxyl group (-OH), which can form hydrogen bonds with water molecules. Water is a polar solvent, and the hydroxyl group in alcohols is also polar, making it capable of forming hydrogen bonds. These interactions increase the solubility of alcohols in water. On the other hand, hydrocarbons are non-polar and cannot form hydrogen bonds with water, making them much less soluble.

2. Polarity:

The hydroxyl group in alcohols makes them polar, while hydrocarbons are non-polar. Water is a polar solvent, and polar substances tend to dissolve more easily in polar solvents. This is the main reason why alcohols are more soluble in water than hydrocarbons of similar molecular weight.

3. Hydrophilic and Hydrophobic Parts:

In alcohols, the -OH group is hydrophilic (water-loving) and can interact with water molecules, whereas the hydrocarbon chain is hydrophobic (water-repelling). However, the hydrophilic nature of the hydroxyl group overcomes the hydrophobic nature of the hydrocarbon part, making alcohols more soluble than hydrocarbons in water.

4. Size of the Alcohol:

The solubility of alcohols in water decreases with increasing size of the hydrophobic hydrocarbon chain. Larger alcohols, such as octanol, are less soluble in water compared to smaller alcohols, like methanol or ethanol. However, alcohols are still more soluble than hydrocarbons of comparable molecular weight due to the presence of the -OH group.

5. Hydrogen Bond Formation:

In water, the hydroxyl group of alcohols can form hydrogen bonds not only with other alcohol molecules but also with water molecules. This significantly increases the solubility

of alcohols. Hydrocarbons, lacking the ability to form hydrogen bonds with water, are much less soluble in water.

Thus, alcohols are more soluble in water because of their ability to form hydrogen bonds with water molecules, whereas hydrocarbons lack this ability.

Quick Tip

Alcohols are more soluble in water than hydrocarbons due to hydrogen bonding between the -OH group and water molecules. The larger the non-polar hydrophobic chain, the lower the solubility, but alcohols are still more soluble than hydrocarbons of comparable molecular weight.

(c)

Differentiate between the following:

(i) Propanal and Propanone,

(ii) Phenol and Benzoic acid.

Solution:

(i) Propanal and Propanone:

- Propanal (C_3H_6O): Propanal is an aldehyde with the structure CH_3CH_2CHO. The carbonyl group ($C = O$) is at the end of the carbon chain, making it an aldehyde. In this structure: - The carbonyl group is attached to a hydrogen atom and a CH_2-CH_3 group. - The functional group in aldehydes is always a terminal carbonyl group, meaning the group is always attached to a carbon atom at the end of the molecule.

- Propanone (C_3H_6O): Propanone is a ketone with the structure CH_3COCH_3. The carbonyl group is attached to two methyl groups (CH_3), making it a ketone. - The carbonyl group is in the middle of the carbon chain, unlike in aldehydes. - In ketones, the carbonyl group is attached to two other carbon atoms, which makes it a characteristic feature of ketones.

Key Difference: The key difference between propanal and propanone lies in the position of the carbonyl group: - In propanal, the carbonyl group is at the end of the molecule (making it an aldehyde). - In propanone, the carbonyl group is in the middle of the molecule (making it a ketone).

(ii) Phenol and Benzoic acid:

- Phenol (C_6H_5OH): Phenol is an aromatic compound with a hydroxyl group ($-OH$) attached to a benzene ring. - The functional group in phenol is the hydroxyl group, which is directly attached to the aromatic ring. - Phenol has mild antiseptic properties and is used in the production of resins and other chemicals.

- Benzoic acid (C_6H_5COOH): Benzoic acid is also an aromatic compound, but it contains a carboxyl group ($-COOH$) attached to the benzene ring. - The carboxyl group consists of a hydroxyl group (-OH) attached to a carbonyl group ($C = O$). - Benzoic acid is commonly used in the production of dyes, perfumes, and preservatives.

Key Difference: The functional groups in these two compounds are different: - Phenol has a hydroxyl group ($-OH$) attached to the benzene ring. - Benzoic acid has a carboxyl group ($-COOH$) attached to the benzene ring. - This difference in functional groups leads to different chemical and physical properties for phenol and benzoic acid.

Quick Tip

Remember that aldehydes and ketones are differentiated by the position of the carbonyl group, and phenol and benzoic acid are differentiated by the functional group attached to the benzene ring.

(d)

Give the name of two water-soluble vitamins and diseases due to deficiency of them.

Solution:

Water-soluble vitamins are vitamins that dissolve in water and are not stored in the body for long periods. They need to be replenished regularly through diet. Here are two examples of water-soluble vitamins:

1. Vitamin C (Ascorbic acid):

- Function: Vitamin C plays a crucial role in collagen synthesis, wound healing, and maintaining the integrity of skin, blood vessels, and bones. It also acts as an antioxidant, protecting cells from damage.

- Disease due to deficiency: Scurvy. Scurvy is characterized by symptoms such as bleeding

gums, joint pain, weakness, and skin rashes. This condition arises due to the lack of collagen synthesis, which Vitamin C is vital for.

- Symptoms: Swollen and bleeding gums, loose teeth, fatigue, and bruising.

2. Vitamin B1 (Thiamine):

- Function: Thiamine plays an essential role in carbohydrate metabolism, as it is a coenzyme in the decarboxylation of alpha-keto acids, and it is vital for nerve function and energy production.

- Disease due to deficiency: Beriberi. There are two types of beriberi: wet and dry. Wet beriberi affects the cardiovascular system, leading to swelling, shortness of breath, and heart failure. Dry beriberi affects the nervous system, causing weakness, numbness, and motor impairment.

- Symptoms: Weakness, fatigue, nerve damage, and swelling in the body.

Water-soluble vitamins are important for overall health, and their deficiency can lead to serious conditions.

> Quick Tip
>
> Water-soluble vitamins, like vitamin C and the B-vitamins, need to be consumed regularly as the body does not store them for long periods. Deficiencies can cause serious health issues like scurvy and beriberi.

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4. (a) Explain Raoult's Law. The vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) are 200 mm Hg and 4.5 mm Hg respectively at 298 K. Calculate the vapour pressure of the solution formed by mixing 51 g of $CHCl_3$ and 20 g of CH_2Cl_2 at 298 K.

Solution:

Raoult's Law states that the partial vapor pressure of each volatile component in a solution is equal to the vapor pressure of the pure component multiplied by its mole fraction in the solution. Mathematically, it is represented as:

$$P_i = X_i P_i^\circ$$

Where: - P_i is the partial vapor pressure of component i,

- X_i is the mole fraction of component i in the solution,

- P_i° is the vapor pressure of the pure component i.

Given: - Vapor pressure of chloroform $P^\circ_{\text{chloroform}} = 200\,\text{mm Hg}$,

- Vapor pressure of dichloromethane $P^\circ_{\text{dichloromethane}} = 4.5\,\text{mm Hg}$,

- Mass of chloroform $m_{\text{chloroform}} = 51\,\text{g}$,

- Mass of dichloromethane $m_{\text{dichloromethane}} = 20\,\text{g}$,

- Molar mass of chloroform $M_{\text{chloroform}} = 119.38\,\text{g/mol}$,

- Molar mass of dichloromethane $M_{\text{dichloromethane}} = 84.93\,\text{g/mol}$.

Step 1: Calculate moles of each component.

For chloroform:

$$n_{\text{chloroform}} = \frac{51\,\text{g}}{119.38\,\text{g/mol}} = 0.427\,\text{mol}$$

For dichloromethane:

$$n_{\text{dichloromethane}} = \frac{20\,\text{g}}{84.93\,\text{g/mol}} = 0.235\,\text{mol}$$

Step 2: Calculate total moles in the solution.

Total moles = $n_{\text{chloroform}} + n_{\text{dichloromethane}} = 0.427 + 0.235 = 0.662\,\text{mol}$.

Step 3: Calculate mole fractions.

Mole fraction of chloroform:

$$X_{\text{chloroform}} = \frac{n_{\text{chloroform}}}{n_{\text{chloroform}} + n_{\text{dichloromethane}}} = \frac{0.427}{0.662} = 0.645$$

Mole fraction of dichloromethane:

$$X_{\text{dichloromethane}} = \frac{n_{\text{dichloromethane}}}{n_{\text{chloroform}} + n_{\text{dichloromethane}}} = \frac{0.235}{0.662} = 0.355$$

Step 4: Apply Raoult's Law to calculate the total vapor pressure.

Vapor pressure of the solution is the sum of the partial pressures:

$$P_{\text{total}} = X_{\text{chloroform}} P^{\circ}_{\text{chloroform}} + X_{\text{dichloromethane}} P^{\circ}_{\text{dichloromethane}}$$

$$P_{\text{total}} = (0.645 \times 200) + (0.355 \times 4.5)$$

$$P_{\text{total}} = 129 + 1.598 = 130.598\,\text{mm Hg}$$

Thus, the vapor pressure of the solution is $130.6\,\text{mm Hg}$.

> **Quick Tip**
>
> Raoult's law holds true for ideal solutions where the intermolecular forces between molecules of different components are similar. For non-ideal solutions, deviations from Raoult's law can occur.

(b) The resistance of a column formed by a 0.10 mol

L^{-1} concentrated solution is 6.5×10^3 ohm. Its diameter is 1 cm and length is 50 cm. Calculate its

Solution:

The formula for resistance R of a solution is given by:

$$R = \frac{\rho L}{A}$$

Where: - R is the resistance,

- ρ is the resistivity,

- L is the length of the column,

- A is the cross-sectional area of the column.

We are given: - Resistance $R = 6.5 \times 10^3\,\Omega$,

- Length $L = 50\,\text{cm} = 0.50\,\text{m}$,

- Diameter $d = 1\,\text{cm} = 0.01\,\text{m}$,

Step 1: Calculate the cross-sectional area.

The cross-sectional area A of the column is given by the area of a circle:

$$A = \pi \left(\frac{d}{2}\right)^2 = \pi \left(\frac{0.01}{2}\right)^2 = 7.854 \times 10^{-5}\,\text{m}^2$$

Step 2: Calculate the resistivity.

Rearranging the formula for resistance, we can solve for resistivity:

$$\rho = \frac{RA}{L} = \frac{(6.5 \times 10^3)(7.854 \times 10^{-5})}{0.50} = 1.02\,\Omega\,\text{m}$$

Thus, the resistivity is $\rho = 1.02\,\Omega\,\text{m}$.

Step 3: Calculate the conductivity.

Conductivity σ is the reciprocal of resistivity:

$$\sigma = \frac{1}{\rho} = \frac{1}{1.02} = 0.980\,\text{S/m}$$

Thus, the conductivity is $\sigma = 0.980\,\text{S/m}$.

Step 4: Calculate the molar conductivity.

Molar conductivity Λ_m is given by:

$$\Lambda_m = \frac{\kappa}{C}$$

Where: - κ is the conductivity,

- C is the concentration of the solution in mol/L.

Given $C = 0.10\,\text{mol/L}$, we can calculate the molar conductivity:

$$\Lambda_m = \frac{0.980}{0.10} = 9.80\,\text{S·m}^2/\text{mol}$$

Thus, the molar conductivity is $\Lambda_m = 9.80\,\text{S·m}^2/\text{mol}$.

> **Quick Tip**
>
> When calculating resistance, conductivity, and molar conductivity, always remember the relationship between them. Molar conductivity depends on both the concentration and conductivity of the solution.

(c) Explain with reason:

(i) $\mathbf{Cr}^{2+} is a reducing agent while \mathbf{Mn}^{3+} is an oxidising agent, while both have d^4$ configuration.

Solution:

- Cr^{2+}: The ion Cr^{2+} has the electron configuration $[Ar]3d^4$. Since Cr^{2+} can easily lose an electron to become Cr^{3+}, it acts as a reducing agent, facilitating the reduction of other species by donating electrons.

- Mn^{3+}: The ion Mn^{3+} has the electron configuration $[Ar]3d^4$, which is unstable and readily accepts an electron to stabilize itself as Mn^{2+}. Hence, Mn^{3+} acts as an oxidizing agent, accepting electrons from other species.

> Quick Tip
>
> A reducing agent donates electrons, while an oxidizing agent accepts electrons. Cr^{2+} reduces by losing electrons, and Mn^{3+} oxidizes by accepting electrons.

(ii) Why metals show their maximum oxidation states in oxides and fluorides?

Solution:

Metals tend to show their maximum oxidation states in oxides and fluorides due to the highly electronegative nature of oxygen and fluorine. Oxygen and fluorine have a strong tendency to accept electrons, which allows the metal to lose its electrons more readily.

- In oxides (with oxygen as the ligand) and fluorides (with fluorine as the ligand), the metal tends to reach its highest oxidation state, as the electron withdrawing effect of oxygen and fluorine makes it easier for the metal to lose electrons. This is why, for example, metals like titanium, manganese, and chromium show their highest oxidation states in these compounds.

> Quick Tip
>
> In oxides and fluorides, metals can achieve their highest oxidation states because oxygen and fluorine are strong electron acceptors, facilitating the oxidation process.

(iii) Transition metals generally form coloured compounds.

Solution:

Transition metals form colored compounds due to the electronic transitions between their d-orbitals. The color is a result of these transitions when electrons move from one d-orbital to another under the influence of visible light.

- In transition metals, the d-orbitals are split into two energy levels under the influence of a ligand field. When light is absorbed, electrons are excited from lower to higher energy

d-orbitals, and the energy corresponding to the absorbed light corresponds to the color observed in the complex. This is why many transition metal compounds, like those of copper, chromium, and cobalt, show distinct colors.

> Quick Tip
>
> The color in transition metal complexes is due to electronic transitions between d-orbitals, which occur when the metal is in a ligand field.

(d) What do you understand by order of a reaction? Calculate the total order of those reactions which have velocity equations:

(i) Velocity $= K[A]^{1/2}[B]^{3/2}$

(ii) Velocity $= K[A]^{3}[B]^{-1}$

Solution:

The order of a reaction refers to the sum of the exponents of the concentrations of the reactants in the rate law. The order indicates how the rate of reaction is affected by the concentration of the reactants.

1. For the first velocity equation Velocity $= K[A]^{1/2}[B]^{3/2}$:

The total order of the reaction is the sum of the exponents of the concentrations of the reactants. In this case, the exponents are 1/2 for A and 3/2 for B. Therefore, the total order is:

$$\text{Total order} = \frac{1}{2} + \frac{3}{2} = 2$$

2. For the second velocity equation Velocity $= K[A]^{3}[B]^{-1}$:

Similarly, the total order of the reaction is the sum of the exponents of the concentrations of the reactants. Here, the exponents are 3 for A and -1 for B. Therefore, the total order is:

$$\text{Total order} = 3 + (-1) = 2$$

Thus, for both reactions, the total order is 2.

Quick Tip

The order of a reaction is the sum of the exponents of the concentration terms in the rate law equation. It determines how the rate of reaction changes with the concentration of reactants.

5.(a)(i) Explain Kohlrausch Law. Limiting molar conductances (λ^0) of Ca^{2+} and Cl^- ions in water at 298 K are 119.0 S cm^2 mol^{-1} and 76.3 S cm^2 mol^{-1} respectively. Calculate λ_m^0 of $CaCl_2$.

Solution:

Kohlrausch's Law:

Kohlrausch's Law of limiting molar conductivity states that the limiting molar conductivity of an electrolyte is the sum of the limiting molar conductances of the individual ions that make up the electrolyte. Mathematically, it is expressed as:

$$\lambda_m^0 = \lambda_{\text{cation}}^0 + \lambda_{\text{anion}}^0$$

Where: - λ_m^0 is the limiting molar conductivity of the electrolyte,

- $\lambda_{\text{cation}}^0$ is the limiting molar conductivity of the cation,

- λ_{anion}^0 is the limiting molar conductivity of the anion.

For $CaCl_2$, the cation is Ca^{2+} and the anion is Cl^-. From the given data:

- $\lambda_{Ca^{2+}}^0 = 119.0\,\text{S cm}^{-1}\,\text{mol}^{-1}$,

- $\lambda_{Cl^-}^0 = 76.3\,\text{S cm}^{-1}\,\text{mol}^{-1}$.

Using Kohlrausch's Law:

$$\lambda_m^0(\text{CaCl}_2) = \lambda_{Ca^{2+}}^0 + \lambda_{Cl^-}^0$$

Substituting the values:

$$\lambda_m^0(\text{CaCl}_2) = 119.0 + 76.3 = 195.3\,\text{S cm}^{-1}\,\text{mol}^{-1}$$

Thus, the limiting molar conductivity of $CaCl_2$ is 195.3 S cm^{-1} mol^{-1}.

Quick Tip

Kohlrausch's Law applies to electrolytes in dilute solutions. It allows us to determine the conductivity of an electrolyte by summing the conductivities of its ions.

5.(a)(ii) Why do the conductivity of a solution decreases with dilution? Explain with reason.

Solution:

Effect of Dilution on Conductivity:

The conductivity of a solution decreases with dilution because as the solution is diluted, the number of ions in the solution per unit volume decreases. This leads to a decrease in the overall current-carrying capacity of the solution. The key factors involved are:

1. Ion Concentration:

Conductivity (κ) of a solution depends on the concentration of ions. As the concentration of ions decreases with dilution, the conductivity also decreases. The relationship is given by:

$$\kappa = \sum_i c_i \lambda_i$$

Where: - κ is the conductivity,

- c_i is the concentration of the i^{th} ion,

- λ_i is the molar conductivity of the i^{th} ion.

As dilution decreases the concentration c_i, the conductivity κ decreases as well.

2. Ion Pairing:

At higher concentrations, ions tend to form ion pairs, which reduce the number of free ions in the solution, thus decreasing the conductivity. When a solution is diluted, ion pairing is minimized, but the total number of free ions decreases due to the lower concentration.

3. Decrease in Collision Frequency:

In concentrated solutions, ions are closer to each other and collide more often, which increases the chances of electrical conduction. As the solution is diluted, the ions are further apart, leading to fewer collisions and lower conductivity.

Thus, with dilution, the total ion concentration and the ion mobility decrease, leading to a

reduction in the overall conductivity of the solution.

> Quick Tip
>
> The conductivity of an electrolyte decreases with dilution due to the reduction in the number of ions per unit volume, which lowers the current-carrying capacity of the solution.

(b)(i) In $2A \rightarrow$ Product, the reaction concentration of A remains 0.4 mol^{-1} from 0.5 mol^{-1} in 10 minutes.
Calculate the velocity of reaction for this period of time.

Solution:

The rate of reaction (velocity of reaction) is defined as the change in concentration of the reactant or product per unit time. For this case, the change in concentration of A is given as:

$$\Delta[A] = 0.5 - 0.4 = 0.1 \text{ mol/L}$$

The time interval is 10 minutes, or 600 seconds. The velocity of the reaction is calculated as:

$$\text{Rate} = \frac{\Delta[A]}{\Delta t} = \frac{0.1 \text{ mol/L}}{600 \text{ s}} = 1.67 \times 10^{-4} \text{ mol/L·s}$$

Thus, the velocity of the reaction is 1.67×10^{-4} mol/L·s.

> Quick Tip
>
> The rate of reaction is calculated as the change in concentration divided by the time interval. Ensure you convert all time units consistently (e.g., seconds).

(b)(ii) Differentiate between:
(x) Order of a reaction and molecularity
(y) Average and instantaneous velocity

Solution:

(x) Order of a reaction and molecularity:

- Order of a reaction refers to the sum of the exponents of the concentration terms in the rate law. It indicates how the rate of reaction is affected by the concentration of the reactants. For example, in a reaction with the rate law Rate $= k[A]^m[B]^n$, the order of the reaction is $m + n$, where m and n are the orders with respect to reactants A and B, respectively.
- Molecularity refers to the number of reacting species (atoms, molecules, or ions) that collide in an elementary step of the reaction. Molecularity is an integer and can only be 1 (unimolecular), 2 (bimolecular), or 3 (termolecular) for most elementary reactions. Unlike order, molecularity is determined from the balanced equation of the elementary reaction, not from the experimental data.

Key Difference: The order of a reaction is determined experimentally, while molecularity is determined from the balanced equation of an elementary reaction.

(y) Average and instantaneous velocity:

- Average velocity is defined as the total displacement (change in position) divided by the total time taken. In terms of reaction rate, it can be defined as the total change in concentration of reactants or products divided by the total time interval.
- Instantaneous velocity is the velocity of an object at a specific instant in time. In terms of reaction rate, it refers to the rate of change of concentration at a particular moment, and it can be calculated by taking the derivative of the concentration with respect to time.

Key Difference: Average velocity is the total change over a time interval, while instantaneous velocity refers to the rate of change at a specific point in time.

Quick Tip

Order is related to the rate law and can be fractional, while molecularity is a whole number and applies only to elementary reactions. Instantaneous velocity requires calculus to determine the rate at a specific point in time.

(c)(i) Write IUPAC name of the following complexes:

Solution:

(x) $[Co(NH_3)_5Cl]Cl_2$:

The IUPAC name of this complex is pentaamminechloridocobalt(III) chloride.

Explanation:

- The complex ion $[Co(NH_3)_5Cl]^{2+}$ consists of cobalt as the central metal ion, five ammonia molecules (NH) and one chloride ion (Cl) as ligands.
- The oxidation state of cobalt is +3, and the complex is neutralized by two chloride ions (Cl) outside the coordination sphere.

(y) $K_2[Ni(CN)_4]$:

The IUPAC name of this complex is potassium tetracyanidonickelate(II).

Explanation:

- The complex ion $[Ni(CN)_4]^{2-}$ consists of nickel as the central metal ion, four cyanide (CN) ligands.
- The oxidation state of nickel is +2, and the complex is neutralized by two potassium ions (K).

(c)(ii) Write the oxidation states, distribution of d-orbitals and coordination number of central metal of following complexes:

Solution:

(x) $K_3[Co(C_2O_4)_3]$:

- Oxidation state of Co: +3 (since each oxalate $C_2O_4^{2-}$ contributes -2 charge, and there are three oxalates, the net charge is -6. The overall charge of the complex is -3, so Co must be +3 to balance this).
- Distribution of d-orbitals: Co^{3+} (d configuration) will have 6 electrons in its d-orbitals.
- Coordination number of Co: 6 (since there are three oxalate ions, each of which is a bidentate ligand, contributing 2 donor atoms per ligand, for a total coordination of 6).

(y) $[Mn(H_2O)_6]SO_4$:

- Oxidation state of Mn: +2 (the complex ion $[Mn(H_2O)_6]^{2+}$ is neutralized by the sulfate ion SO_4^{2-}, indicating Mn is in the +2 oxidation state).
- Distribution of d-orbitals: Mn^{2+} (d configuration) will have 5 electrons in its d-orbitals.
- Coordination number of Mn: 6 (since there are six water molecules, each contributing one donor atom, making the coordination number 6).

Quick Tip

For coordination complexes, the coordination number is determined by the number of donor atoms (ligands) attached to the central metal ion. A bidentate ligand, like oxalate (CO^2), contributes 2 donor atoms, whereas a monodentate ligand, like water (HO), contributes only 1.

(d) Write important structural and functional differences between DNA and RNA.

Solution:

DNA (Deoxyribonucleic Acid) and RNA (Ribonucleic Acid) are both nucleic acids but differ in their structural and functional characteristics. Below are the key differences:

Structural Differences:

1. Sugar Molecule:

- DNA contains deoxyribose sugar, which lacks one oxygen atom (at the 2' carbon) compared to ribose.
- RNA contains ribose sugar, which has a hydroxyl group (-OH) attached to the 2' carbon atom.

2. Strand Type:

- DNA is typically double-stranded, forming a double helix structure.
- RNA is usually single-stranded and can form various structures like hairpins.

3. Nitrogenous Bases:

- DNA contains the bases adenine (A), thymine (T), cytosine (C), and guanine (G).
- RNA contains the bases adenine (A), uracil (U), cytosine (C), and guanine (G). Note that RNA uses uracil instead of thymine.

4. Helical Structure:

- DNA has a right-handed double helix structure.
- RNA is single-stranded and may adopt various secondary structures.

5. Length and Stability:

- DNA is generally longer and more stable than RNA, designed to store genetic information.
- RNA is usually shorter and less stable, designed for transient functions in the cell.

Functional Differences:

1. Genetic Material:

- DNA carries the genetic blueprint for the synthesis of proteins and is involved in the storage and transmission of genetic information.
- RNA plays a role in transcribing the genetic code from DNA and is involved in the synthesis of proteins (as mRNA, rRNA, and tRNA).

2. Types of RNA:

- DNA does not have different types but is used in the formation of mRNA, rRNA, and tRNA in RNA transcription.
- RNA has several types: mRNA (messenger RNA), rRNA (ribosomal RNA), and tRNA (transfer RNA), each playing a role in protein synthesis.

3. Replication and Transcription:

- DNA is self-replicating, meaning it can duplicate itself during cell division.
- RNA is transcribed from DNA and is not capable of replication itself but can be synthesized through transcription.

4. Function in Protein Synthesis:

- DNA stores the instructions for protein synthesis, while RNA is involved in the direct synthesis of proteins in the cytoplasm.

> Quick Tip
>
> Remember, DNA is stable and stores genetic information, while RNA is involved in protein synthesis and is more transient in nature.

6.(a) Write structural formula and IUPAC name of the following:

(i) sec-butyl chloride

(ii) isopentyl bromide

(iii) tert-butyl chloride

(iv) isobutyl chloride

(v) neopentyl chloride

Solution:

(i) sec-butyl chloride:

- Structural formula: CH_3CH_2CHCl

- IUPAC name: Butyl chloride (2-chlorobutane). This is the sec-butyl group, where the chlorine atom is attached to the second carbon of the butane chain.

(ii) isopentyl bromide:

- Structural formula: $CH_3CH_2CH_2CH_2Br$

- IUPAC name: Pentyl bromide (3-bromobutane). This is the isopentyl group, where the bromine atom is attached to the third carbon of the pentane chain.

(iii) tert-butyl chloride:

- Structural formula: $(CH_3)_3CCl$

- IUPAC name: Butyl chloride (2-chloro-2-methylpropane). This is the tert-butyl group, where the chlorine atom is attached to the central carbon in the isopropyl group.

(iv) isobutyl chloride:

- Structural formula: CH_3CH_2CHCl

- IUPAC name: Butyl chloride (1-chlorobutane). This is the isobutyl group, where the chlorine atom is attached to the first carbon of the butane chain.

(v) neopentyl chloride:

- Structural formula: $CH_2ClCH_2CH_2CH_3$

- IUPAC name: Pentyl chloride (1-chloro-2-methylpropane). This is the neopentyl group, where the chlorine atom is attached to the first carbon of the chain.

Quick Tip

When naming alkyl halides, remember the IUPAC rule of identifying the longest carbon chain and number it so that the halogen (e.g., chlorine, bromine) is attached to the lowest-numbered carbon.

OR

(i) Haloalkanes give nucleophilic substitution reactions while haloarenes give electrophilic substitution reactions.

Solution:

- Haloalkanes: Haloalkanes (R-X) undergo nucleophilic substitution reactions where the halide ion (X) is replaced by a nucleophile. The mechanism involves the attack of a nucleophile (such as OH^-, Cl^-, or Br^-) on the carbon bonded to the halogen. This happens due to the polar nature of the C-X bond where the carbon is partially positive, making it susceptible to attack by nucleophiles. The typical mechanism for haloalkanes is SN1 or SN2 depending on the substrate.
- Haloarenes: Haloarenes (C6H5-X) undergo electrophilic substitution reactions where the halide is replaced by an electrophile (like NO_2, SO_3, or Cl_2) on the aromatic ring. The halogen in haloarenes is relatively electron-withdrawing, making the aromatic ring less reactive towards nucleophiles. Instead, the ring undergoes electrophilic substitution where the halogen leaves as a halide ion (X^-) and the electrophile takes its place. The reaction often occurs under the influence of catalysts like $AlCl_3$ or $FeCl_3$.

Quick Tip

In haloalkanes, the reaction mechanism is nucleophilic substitution (SN1 or SN2), whereas in haloarenes, it is electrophilic substitution due to the nature of the bond and reactivity.

(ii) Hydrogen atom of chloroform is acidic in nature.

Solution:

- Chloroform ($CHCl_3$) has three chlorine atoms attached to a central carbon, which makes the C-H bond in chloroform weak and more likely to be dissociated. When chloroform loses a proton (H^+), it forms a trichloromethyl anion (CCl_3^-). This hydrogen is acidic due to the inductive effect of the chlorine atoms. Chlorine is highly electronegative and pulls electron density away from the C-H bond, making the hydrogen more positive and easily removable. This is why chloroform exhibits acidic properties.

Quick Tip

The acidic nature of chloroform arises due to the electron-withdrawing inductive effect of chlorine, which weakens the C-H bond and facilitates proton release.

(iii) Potassium cyanide gives alkyl cyanide on reaction with haloalkanes (R-X) while silver cyanide forms an isocyanide as main product.

Solution:

- Potassium cyanide (KCN) reacts with haloalkanes (R-X) in a nucleophilic substitution reaction, where the cyanide ion (CN^-) attacks the electrophilic carbon in the C-X bond, displacing the halide ion (X^-) and forming an alkyl cyanide (R-CN). The product is a simple alkyl cyanide.
- Silver cyanide (AgCN), on the other hand, forms an isocyanide (R-NC) when it reacts with haloalkanes. The difference arises because in the presence of silver, the cyanide ion exists as a complex with Ag^+, making it more likely to attack the carbon from the nitrogen side, leading to the formation of an isocyanide (also known as isonitrile). In this reaction, the CN^- group attaches to the carbon in a different orientation than in the case of KCN.

Quick Tip

Potassium cyanide gives alkyl cyanides via a nucleophilic substitution reaction, while silver cyanide forms isocyanides due to the silver ion's involvement in altering the reaction mechanism.

(b) How can these conversions be done? Give chemical equations only.

(i) Propan-2-ol from propene

(ii) Benzyl alcohol from benzyl chloride

(iii) Propan-1-ol from ethyl magnesium chloride

(iv) 2-methyl propan-2-ol from methyl magnesium bromide

(v) Picric acid from phenol

Solution:

(i) Propan-2-ol from propene:

Propene can be converted into propan-2-ol by hydration in the presence of a catalyst. The reaction is as follows:

$$CH_3CH{=}CH_2 + H_2O \xrightarrow{H_2SO_4} CH_3CH(OH)CH_3$$

(ii) Benzyl alcohol from benzyl chloride:

Benzyl chloride can be converted into benzyl alcohol by hydrolysis, which involves a nucleophilic substitution reaction. The reaction is as follows:

$$C_6H_5CH_2Cl + H_2O \rightarrow C_6H_5CH_2OH + HCl$$

(iii) Propan-1-ol from ethyl magnesium chloride:

Ethyl magnesium chloride reacts with water (hydrolysis) to form propan-1-ol. The reaction is as follows:

$$CH_3CH_2MgCl + H_2O \rightarrow CH_3CH_2OH + MgCl_2$$

(iv) 2-methyl propan-2-ol from methyl magnesium bromide:

Methyl magnesium bromide reacts with water to form 2-methyl propan-2-ol. The reaction is as follows:

$$CH_3CH_2MgBr + H_2O \rightarrow CH_3C(OH)(CH_3)CH_3 + MgBr_2$$

(v) Picric acid from phenol:

Picric acid (2,4,6-trinitrophenol) can be synthesized from phenol by nitration with a mixture of concentrated nitric acid and sulfuric acid. The reaction is as follows:

$$C_6H_5OH + 3HNO_3 \xrightarrow{H_2SO_4} C_6H_2(NO_2)_3OH$$

Quick Tip

In organic reactions, always consider the reagent and the conditions (e.g., acid/base, temperature, catalysts) that affect the outcome of the conversion. Reactions like nucleophilic substitution and electrophilic substitution play key roles in organic transformations.

OR

How will you synthesize the following? Give chemical equations only.

(i) 1-phenylethanol from a suitable alkene

(ii) Cyclohexylmethanol with the help of alkyl halide by S_N2 reaction.

(iii) Pentan-1-ol from a suitable alkyl halide.

Solution:

(i) 1-phenylethanol from a suitable alkene:

1-phenylethanol can be synthesized from styrene (ethenylbenzene) by hydroboration-oxidation reaction. The reaction is as follows:

$$C_6H_5CH = CH_2 \xrightarrow{B_2H_6} C_6H_5CH_2CH_2OH$$

(ii) Cyclohexylmethanol with the help of alkyl halide by SN2 reaction:

Cyclohexylmethanol can be synthesized by performing an SN2 reaction between cyclohexyl chloride and sodium hydroxide. The reaction is as follows:

$$C_6H_1CH_2Cl + NaOH \rightarrow C_6H_1CH_2OH + NaCl$$

(iii) Pentan-1-ol from a suitable alkyl halide:

Pentan-1-ol can be synthesized from 1-bromopentane by a nucleophilic substitution reaction with sodium hydroxide. The reaction is as follows:

$$C_5H_{11}Br + NaOH \rightarrow C_5H_{11}OH + NaBr$$

Quick Tip

In organic synthesis, the choice of reaction mechanism (such as SN1, SN2, or hydroboration-oxidation) depends on the nature of the substrate and the reaction conditions. For SN2 reactions, a primary alkyl halide and a strong nucleophile are necessary for efficient substitution.

7. (a) What do you understand by these following terms? Give one example of each.

(i) Aldol

(ii) Schiff's base

(iii) Cannizaro's reaction

(iv) Oxime

(v) Acetal

Solution:

(i) Aldol

An Aldol reaction is a type of organic reaction where an enolate ion (or sometimes an aldehyde or ketone) reacts with a carbonyl compound to form a -hydroxy aldehyde or ketone, also called an aldol. The reaction occurs due to the nucleophilic attack of the enolate or aldehyde carbonyl carbon. The general form of the aldol reaction is:

$$\text{RCHO + R'CHO} \rightarrow \text{RCH(OH)CH(R')CHO}$$

Example: The reaction between acetaldehyde (CHCHO) and acetaldehyde gives 4-hydroxybutanal (a -hydroxy aldehyde), which is an aldol addition product.

> Quick Tip
>
> Aldol reactions involve the formation of -hydroxy aldehydes or ketones and are catalyzed by either a base or acid.

(ii) Schiff's Base

A Schiff's base is a type of imine compound that forms when a primary amine reacts with an aldehyde or ketone. The reaction results in the formation of a C=N bond, known as an imine group. The reaction is typically catalyzed by acidic or basic conditions.

$$\text{RCHO + R'NH} \rightarrow \text{RCH=N-R'}$$

Example: The reaction between benzaldehyde (CHCHO) and aniline (CHNH) forms Schiff's base (CHCH=N-CH).

Quick Tip

Schiff's bases are useful in organic synthesis and can form colored complexes with metal ions.

(iii) Cannizzaro's Reaction

Cannizzaro's reaction is a redox reaction in which a non-enolizable aldehyde undergoes disproportionation in the presence of a strong base to yield an alcohol and a carboxylate anion. In this reaction, one molecule of aldehyde is reduced to alcohol, and another is oxidized to the carboxylate.

$$2\text{RCHO} \xrightarrow{\text{OH}^-} \text{RCH}_2\text{OH} + \text{RCOO}^-$$

Example: Benzaldehyde (CHCHO) undergoes Cannizzaro's reaction to form benzyl alcohol (CHCHOH) and benzoate ion (CHCOO).

Quick Tip

Cannizzaro's reaction occurs with aldehydes that lack -hydrogen and involves strong base catalysis.

(iv) Oxime

An oxime is a compound formed when an aldehyde or ketone reacts with hydroxylamine (NHOH), resulting in the formation of a C=N-OH group, commonly referred to as an imine. Oximes are used to identify carbonyl compounds.

$$\text{RCHO} + \text{NH}_2\text{OH} \rightarrow \text{RCH=NOH}$$

Example: Acetone (CHCOCH) reacts with hydroxylamine to form acetoxime (CHC=NOH).

Quick Tip

Oximes are often used in the identification of aldehydes and ketones and can be hydrolyzed back to the original aldehyde or ketone.

(v) Acetal

An acetal is a functional group where a carbon atom is bonded to two alkoxy groups (-OR) and a hydrogen atom. Acetals are typically formed when an aldehyde or ketone reacts with an alcohol in the presence of an acid catalyst.

$$\text{RCHO} + \text{ROH} \xrightarrow{\text{acid}} \text{RCH(OR)}$$

Example: The reaction of acetaldehyde (CHCHO) with methanol (CHOH) in acidic conditions forms acetaldehyde acetal (CHCH(OMe)).

Quick Tip

Acetals are widely used as protecting groups in organic synthesis, especially for aldehydes and ketones.

OR

(i) Write the structure of the product for the reaction:

$$\text{C}_6\text{H}_6 + \text{C}_2\text{H}_5\text{Cl} \xrightarrow{\text{Anhydrous AlCl}_3} \text{C}_6\text{H}_5\text{C}_2\text{H}_5$$

Solution:

The reaction involves the Friedel-Crafts alkylation of benzene using ethyl chloride in the presence of anhydrous $AlCl_3$. This results in the formation of ethylbenzene.

$$\text{C}_6\text{H}_6 + \text{C}_2\text{H}_5\text{Cl} \xrightarrow{\text{Anhydrous AlCl}_3} \text{C}_6\text{H}_5\text{C}_2\text{H}_5$$

Quick Tip

In Friedel-Crafts alkylation reactions, the alkyl group is introduced into the aromatic ring using a strong Lewis acid, such as anhydrous $AlCl_3$.

(ii) Write the structure of the product for the reaction:

$$C_6H_5C_2H_5 + Cd \rightarrow 2C_2H_5COCl$$

Solution:

This is a reaction of an alkyl group with cadmium, resulting in the formation of two molecules of ethyl chloride. The reaction is a dehalogenation and redistribution reaction.

$$C_6H_5C_2H_5 + Cd \rightarrow 2C_2H_5COCl$$

Quick Tip

The reaction with cadmium causes the dehalogenation of the organic molecule, breaking the bonds and producing two smaller products.

(iii) Write the structure of the product for the reaction:

$$CH_3C \equiv CH \xrightarrow{Hg^{2+},H_2SO_4} CH_3C(OH)CH_3$$

Solution:

In this reaction, the mercuric ion (Hg^{2+}) with sulfuric acid (H_2SO_4) catalyzes the hydration of the alkyne to form an alcohol. The product of the reaction is propan-2-ol.

$$CH_3C \equiv CH \xrightarrow{Hg^{2+},H_2SO_4} CH_3C(OH)CH_3$$

Quick Tip

The mercury(II) ion in combination with sulfuric acid catalyzes the addition of water across a triple bond, resulting in the formation of an alcohol.

(iv) Write the structure of the product for the reaction:

$$C_6H_5CH_3 \xrightarrow{CrO_2Cl_2} C_6H_5CHO$$

Solution:

This reaction involves the oxidation of methylbenzene (toluene) using chromium trioxide chloride (CrO_2Cl_2). The result is the formation of benzaldehyde.

$$C_6H_5CH_3 \xrightarrow{CrO_2Cl_2} C_6H_5CHO$$

Quick Tip

Chromium trioxide chloride (CrO_2Cl_2) is a strong oxidizing agent and is used to oxidize methyl groups to aldehydes.

(v) Write the structure of the product for the reaction:

$$C_6H_5COOH + CH_3CH_2NH_2 \xrightarrow{H^+} C_6H_5CH_2NH_2$$

Solution:

This reaction is a reduction of benzoic acid (C_6H_5COOH) with an amine (ethylamine) in the presence of an acid (H^+) to form phenylethylamine.

$$C_6H_5COOH + CH_3CH_2NH_2 \xrightarrow{H^+} C_6H_5CH_2NH_2$$

Quick Tip

Reduction of carboxylic acids with amines in acidic conditions results in the formation of secondary amines, such as phenylethylamine in this case.

(b) Write the following in order:

(i) Decreasing order of pK_b value: $C_2H_5NH_2, C_6H_5NHCH_3, C_2H_5NH_2$.

(ii) Decreasing order of basic strength: $C_6H_5NH_2, C_6H_5N(CH_3)_2, C_6H_5NH_2$.

(iii) Increasing order of basic strength: Aniline; p-nitroaniline; and paratoludine.

(iv) Solubility order in water: $C_6H_5NH_2, (C_2H_5)_2NH, C_2H_5NH_2$.

(v) Increasing order of boiling point: $C_2H_5OH, CH_3NH_2, C_2H_5NH_2$.

Solution:

(i) Decreasing order of pK_b value:

pK_b is inversely related to the basicity. A higher pK_b corresponds to a weaker base. The basicity of amines is influenced by the electron-donating ability of the substituents. The order from weakest to strongest base is:

$$C_6H_5NHCH_3 < C_2H_5NH_2 < C_6H_5NH_2$$

- $C_6H_5NHCH_3$ has the electron-donating methyl group attached to the nitrogen, slightly increasing basicity.
- $C_2H_5NH_2$ has an ethyl group attached, which is more electron-donating than a phenyl group.
- $C_6H_5NH_2$ has a phenyl group attached, which is electron-withdrawing, making it a weaker base.

(ii) Decreasing order of basic strength:

Basic strength is determined by the availability of the lone pair on nitrogen for protonation. The order from strongest to weakest base is:

$$C_6H_5NH_2 > C_6H_5N(CH_3)_2 > C_6H_5NH_2$$

- $C_6H_5NH_2$ is the strongest base as the lone pair on nitrogen is readily available for protonation.
- $C_6H_5N(CH_3)_2$ has two methyl groups attached, making it more electron-donating, increasing basicity.
- $C_6H_5NH_2$ has an electron-withdrawing phenyl group attached, making it the weakest base.

(iii) Increasing order of basic strength:
In the case of substituted anilines, electron-withdrawing substituents decrease basic strength. The order from weakest to strongest is:

$$\text{p-nitroaniline} < \text{aniline} < \text{paratoludine}$$

- p-Nitroaniline has a nitro group (NO_2), which is electron-withdrawing, making it the weakest base.
- Aniline has no substituents, so it has a moderate basic strength.
- Paratoludine has a methyl group (CH_3), which is electron-donating, making it the strongest base.

(iv) Solubility order in water:
Amines with smaller alkyl groups are more soluble in water due to hydrogen bonding. The solubility order is:

$$C_6H_5NH_2 > (C_2H_5)_2NH > C_2H_5NH_2$$

- $C_6H_5NH_2$ (aniline) is the most soluble in water due to the ability to form hydrogen bonds.
- $(C_2H_5)_2NH$ (diethylamine) is less soluble due to the increased hydrophobic character of the ethyl groups.
- $C_2H_5NH_2$ (ethylamine) has moderate solubility.

(v) Increasing order of boiling point:
The boiling points of amines increase with the size of the alkyl group and the ability to form hydrogen bonds. The order from lowest to highest boiling point is:

$$C_2H_5OH < CH_3NH_2 < C_2H_5NH_2$$

- C_2H_5OH (ethanol) has the lowest boiling point because it is a small molecule and only forms hydrogen bonds weakly.
- CH_3NH_2 (methylamine) has a higher boiling point due to stronger hydrogen bonding.
- $C_2H_5NH_2$ (ethylamine) has the highest boiling point because it has a larger molecular size and stronger hydrogen bonding.

Quick Tip

For the comparison of basic strengths, remember that electron-donating groups (like methyl) increase basicity, while electron-withdrawing groups (like nitro and phenyl) decrease basicity.

(C) (i) Aniline does not show Friedel-Crafts reaction.

Solution:

Aniline does not undergo the Friedel-Crafts reaction due to the presence of the amino group ($-NH_2$) attached to the benzene ring. The amino group is an electron-donating group through its lone pair of electrons on nitrogen. This electron-donating effect increases the electron density on the benzene ring, making the ring more reactive towards electrophilic attack. However, the presence of the amino group also reduces the reactivity of the ring towards the Friedel-Crafts alkylation and acylation reactions. In Friedel-Crafts reactions, a Lewis acid such as $AlCl_3$ is used as a catalyst to generate an electrophile, but the lone pair on nitrogen in aniline can coordinate with the Lewis acid, which deactivates the catalyst and inhibits the reaction. Hence, aniline does not show Friedel-Crafts reactions.

Quick Tip

Aniline does not undergo Friedel-Crafts reactions because the electron-donating nature of the amino group deactivates the ring towards electrophilic substitution and also forms a complex with the Lewis acid catalyst.

(ii) Gabriel-Pthalimide synthesis is given priority in the synthesis of primary amines.

Solution:

Gabriel-Pthalimide synthesis is preferred for synthesizing primary amines because it offers a selective and reliable method for their preparation. The key advantage of this method is that it exclusively yields primary amines, avoiding the formation of secondary and tertiary amines, which are often byproducts in other amination reactions.

In the Gabriel-Pthalimide synthesis, phthalimide (an imide derivative) is reacted with an alkyl halide in the presence of a base (such as potassium hydroxide, KOH) to perform an nucleophilic substitution. This reaction results in the formation of an N-alkylphthalimide intermediate. The next step involves the hydrolysis of this intermediate to release the primary amine and regenerate phthalic acid (which is typically removed). The reaction proceeds as follows:

$$\text{Phthalimide} + \text{R-Cl} \xrightarrow{\text{KOH}} \text{N-alkylphthalimide}$$

$$\text{N-alkylphthalimide} \xrightarrow{\text{Hydrolysis}} \text{Primary amine} + \text{Phthalic acid}$$

This method provides good yields of primary amines and is favored because it avoids the formation of unwanted amine byproducts. Additionally, Gabriel-Pthalimide synthesis is relatively simple and provides a high degree of purity for the primary amines produced.

Quick Tip

The Gabriel-Pthalimide synthesis is a preferred method for preparing primary amines because it avoids the formation of secondary and tertiary amines, which are commonly encountered in other synthetic routes.

(iii) Methyl amine gives precipitate of hydrated ferric oxide on reaction with ferric chloride in water.

Solution:

Methylamine (CH_3NH_2) is a weak base. When it reacts with ferric chloride ($FeCl_3$) in the presence of water, it forms a precipitate of hydrated ferric oxide. This occurs due to the basic nature of methylamine, which allows it to react with ferric ions (Fe^{3+}).

The reaction between methylamine and ferric chloride proceeds as follows: 1. Methylamine (CH_3NH_2) acts as a base and reacts with Fe^{3+} ions from ferric chloride. 2. The reaction produces a complex between the ferric ion and the amine. 3. The resulting complex leads to the formation of ferric hydroxide, which eventually dehydrates to form hydrated ferric oxide ($Fe_2O_3 \cdot xH_2O$), which appears as a precipitate.
The reaction can be represented as:

$$CH_3NH_2 + FeCl_3 + H_2O \rightarrow Fe_2O_3 \cdot xH_2O \text{ (precipitate)}$$

This reaction is a typical characteristic of amines reacting with ferric salts, where the basicity of the amine induces the precipitation of metal hydroxides or oxides.

Quick Tip

Amines, such as methylamine, react with ferric salts ($FeCl_3$) to form metal hydroxides, which can then dehydrate to produce ferric oxide, as seen in this reaction.
