Maharashtra 12 Chemistry 2023 Question Paper with Solutions

Time Allowed :3 Hours	**Maximum Marks :**80	**Total questions :**96

General Instructions

Important instructions:

1. Each activity has to be answered in complete sentence/s. One word answers will **not** be given complete credit. Just the correct activity number written in case of options will **not** be given credit.
2. Web diagrams, flow charts, tables etc. are to be presented exactly as they are with answers.
3. In point 2 above, just words without the presentation of the activity format/design, will **not** be given credit.
4. Use of colour pencils/pens etc. is **not** allowed. (Only blue/black pens are allowed.)
5. Multiple answers to the same activity will be treated as wrong and will **not** be given any credit.
6. Maintain the sequence of the Sections/ Question Nos./ Activities throughout the activity sheet.

1.i. The relation between radius of sphere and edge length in body centered cubic lattice is given by formula:

(A) $\sqrt{3}r = 4a$
(B) $r = \frac{\sqrt{3}}{4} \times a$
(C) $r = \frac{\sqrt{5}}{4} \times a$
(D) $r = \frac{\sqrt{2}}{4} \times a$

Correct Answer: (B) $r = \frac{\sqrt{3}}{4} \times a$

Solution:
Step 1: Understanding the body centered cubic lattice.
In a body centered cubic (BCC) lattice, the relationship between the edge length a and the radius r of the atom is given by the formula:

$$\sqrt{3}r = 4a$$

This comes from the geometry of the lattice, where the diagonal of the cube is equal to $4r$, and the body diagonal is related to the edge length by $\sqrt{3}a$.
Step 2: Solving for the radius.
Rearranging the formula:

$$r = \frac{\sqrt{3}}{4} \times a$$

Thus, the correct answer is (B).

Quick Tip

In a body centered cubic lattice, the relationship between the edge length and the radius of the atom is crucial for understanding crystal structures.

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ii. The pH of weak monoacidic base is 11.2, its OH^- ion concentration is:

(A) 1.585×10^{-3} mol dm^{-3}
(B) 3.010×10^{-11} mol dm^{-3}
(C) 3.010×10^{-3} mol dm^{-3}

(D) 1.585×10^{-11} mol dm^{-3}

Correct Answer: (A) 1.585×10^{-3} mol dm^{-3}

Solution:

Step 1: Use the pH and OH$^-$ concentration relationship.

We know that for a weak base, $pH + pOH = 14$. The pH is given as 11.2, so we calculate pOH:

$$pOH = 14 - pH = 14 - 11.2 = 2.8$$

Next, the OH$^-$ concentration is given by:

$$[OH^-] = 10^{-pOH} = 10^{-2.8} = 1.585 \times 10^{-3} \text{ mol dm}^{-3}$$

Thus, the correct answer is (A).

> Quick Tip
>
> To calculate the OH$^-$ concentration from pOH, use the formula $[OH^-] = 10^{-pOH}$.

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iii. Which of the following correctly represents the integrated rate law equation for a first order reaction in the gas phase?

(A) $k = \frac{2.303}{t} \times \log \frac{P_i}{P_i - P}$

(B) $k = \frac{2.303}{t} \times \log \frac{P_i}{2P_i - P}$

(C) $k = \frac{2.303}{t} \times \log \frac{2P_i}{P_i - P}$

(D) $k = \frac{2.303}{t} \times \log \frac{P_i - P}{2P_i}$

Correct Answer: (A) $k = \frac{2.303}{t} \times \log \frac{P_i}{P_i - P}$

Solution:

Step 1: Understand the integrated rate law for a first order reaction.

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

$$\ln \frac{P_i}{P_i - P} = kt$$

We can express this in log base 10 as:

$$\log \frac{P_i}{P_i - P} = \frac{kt}{2.303}$$

Rearranging for k:

$$k = \frac{2.303}{t} \times \log \frac{P_i}{P_i - P}$$

Thus, the correct answer is (A).

Quick Tip

For first-order reactions, the integrated rate law involves a logarithmic relationship between the concentration and time.

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iv. The spin only magnetic moment of Mn^{2+} ion is:

(A) 4.901 BM

(B) 5.916 BM

(C) 3.873 BM

(D) 2.846 BM

Correct Answer: (B) 5.916 BM

Solution:

Step 1: Understand the formula for magnetic moment.

The magnetic moment for a transition metal ion is given by the formula:

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

where n is the number of unpaired electrons. For Mn^{2+}, the electron configuration is $[Ar]3d^5$, so there are 5 unpaired electrons. Substituting into the formula:

$$\mu = \sqrt{5(5+2)} = \sqrt{35} = 5.916\,\text{BM}$$

Thus, the correct answer is (B).

Quick Tip

The magnetic moment is calculated using the number of unpaired electrons in the ion.

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v. The correct formula of a complex having IUPAC name Tetraaminedibromoplatinum (IV) bromide is:

(A) $[PtBr_2\ (NH_3)_4]$ Br

(B) $[PtBr_3\ (NH_3)_4]$ Br

(C) $[PtBr_2\ (NH_3)_4]\ Br_2$

(D) $[PtBr_3\ (NH_3)_4]\ Br_2$

Correct Answer: (A) $[PtBr_2\ (NH_3)_4]$ Br

Solution:

Step 1: Understand the IUPAC naming convention.

The IUPAC name "Tetraaminedibromoplatinum (IV) bromide" indicates the following: - "Tetraamine" refers to four ammonia molecules (NH_3) coordinated to the platinum ion. - "Dibromo" indicates two bromine atoms as ligands. - The platinum is in the +4 oxidation state, hence "platinum (IV)". - The bromide (Br) ion is a counter ion.

Step 2: Writing the formula.

The formula for this complex is:

$$[\mathrm{PtBr_2(NH_3)_4}]\mathrm{Br}$$

Thus, the correct answer is (A).

Quick Tip

When deciphering IUPAC names, focus on the coordination number and oxidation state to determine the formula.

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vi. The allylic halide, among the following is:

(A) $R - \text{CH} - R$

(B) $\text{CH}_2 - \text{CH} - \text{X}$

(C) $\text{C}_6\text{H}_5 - \text{X}$

(D) $\text{CH}_2 - \text{CH} - \text{CH}_2 - \text{X}$

Correct Answer: (B) $\text{CH}_2 - \text{CH} - \text{X}$

Solution:

Step 1: Understanding Allylic Halides.

Allylic halides are compounds where a halogen is attached to a carbon atom adjacent to a double bond (the allylic position). The structure $\text{CH}_2 - \text{CH} - \text{X}$ is an example of an allylic halide.

Step 2: Analyzing the Options.

- (A) $R - \text{CH} - R$: This is not an allylic halide because it doesn't have a halogen attached to the allylic carbon. - (B) $\text{CH}_2 - \text{CH} - \text{X}$: Correct. This is an allylic halide because the halogen is attached to the carbon next to the double bond. - (C) $\text{C}_6\text{H}_5 - \text{X}$: This is not an allylic halide because it is an aryl halide. - (D) $\text{CH}_2 - \text{CH} - \text{CH}_2 - \text{X}$: This is not an allylic halide because the halogen is not directly attached to an allylic carbon.

Thus, the correct answer is (B).

> **Quick Tip**
>
> Allylic halides have a halogen attached to a carbon adjacent to a double bond, which is key to their reactivity in substitution reactions.

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vii. The product of the following reaction is:

(A) $\text{CH}_3 - \text{CH} = \text{CH}_2 - \text{CH}_2 - \text{OH}$

(B) $\text{CH}_3 - \text{CH} - \text{CH}_2 - \text{CH}_2 - \text{OH}$

(C) $\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{COOH}$

(D) $\text{CH}_3 - \text{CH} = \text{CH}_2 - \text{COOH}$

Correct Answer: (A) $\text{CH}_3 - \text{CH} = \text{CH}_2 - \text{CH}_2 - \text{OH}$

Solution:

Step 1: Analyze the reaction.

The given reaction involves the reduction of an aldehyde ($CH_3 - CH = CH_2 - CHO$) with $LiAlH_4$, followed by hydrolysis with water. Lithium aluminum hydride ($LiAlH_4$) is a strong reducing agent that reduces aldehydes to primary alcohols.

Step 2: Determine the product.

Upon reduction of the aldehyde group and subsequent hydrolysis, the product is a primary alcohol:

$$CH_3 - CH = CH_2 - CH_2 - OH$$

Thus, the correct answer is (A).

Quick Tip

LiAlH4 is used to reduce aldehydes and ketones to alcohols, and the reaction is followed by hydrolysis.

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viii. Ozonolysis of 2, 3 dimethyl but-2-ene, followed by decomposition by Zn dust and water gives:

(A) acetaldehyde

(B) propionaldehyde and acetone

(C) acetaldehyde and butyraldehyde

(D) acetalaldehyde and butyraldehyde

Correct Answer: (B) propionaldehyde and acetone

Solution:

Step 1: Analyze the ozonolysis reaction.

Ozonolysis of an alkene involves the addition of ozone (O_3), followed by cleavage of the double bond. In this case, ozonolysis of 2, 3 dimethyl but-2-ene will break the carbon-carbon double bond.

Step 2: Products of ozonolysis.

The ozonolysis of 2, 3 dimethyl but-2-ene will produce two aldehydes:

$$CH_3CHO\,(\text{acetaldehyde}) \quad \text{and} \quad CH_3CO \quad (\text{acetone}).$$

After decomposition with Zn dust and water, the products will be acetaldehyde and acetone.
Thus, the correct answer is (B).

Quick Tip

Ozonolysis is commonly used to break alkenes into two carbonyl compounds, which can be aldehydes or ketones depending on the structure.

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ix. The glycosidic linkage present in maltose is:

(A) $\alpha, \beta - 1, 2$-glycosidic linkage
(B) $\alpha, \beta - 1, 4$-glycosidic linkage
(C) $\beta - 1, 4$-glycosidic linkage
(D) $\alpha - 1, 4$-glycosidic linkage

Correct Answer: (D) $\alpha - 1, 4$-glycosidic linkage

Solution:
Step 1: Understanding Maltose.
Maltose is a disaccharide consisting of two glucose molecules. The two glucose units are connected by an $\alpha - 1, 4$-glycosidic bond.
Step 2: Analyzing the linkage.
In maltose, the glycosidic linkage between the two glucose units is $\alpha - 1, 4$. This is a key feature of maltose.
Thus, the correct answer is (D).

Quick Tip

Glycosidic linkages are important in the structure of carbohydrates and play a significant role in their reactivity and properties.

x. The monomer of natural rubber is:

(A) Isoprene

(B) Acrylonitrile

(C) ε-Caprolactam

(D) Tetrafluoroethylene

Correct Answer: (A) Isoprene

Solution:

Step 1: Understand the structure of natural rubber.

Natural rubber is a polymer made from the monomer isoprene, which is a diene compound. The polymerization of isoprene molecules results in the formation of polyisoprene, commonly known as natural rubber.

Step 2: Identify the correct monomer.

The monomer of natural rubber is isoprene (C_5H_8).

Thus, the correct answer is (A).

> Quick Tip
>
> Natural rubber is made from isoprene units that undergo polymerization to form polyisoprene.

Q2. Answer the following questions:

i. Write the name of the technique used to know the geometry of nanoparticles.

Solution:

The technique commonly used to determine the geometry of nanoparticles is **Transmission Electron Microscopy (TEM)**. TEM allows for high-resolution imaging of the internal and external structure of nanoparticles, helping to determine their shape, size, and geometry.

Quick Tip

Transmission Electron Microscopy (TEM) is one of the most powerful tools to study the morphology and geometry of nanoparticles at the atomic level.

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ii. Write the name of the product formed by the action of $LiAlH_4$ ether on acetamide.

Solution:

The action of lithium aluminum hydride ($LiAlH_4$) in ether on acetamide reduces the amide group to the corresponding amine. In this case, acetamide (CH_3CONH_2) is reduced to ethylamine (CH_3NH_2).

The reaction is as follows:

$$CH_3CONH_2 \xrightarrow{LiAlH_4} CH_3NH_2$$

Thus, the product formed is ethylamine.

Quick Tip

Lithium aluminum hydride ($LiAlH_4$) is a strong reducing agent that reduces amides to amines.

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iii. Write the structure of the product formed when chlorobenzene is treated with sodium metal in the presence of dry ether.

Solution:

When chlorobenzene is treated with sodium metal in dry ether, the reaction follows the Wurtz-Fittig coupling mechanism. This leads to the formation of biphenyl (C_6H_5-C_6H_5).

The reaction is:

$$C_6H_5Cl + 2Na \xrightarrow{ether} C_6H_5\text{-}C_6H_5$$

Thus, the product formed is biphenyl with the structure:

$$C_6H_5\text{-}C_6H_5$$

Quick Tip

The Wurtz-Fittig coupling reaction between an aromatic halide and sodium metal in ether leads to the formation of biphenyl.

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iv. Write the chemical composition of cryolite.

Solution:

Cryolite is a mineral composed of sodium, aluminum, and fluoride. Its chemical composition is:

$$Na_3AlF_6$$

Thus, the chemical formula of cryolite is Na_3AlF_6.

Quick Tip

Cryolite is used in the extraction of aluminum, and its formula is Na_3AlF_6.

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v. Write the name of the platinum complex used in the treatment of cancer.

Solution:

The platinum complex used in the treatment of cancer is cisplatin. Its chemical name is cis-diamminedichloroplatinum(II).

Cisplatin is widely used as a chemotherapy drug for the treatment of various cancers, including ovarian, testicular, and bladder cancer.

Quick Tip

Cisplatin is a platinum-based chemotherapy drug, commonly used to treat various types of cancer.

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vi. Write the SI unit of cryoscopic constant.

Solution:

The cryoscopic constant, also known as the freezing point depression constant, is used to calculate the depression in freezing point when a solute is added to a solvent. The SI unit of the cryoscopic constant is:

$$\mathrm{K} \cdot \mathrm{kg/mol}$$

This unit corresponds to the change in freezing point per unit molality (moles of solute per kilogram of solvent).

Quick Tip

The cryoscopic constant has units of $\mathrm{K} \cdot \mathrm{kg/mol}$, which relates to the freezing point depression in a solution.

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vii. Write the correct condition for spontaneity in terms of Gibbs energy.

Solution:

The condition for spontaneity of a process in terms of Gibbs free energy (G) is given by:

$$\Delta G = \Delta H - T\Delta S$$

For a process to be spontaneous, the change in Gibbs free energy must be negative:

$$\Delta G < 0$$

Thus, the correct condition for spontaneity is:

$$\Delta G < 0$$

Quick Tip

A process is spontaneous if the change in Gibbs free energy, ΔG, is negative.

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viii. Calculate the molar conductivity for 0.5 M $BaCl_2$ if its conductivity at 298K is 0.01 $\Omega^{-1}\mathrm{cm}^{-1}$.

Solution:

Step 1: Molar conductivity (Λ_m) is related to the conductivity (κ) and the molarity (C) by the formula:

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

Step 2: Given:

$$\kappa = 0.01\,\Omega^{-1}\text{cm}^{-1}, \quad C = 0.5\,\text{M}$$

Step 3: Calculate the molar conductivity:

$$\Lambda_m = \frac{0.01}{0.5} = 0.02\,\Omega^{-1}\text{cm}^2\text{mol}^{-1}$$

Thus, the molar conductivity is:

$$\boxed{0.02\,\Omega^{-1}\text{cm}^2\text{mol}^{-1}}$$

Quick Tip

Molar conductivity is calculated by dividing the conductivity of the solution by its molarity.

Q3. Distinguish between lanthanides and actinides.

Solution:

The lanthanides and actinides are two series of elements found in the periodic table. Below is the distinction between them:

1. Lanthanides: - Lanthanides are elements with atomic numbers from 57 to 71 (from Lanthanum to Lutetium). - They are also known as rare earth elements. - They are f-block elements and are located in the 4f orbital. - Lanthanides have a typical oxidation state of +3. - They are less radioactive compared to actinides. - Lanthanides are commonly used in catalysts, phosphors, and magnets.

2. Actinides: - Actinides are elements with atomic numbers from 89 to 103 (from Actinium to Lawrencium). - They are also f-block elements but are located in the 5f orbital. - Actinides are radioactive and most of them are unstable. - They commonly exhibit a wide

range of oxidation states, with +3, +4, and +6 being common. - Actinides are important in nuclear energy applications, such as Uranium and Plutonium.

Quick Tip

The key difference is that lanthanides are less radioactive and mainly have a +3 oxidation state, whereas actinides are highly radioactive and can have multiple oxidation states.

Q4. Calculate the mole fraction of solute, if the vapour pressure of pure benzene at certain temperature is 640 mmHg and vapour pressure of solution of a solute in benzene is 600 mmHg.

Solution:

Step 1: According to Raoult's Law, the vapour pressure of a solution is given by:

$$P_{\text{solution}} = P_{\text{solvent}} \times X_{\text{solvent}} + P_{\text{solute}} \times X_{\text{solute}}$$

Where: - P_{solution} is the vapour pressure of the solution. - P_{solvent} is the vapour pressure of the pure solvent. - X_{solvent} and X_{solute} are the mole fractions of the solvent and solute, respectively.

Step 2: The equation can be rewritten as:

$$P_{\text{solution}} = P_{\text{solvent}} \times X_{\text{solvent}}$$

Since the solute has no vapour pressure, we can ignore the second term.

Step 3: Rearranging the equation to solve for the mole fraction of the solute X_{solute}:

$$P_{\text{solution}} = P_{\text{solvent}}(1 - X_{\text{solute}})$$

$$X_{\text{solute}} = 1 - \frac{P_{\text{solution}}}{P_{\text{solvent}}}$$

Step 4: Substitute the given values:

$$X_{\text{solute}} = 1 - \frac{600\,\text{mmHg}}{640\,\text{mmHg}} = 1 - 0.9375 = 0.0625$$

Thus, the mole fraction of the solute is:

$$\boxed{0.0625}$$

Quick Tip

To find the mole fraction of the solute, use the relationship between vapour pressures and mole fractions given by Raoult's Law.

Q5. Define Green chemistry. Write two advantages of nanoparticles and nanotechnology.

Solution:

1. Green Chemistry: Green chemistry is the design of chemical processes and products that reduce or eliminate the use and generation of hazardous substances. The primary focus is on sustainable practices, minimizing waste, reducing energy consumption, and using renewable resources.

Key Principles of Green Chemistry: - Waste prevention, not treatment. - Atom economy, where all atoms in the reactants end up in the products. - Use of renewable feedstocks.

2. Advantages of Nanoparticles and Nanotechnology: - Enhanced Chemical Reactivity: Nanoparticles have a high surface area to volume ratio, which increases their reactivity. This makes them useful in catalysis, drug delivery, and environmental cleanup. - Improved Material Properties: Nanotechnology can improve the strength, durability, and conductivity of materials, which is beneficial for electronics, medical devices, and manufacturing.

Quick Tip

Green chemistry aims to make chemical processes more environmentally friendly by focusing on sustainability and reducing hazards.

Q6. Explain the following terms:

- Substitutional impurity defect
- Interstitial impurity defect

Solution:
1. Substitutional Impurity Defect: A substitutional impurity defect occurs when an atom in the crystal lattice is replaced by an atom of a different element. This replacement causes a disturbance in the lattice structure. The impurity atom may be of a different size or charge, leading to changes in the properties of the material. For example, when sodium ions replace some of the potassium ions in a potassium chloride crystal, a substitutional impurity defect is created.
2. Interstitial Impurity Defect: An interstitial impurity defect happens when an atom occupies a space (interstice) between the regular atoms in the crystal lattice. The impurity atom is smaller than the host atoms and fits into the voids in the lattice. This defect can cause distortions in the lattice and affect the material's properties. For example, when small atoms like hydrogen or carbon are introduced into the interstitial sites of a metal lattice, an interstitial impurity defect is formed.

Quick Tip

Substitutional defects involve replacing atoms in the lattice, while interstitial defects involve inserting smaller atoms into the interstitial spaces.

Q7. Write the chemical reactions for the following:

- Chlorobenzene is heated with fuming H_2SO_4
- Ethyl bromide is heated with silver acetate

Solution:
1. Chlorobenzene is heated with fuming H_2SO_4: When chlorobenzene is heated with fuming sulfuric acid (H_2SO_4), a sulfonation reaction takes place, where a sulfonic group (-SO_3H) is introduced into the benzene ring at the position of the chlorine atom.

The reaction is as follows:

$$C_6H_5Cl + H_2SO_4 \xrightarrow{\text{fuming } H_2SO_4} C_6H_4ClSO_3 + H_2O$$

In this reaction, chlorobenzene reacts with fuming H_2SO_4 to form 2-chlorobenzenesulfonic acid ($C_6H_4ClSO_3$).

2. Ethyl bromide is heated with silver acetate: When ethyl bromide (C_2H_5Br) is heated with silver acetate (AgOAc), an esterification reaction occurs, leading to the formation of ethyl acetate (C_2H_5OAc) and the release of silver bromide (AgBr).

The reaction is as follows:

$$C_2H_5Br + AgOAc \rightarrow C_2H_5OAc + AgBr$$

In this reaction, ethyl bromide reacts with silver acetate to form ethyl acetate and silver bromide.

Quick Tip

In electrophilic aromatic substitution, sulfonation of chlorobenzene introduces a -SO3H group. In nucleophilic substitution, ethyl bromide reacts with silver acetate to form an ester.

Q8. Define: Acidic buffer solution. Write the relationship between solubility and solubility product for PbI_2.

Solution:

1. Acidic Buffer Solution: An acidic buffer solution is a solution that resists changes in its pH when small amounts of acid or base are added. It is made by mixing a weak acid and its conjugate base (or a salt of the weak acid) in appropriate concentrations. The buffer maintains a relatively constant pH even when acidic or basic substances are introduced. A common example of an acidic buffer is a solution of acetic acid (CH_3COOH) and sodium acetate (CH_3COONa).

2. Relationship between Solubility and Solubility Product for PbI_2: The solubility product K_{sp} for lead iodide (PbI_2) is a constant at a given temperature and describes the equilibrium between solid PbI_2 and its ions in solution.

The dissociation of PbI_2 in water can be represented as:

$$PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2I^-(aq)$$

The solubility product expression is:

$$K_{sp} = [Pb^{2+}][I^-]^2$$

Let the solubility of PbI_2 be s mol/L. At equilibrium, the concentration of Pb^{2+} will be s, and the concentration of I^- will be $2s$. Therefore, the solubility product can be written as:

$$K_{sp} = s \cdot (2s)^2 = 4s^3$$

So, the solubility of PbI_2 is related to the solubility product by:

$$s = \left(\frac{K_{sp}}{4}\right)^{1/3}$$

Thus, the solubility of PbI_2 is the cube root of K_{sp} divided by 4.

Quick Tip

In an acidic buffer, the weak acid and its conjugate base control the pH. The solubility of sparingly soluble salts like PbI_2 can be calculated using its solubility product K_{sp}.

Q9. What is the action of the following reagents on ethylamine?

- Chloroform and caustic potash
- Nitrous acid

Solution:

1. Chloroform and Caustic Potash on Ethylamine: When ethylamine ($C_2H_5NH_2$) reacts with chloroform ($CHCl_3$) in the presence of caustic potash (KOH), a reaction occurs forming an isocyanide (also known as an isonitrile). The reaction is:

$$C_2H_5NH_2 + CHCl_3 + KOH \rightarrow C_2H_5NC + KCl + H_2O$$

The product is ethyl isocyanide (C_2H_5NC).

2. Nitrous Acid on Ethylamine: When ethylamine reacts with nitrous acid (HNO_2), it undergoes diazotization to form a diazonium salt. The reaction is:

$$C_2H_5NH_2 + HNO_2 \rightarrow C_2H_5N_2^+Cl^- + H_2O$$

The product is ethyl diazonium chloride.

Quick Tip

Ethylamine reacts with chloroform and caustic potash to form isocyanides, and with nitrous acid to form diazonium salts.

Q10. Calculate standard Gibbs energy change at 25°C for the cell reaction

$$\mathrm{Cd(s)} + \mathrm{Sn}^{2+}_{(aq)} \rightleftharpoons \mathrm{Cd}^{2+}_{(aq)} + \mathrm{Sn(s)}$$

Given:

$$E^\circ_{\text{cd}} = -0.403V, \quad E^\circ_{\text{sn}} = -0.136V$$

Solution:

Step 1: The standard Gibbs free energy change ΔG° is related to the standard cell potential E°_{cell} by the equation:

$$\Delta G^\circ = -nFE^\circ_{\text{cell}}$$

Where: - n is the number of moles of electrons transferred. - F is the Faraday constant ($96485\,$C/mol). - E°_{cell} is the standard cell potential.

Step 2: Calculate E°_{cell}. For the cell reaction:

$$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$$

Here: - The cathode is where reduction occurs (Cd^{2+} to Cd). - The anode is where oxidation occurs (Sn to Sn^{2+}).

$$E^\circ_{\text{cell}} = E^\circ_{\text{Cd}} - E^\circ_{\text{Sn}} = (-0.403\,\mathrm{V}) - (-0.136\,\mathrm{V}) = -0.403 + 0.136 = -0.267\,\mathrm{V}$$

Step 3: For this reaction, 2 electrons are transferred ($n = 2$).

Step 4: Now calculate the Gibbs free energy change:

$$\Delta G^\circ = -2 \times 96485 \times (-0.267)\,\text{J/mol}$$

$$\Delta G^\circ = 2 \times 96485 \times 0.267 = 51571.5\,\text{J/mol} = 51.57\,\text{kJ/mol}$$

Thus, the standard Gibbs energy change is:

$$\boxed{\Delta G^\circ = 51.57\,\text{kJ/mol}}$$

Quick Tip

To calculate Gibbs free energy change from cell potential, use the relation $\Delta G^\circ = -nFE^\circ_{\text{cell}}$.

Q11. Write the chemical reaction for the preparation of glucose from sucrose. Write structure of D-ribose.

Solution:

1. Preparation of Glucose from Sucrose: Sucrose (a disaccharide) can be hydrolyzed to give glucose and fructose. This is a simple hydrolysis reaction that requires an acid or enzyme for catalysis. The chemical reaction is:

$$\text{C}_12\text{H}_22\text{O}_{11} \xrightarrow{\text{acid}} \text{C}_6\text{H}_12\text{O}_6 + \text{C}_6\text{H}_12\text{O}_6$$

Sucrose ($\text{C}_12\text{H}_22\text{O}_{11}$) breaks down into glucose ($\text{C}_6\text{H}_12\text{O}_6$) and fructose ($\text{C}_6\text{H}_12\text{O}_6$) under acidic conditions.

2. Structure of D-Ribose: D-Ribose is a five-carbon monosaccharide (pentose sugar) with an aldehyde group. Its structure is:

$$\text{HOCH}_2\text{(CHOH)}_3\text{CHO}$$

The structure shows the hydroxyl groups on the second, third, and fourth carbon atoms, and an aldehyde group on the first carbon.

Quick Tip

Hydrolysis of sucrose gives glucose and fructose, while D-ribose is a pentose sugar with a characteristic aldehyde group.

Q12. Define Extensive property. Calculate the work done during the expansion of 2 moles of an ideal gas from 10 dm^{3}to 20 dm^{3}at 298 K in vacuum.

Solution:

1. Extensive Property: An extensive property is a physical property that depends on the amount or size of the substance in the system. Examples include mass, volume, and energy. These properties change as the size or amount of material in the system changes.

2. Work Done by the Gas: The work done by an ideal gas during expansion or compression is given by the formula:

$$W = -P\Delta V$$

Where: - W is the work done by the gas. - P is the pressure of the gas (which is constant in this case since it's a vacuum). - ΔV is the change in volume.

Since the expansion occurs in vacuum, there is no external pressure opposing the expansion ($P = 0$). Thus, the work done is:

$$W = 0 \times (V_f - V_i) = 0$$

Thus, the work done during the expansion is:

$$\boxed{0}$$

Quick Tip

Work is only done when there is an opposing pressure. In a vacuum, there is no external pressure, so the work done by the gas is zero.

Q13. Write the reactions for the formation of nylon 6,6 polymer.

Solution:

Nylon 6,6 is a synthetic polymer made by the condensation reaction between hexamethylenediamine and adipic acid. The reaction is a type of step-growth polymerization, and the formation of the polymer is as follows:

The chemical reaction is:

$$\text{Hexamethylenediamine}(H_2N{-}CH_2CH_2CH_2CH_2CH_2NH_2)+\text{Adipic acid}(HOOC{-}CH_2CH_2COOH) \rightarrow N$$

The reaction occurs in two steps: 1. The amine group of hexamethylenediamine reacts with the carboxyl group of adipic acid to form an amide linkage, releasing water. 2. This reaction repeats to form long polymer chains of nylon 6,6.

$$H_2N{-}CH_2CH_2CH_2CH_2CH_2NH_2+HOOC{-}CH_2CH_2COOH \rightarrow \text{[-NH-(CH}_2)_6\text{-NH-CO-(CH}_2)_4\text{-CO-]}_n+n$$

Thus, nylon 6,6 is formed by the condensation polymerization of hexamethylenediamine and adipic acid.

Quick Tip

Nylon 6,6 is formed by a condensation reaction between hexamethylenediamine and adipic acid, releasing water in the process.

Q14. Draw structures of the following compounds:

- Chloric acid
- Peroxy disulfuric acid

Solution:

1. Chloric Acid: Chloric acid has the chemical formula $HClO_3$. Its structure is:

$$HO - Cl = O - O - O$$

In this structure, the chlorine atom is bonded to three oxygen atoms, with one of the oxygens being bonded to a hydrogen atom.

2. Peroxy Disulfuric Acid: Peroxy disulfuric acid has the chemical formula $H_2S_2O_8$. Its structure is:

$$HO_3S - O - O - SO_3H$$

In this structure, the sulfur atoms are connected by an oxygen-oxygen bond, and each sulfur is bonded to three oxygens, one of which is bonded to a hydrogen atom.

Quick Tip

Chloric acid ($HClO_3$) has a central chlorine atom bonded to three oxygen atoms. Peroxy disulfuric acid ($H_2S_2O_8$) contains two sulfur atoms connected by an oxygen-oxygen bond.

---

15. Define Osmosis. How will you determine the molar mass of a non-volatile solute by elevation of boiling point?

Solution:

Step 1: Define Osmosis.

Osmosis is the movement of solvent molecules from a region of lower solute concentration to a region of higher solute concentration, through a semi-permeable membrane. This continues until equilibrium is reached.

Step 2: Molar Mass Determination by Boiling Point Elevation.

The relationship between the boiling point elevation (ΔT_b) and molality (m) of a solution is given by:

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

Where: - ΔT_b is the boiling point elevation, - K_b is the ebullioscopic constant of the solvent, - m is the molality of the solution.

To calculate the molar mass, rearrange the formula to find:

$$\text{Molar Mass} = \frac{m_{\text{solvent}} \cdot \Delta T_b}{K_b \cdot n_{\text{solute}}}$$

Quick Tip

Boiling point elevation is directly proportional to the molality of the solution. Higher molality means a higher boiling point elevation. Ensure correct units for accurate calculations.

---

16. Convert the following: i. Ethyl alcohol into ethyl acetate

ii. Phenol into benzene

iii. Diethyl ether into ethyl chloride

Solution:

i. Ethyl Alcohol into Ethyl Acetate:

To convert ethyl alcohol (ethanol) into ethyl acetate, you need to perform an esterification reaction. This is done by reacting ethanol with acetic acid (CH_3COOH) in the presence of sulfuric acid (H_2SO_4):

$$CH_3CH_2OH + CH_3COOH \xrightarrow{H_2SO_4} CH_3COOCH_2CH_3 + H_2O$$

ii. Phenol into Benzene:

Phenol can be converted into benzene via reduction. The most common method is by using zinc dust in a reduction reaction:

$$C_6H_5OH \xrightarrow{Zn,heat} C_6H_6$$

iii. Diethyl Ether into Ethyl Chloride:

To convert diethyl ether to ethyl chloride, you can perform a substitution reaction using hydrochloric acid (HCl):

$$C_2H_5O - C_2H_5 + HCl \rightarrow C_2H_5Cl + C_2H_5OH$$

Quick Tip

In organic synthesis, identify the type of reaction (like esterification or reduction) and the suitable reagents (like acids or catalysts) to successfully convert one compound into another.

17. A weak monobasic acid is 10% dissociated in 0.05 M solution. What is the percent dissociation in 0.15 M solution?

Solution:

Step 1: Use the formula for dissociation.

The dissociation of a weak acid is governed by the equation:

$$\alpha = \sqrt{\frac{K_a \cdot C}{1 + \alpha}}$$

Where K_a is the dissociation constant, C is the concentration of the acid, and α is the degree of dissociation.

Step 2: Given information.

The acid is 10% dissociated at 0.05 M, so we can use this to calculate K_a.

$$\alpha = \frac{10}{100} = 0.1$$

Now we can substitute into the dissociation equation to find the value of K_a. Once K_a is calculated, use it to determine the dissociation at 0.15 M by substituting into the dissociation equation again.

Quick Tip

To calculate percent dissociation, always use the concentration at which the dissociation constant is given, then solve for the new dissociation at the target concentration using the relationship between K_a and concentration.

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18. Explain the dehydrohalogenation reaction of 2-chlorobutane. Write use and environmental effect of CFC.

Solution:

Step 1: Dehydrohalogenation of 2-Chlorobutane.

The dehydrohalogenation reaction involves the elimination of a hydrogen atom and a halogen atom (chlorine) from a compound. In 2-chlorobutane, the reaction occurs in the presence of a strong base like potassium hydroxide (KOH) to form 2-butene:

$$C_4H_9Cl + KOH \rightarrow C_4H_8 + KCl + H_2O$$

This follows an E2 elimination mechanism, where both the base and substrate react simultaneously.

Step 2: Use and Environmental Effect of CFCs.

Chlorofluorocarbons (CFCs) were once widely used as refrigerants, solvents, and in aerosol propellants. However, their use has been phased out due to their role in ozone layer depletion. CFCs break down ozone molecules in the stratosphere, leading to increased UV radiation reaching Earth, which causes skin cancer, cataracts, and other health issues.

Quick Tip

CFCs have been phased out under the Montreal Protocol due to their harmful environmental effects, particularly in depleting the ozone layer. Always check if a chemical has eco-friendly alternatives.

---

19. 2000 mmol of an ideal gas expanded isothermally and reversibly from 20 L to 30 L at 300 K, calculate the work done in the process (R = 8.314 J K^{-1} mol^{-1}).

Solution:

For an isothermal and reversible expansion, the work done by an ideal gas is given by the equation:

$$W = -nRT \ln\left(\frac{V_f}{V_i}\right)$$

Where: - n is the number of moles of gas, - R is the universal gas constant, - T is the temperature, - V_f and V_i are the final and initial volumes, respectively.

Step 1: Convert moles of gas to mols.

Given that the number of moles is 2000 mmol = 2 mol, the formula becomes:

$$W = -2 \times 8.314 \times 300 \ln\left(\frac{30}{20}\right)$$

Step 2: Simplify the equation.

$$W = -2 \times 8.314 \times 300 \ln(1.5)$$

Step 3: Calculate the work done.

$$W = -2 \times 8.314 \times 300 \times 0.4055$$

$$W = -2014.5\,\mathrm{J}$$

Thus, the work done is $-2014.5\,\mathrm{J}$. The negative sign indicates work is done by the gas.

Quick Tip

For isothermal and reversible processes, the work done is dependent on the volume change and temperature. Always ensure that the temperatures and volumes are in the correct units for accurate calculation.

---

20. What are interstitial compounds? Give the classification of alloys with examples.

Solution:

Step 1: Interstitial Compounds.

Interstitial compounds are compounds formed when small atoms such as hydrogen, carbon, or nitrogen occupy the interstitial spaces between the larger metal atoms in a metal lattice. These compounds are typically hard and have high melting points, as the smaller atoms create strain in the lattice.

Step 2: Classification of Alloys.

Alloys can be classified into two main categories: - Substitutional alloys: The atoms of the alloying element replace the metal atoms in the host structure. Example: Brass (Cu-Zn alloy). - Interstitial alloys: The atoms of the alloying element occupy the interstitial spaces between the metal atoms. Example: Steel (Fe-C alloy).

Quick Tip

When studying alloys, note that substitutional alloys have atoms that replace the host metal atoms, while interstitial alloys have smaller atoms that fit into the interstitial spaces of the metal lattice.

---

21. Draw labelled diagram of H_2 - O_2 fuel cell. Write two applications of fuel cell.

Solution:

Step 1: Labelled Diagram of H_2 - O_2 Fuel Cell.

The diagram of a hydrogen-oxygen fuel cell consists of an anode where hydrogen is oxidized and a cathode where oxygen is reduced. The electrolyte between the anode and cathode conducts ions, and the external circuit conducts the electrons generated from the reaction.

Step 2: Applications of Fuel Cell.

- Power generation for vehicles: Fuel cells are used in electric vehicles to provide clean energy. - Backup power sources: Fuel cells are used as backup power sources in remote areas where regular electricity supply is unavailable.

Quick Tip

Fuel cells provide an efficient, clean, and environmentally friendly energy source by generating electricity through the reaction of hydrogen and oxygen without producing harmful emissions.

---

22. Explain formation of $[CoF_6]^{3-}$ complex with respect to i. Hybridisation ii. Magnetic properties iii. Inner/outer complex iv. Geometry

Solution:

i. Hybridisation:

In the complex $[CoF_6]^{3-}$, cobalt is in the +3 oxidation state (Co^{3+}), which has an electronic configuration of [Ar] $3d^6$. The Co^{3+} ion undergoes sp^3d^2 hybridization to form six bonds with fluoride ions.

ii. Magnetic Properties:

The $[CoF_6]^{3-}$ complex has no unpaired electrons because all the electrons are paired in the $3d$ orbitals. Therefore, the complex is diamagnetic.

iii. Inner/Outer Complex:

The fluoride ions in $[CoF_6]^{3-}$ are considered ligands that directly coordinate with the cobalt ion, so this is an inner complex.

iv. Geometry:

The geometry of the $[CoF_6]^{3-}$ complex is octahedral, as the six fluoride ions are arranged symmetrically around the central cobalt ion.

Quick Tip

In coordination complexes, the geometry and magnetic properties depend on the metal ion's oxidation state, the ligands, and their arrangement. Understanding the hybridization and electron configuration helps determine these properties.

---

23. What is Pseudo first order reaction? Derive integrated rate law equation for zero order reaction.

Solution:

Pseudo First-Order Reaction:

A reaction that is not actually first-order but behaves as if it were first-order is called a pseudo-first-order reaction. This typically occurs when one of the reactants is in excess and its concentration remains almost constant during the reaction, making the reaction rate depend only on the concentration of the limiting reactant.

For example, the hydrolysis of an ester in water is a second-order reaction overall but is often treated as a pseudo-first-order reaction if the concentration of water is in large excess.

Step 1: Zero Order Integrated Rate Law.

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

$$\text{Rate} = k$$

Where k is the rate constant. The integrated rate law for a zero-order reaction is derived from the equation:

$$\frac{d[A]}{dt} = -k$$

Integrating with respect to time:

$$\int_{[A]_0}^{[A]} d[A] = -k \int_0^t dt$$

$$[A] - [A]_0 = -kt$$

$$[A] = [A]_0 - kt$$

This is the integrated rate law for a zero-order reaction.

Quick Tip

For zero-order reactions, the concentration decreases linearly with time, and the slope of the concentration vs. time graph is equal to $-k$.

---

24. Explain Aldol condensation of ethanal.

Solution:

The Aldol Condensation is a reaction in which an enolate ion attacks the carbonyl carbon of an aldehyde or ketone to form a -hydroxy aldehyde or ketone, which then undergoes dehydration to form an ,-unsaturated carbonyl compound.

Step 1: Aldol Addition Reaction.

When ethanal (acetaldehyde, CH_3CHO) undergoes the Aldol addition, the enolate ion formed from one molecule of ethanal reacts with another molecule of ethanal:

$$CH_3CHO + CH_3CHO \xrightarrow{OH^-} CH_3CH(OH)CH_2CHO$$

This forms -hydroxybutanal, also known as an Aldol addition product.

Step 2: Dehydration to form Aldol Condensation Product.

The -hydroxy aldehyde undergoes elimination of water, resulting in the formation of an ,-unsaturated aldehyde:

$$CH_3CH(OH)CH_2CHO \xrightarrow{heat} CH_3CH = CHCHO$$

This product, crotonaldehyde, is the result of the Aldol condensation.

Quick Tip

Aldol condensation reactions are widely used in organic synthesis to form carbon-carbon bonds, particularly in the synthesis of ,-unsaturated carbonyl compounds.

---

25. Explain anomalous behaviour of oxygen in group 16 with respect to: i. Atomicity ii. Magnetic property iii. Oxidation state

Solution:

i. Atomicity:

In group 16, oxygen exists as a diatomic molecule (O_2), unlike other elements in the group, such as sulfur, which exist in polyatomic forms. Oxygen's small size, high electronegativity, and the ability to form strong bonds lead it to exist as a diatomic molecule.

ii. Magnetic Properties:

Oxygen (O_2) is paramagnetic, meaning it has unpaired electrons. This is due to the presence of two unpaired electrons in its molecular orbital configuration, which makes it attract a magnetic field.

iii. Oxidation State:

Oxygen shows an oxidation state of -2 in most of its compounds, but it can also exhibit positive oxidation states, such as +1 in peroxide (O_2^{2-}) and +2 in oxygen difluoride (OF_2). The tendency of oxygen to exhibit positive oxidation states is an anomaly compared to other elements in group 16.

Quick Tip

Oxygen's unique magnetic properties (paramagnetic behavior) and its ability to exhibit various oxidation states make it different from other elements in group 16.

---

26. Write chemical reactions for the following conversions: i. Acetic acid into acetic anhydride ii. Acetic acid into ethyl alcohol Write IUPAC name and structure of methylphenylamine.

Solution:

i. Acetic Acid into Acetic Anhydride:

Acetic acid can be converted into acetic anhydride by dehydration in the presence of a dehydrating agent such as phosphorus pentachloride (PCl_5):

$$2CH_3COOH \xrightarrow{PCl_5} (CH_3CO)_2O + 2HCl$$

This forms acetic anhydride.

ii. Acetic Acid into Ethyl Alcohol:

Acetic acid can be reduced to ethyl alcohol (ethanol) using reducing agents such as lithium aluminium hydride ($LiAlH_4$):

$$CH_3COOH \xrightarrow{LiAlH_4} CH_3CH_2OH$$

This is the reduction of acetic acid to ethanol.

iii. IUPAC Name and Structure of Methylphenylamine:

The IUPAC name of methylphenylamine is N-methylaniline. Its structure is as follows:

$$\mathrm{C_6H_5NHCH_3}$$

Quick Tip

In organic chemistry, always ensure that the reagents are suitable for the transformation you want to achieve (e.g., using PCl_5 for dehydration, and $LiAlH_4$ for reductions).

---

27. Show that, time required for 99.9% completion of a first order reaction is three times the time required for 90% completion. Give electronic configuration of Gd (Z = 64). Write the name of nano structured material used in car tyres to increase the life of tyres.

Solution:

Step 1: First Order Integrated Rate Law.

For a first-order reaction, the integrated rate law is:

$$\ln\left(\frac{[A]_0}{[A]}\right) = kt$$

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

Step 2: Time for 90% Completion.

For 90% completion, the concentration of the reactant is 10% of its initial concentration:

$$\ln\left(\frac{[A]_0}{0.1[A]_0}\right) = kt_{90}$$

$$\ln(10) = kt_{90}$$

$$t_{90} = \frac{\ln(10)}{k}$$

Step 3: Time for 99.9% Completion.

For 99.9% completion, the concentration of the reactant is 0.1% of its initial concentration:

$$\ln\left(\frac{[A]_0}{0.001[A]_0}\right) = kt_{99.9}$$

$$\ln(1000) = kt_{99.9}$$

$$t_{99.9} = \frac{\ln(1000)}{k} = 3 \times t_{90}$$

Thus, the time required for 99.9% completion is three times the time required for 90% completion.

Step 4: Electronic Configuration of Gd (Z = 64).

The electronic configuration of Gd (Z = 64) is:

$$\text{Gd} : [Xe]4f^7 5d^1 6s^2$$

Step 5: Nano Structured Material in Tyres.

The nano-structured material used in car tyres to increase their life is silica.

Quick Tip

In first-order reactions, the time for completion is logarithmic, and the time for higher completion (such as 99.9%) increases significantly compared to lower completion (like 90%).

28. Derive relationship between ΔH and ΔU for gaseous reaction. Define: Vulcanization What is peptide bond?

Solution:

Step 1: Relationship between ΔH and ΔU for Gaseous Reaction.

The relationship between enthalpy change (ΔH) and internal energy change (ΔU) for a gaseous reaction is:

$$\Delta H = \Delta U + \Delta n_g RT$$

Where: - ΔH is the change in enthalpy, - ΔU is the change in internal energy, - Δn_g is the change in the number of moles of gas, - R is the gas constant, - T is the temperature.

Step 2: Vulcanization.

Vulcanization is the process of cross-linking polymer chains, typically rubber, by adding sulfur. This process improves the elasticity, strength, and durability of the material, making it suitable for use in tyres and other rubber products.

Step 3: Peptide Bond.

A peptide bond is the covalent bond formed between two amino acids when the carboxyl group of one amino acid reacts with the amino group of another, releasing a molecule of water. This bond is a fundamental link in protein structure.

Quick Tip

For gaseous reactions, the change in volume (Δn_g) directly affects the relationship between enthalpy and internal energy. Vulcanization is crucial for improving material properties in rubber.

---

29. Silver crystallizes in fcc structure. If edge length of unit cell is 400 pm, calculate density of silver (Atomic mass of Ag = 108). Write a note on Halform reaction.

Solution:

Step 1: Formula for Density of a Cubic Unit Cell.

The density (ρ) of a crystal is given by the formula:

$$\rho = \frac{Z \cdot M}{N_A \cdot V}$$

Where: - Z is the number of atoms per unit cell (for fcc structure, $Z = 4$), - M is the molar mass of the substance (108 g/mol for silver), - N_A is Avogadro's number (6.022×10^{23} atoms/mol), - V is the volume of the unit cell.

Step 2: Volume of the Unit Cell.

For fcc structure, the edge length a is related to the volume V of the unit cell:

$$V = a^3$$

Where $a = 400\,\text{pm} = 400 \times 10^{-12}\,\text{m}$.

The volume of the unit cell is:

$$V = (400 \times 10^{-12})^3 = 6.4 \times 10^{-29}\,\text{m}^3$$

Step 3: Calculate the Density.

Substitute the values into the density formula:

$$\rho = \frac{4 \cdot 108\,\text{g/mol}}{6.022 \times 10^{23} \cdot 6.4 \times 10^{-29}\,\text{m}^3}$$

$$\rho = 10.5\,\text{g/cm}^3$$

Thus, the density of silver is $10.5\,\text{g/cm}^3$.

Step 4: Halform Reaction.

The Haloform reaction is a chemical reaction where a haloform (CHCl3, CHBr3, or CHI3) is produced when a methyl group is attached to a carbonyl group, typically in the presence of halogens. For example, when chloroform is reacted with a base, it forms chloroform and a carboxylate ion:

$$CH_3CH(OH)COOH + 3Cl_2 \rightarrow CHCl_3 + \text{carboxylate ion}$$

Quick Tip

For fcc crystals, the density depends on the number of atoms per unit cell and the edge length. In the Haloform reaction, halogenation occurs at the methyl group adjacent to a carbonyl group.

---

30. Define: Stereoisomers. Give cis and trans isomers of $[Co(NH_3)_4Cl_2]^+$. What is reference electrode?

Solution:

Step 1: Stereoisomers Definition.

Stereoisomers are isomers that have the same molecular formula and the same connectivity of atoms, but differ in the spatial arrangement of atoms or groups. They can be of two types: - Geometrical isomers (cis-trans isomers), - Optical isomers (enantiomers).

Step 2: Cis and Trans Isomers of $[Co(NH_3)_4Cl_2]^+$.

In the complex $[Co(NH_3)_4Cl_2]^+$, the cis and trans isomers refer to the spatial arrangement of the chloride ions around the central metal ion: - Cis Isomer: The two chloride ions are adjacent to each other.

$$\text{Cis:Cl-Co-Cl}$$

- Trans Isomer: The two chloride ions are opposite each other.

$$\text{Trans:Cl-Co-Cl}$$

Step 3: Reference Electrode.

A reference electrode is an electrode that maintains a constant potential and is used to measure the potential of another electrode in electrochemical cells. Examples include the standard hydrogen electrode (SHE) and the silver/silver chloride electrode.

Quick Tip

Stereoisomers differ in the spatial arrangement of atoms, and this difference plays a crucial role in their chemical behavior, especially in coordination chemistry.

---

31. Write Dow process for preparation of Phenol. What is the action of bromine water on phenol? Give reason: Group 16th elements have lower ionization enthalpy compared to group 15th elements. Write two uses of dioxygen.

Solution:

Step 1: Dow Process for Preparation of Phenol.

The Dow process involves the chlorination of benzene to form benzene hexachloride (also known as "Lindane") which is then treated with sodium hydroxide to produce phenol:

$$\mathrm{C_6H_6} + \mathrm{Cl_2} \xrightarrow{\mathrm{FeCl_3}} \mathrm{C_6H_5Cl_6}$$

$$\mathrm{C_6H_5Cl_6} + 6NaOH \rightarrow \mathrm{C_6H_5OH} + 6NaCl$$

This yields phenol (C_6H_5OH).

Step 2: Action of Bromine Water on Phenol.

When phenol reacts with bromine water, it undergoes electrophilic substitution to form 2,4,6-tribromophenol:

$$C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$$

The bromine atoms are added to the ortho and para positions of the phenol ring.

Step 3: Ionization Enthalpy Comparison.

Group 16 elements have lower ionization enthalpy compared to group 15 elements because: - Group 16 elements have a lower effective nuclear charge due to the additional electron in the p-orbital, making the outer electrons easier to remove. - Group 15 elements, being nitrogen, phosphorus, arsenic, etc., have a half-filled p-orbital which is more stable, resulting in higher ionization enthalpy.

Step 4: Uses of Dioxygen.

- Respiration: Dioxygen is essential for respiration in most aerobic organisms. - Combustion: Dioxygen supports combustion and is used in various industrial processes like steelmaking.

Quick Tip

The Dow process is one of the main industrial methods for preparing phenol, and bromine water reacts with phenol to form a tribromophenol due to electrophilic aromatic substitution.