CBSE EXAMINATION PAPER-2024

CHEMISTRY

(Solved)

Time allowed : 3 hours | Maximum Marks : 74

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **37 questions.** All questions are **compulsory.**

ii. This question paper is divided into **5 sections.**

iii. **Section A** – questions number **1 to 3** are case based questions

iv. **Section B** – questions number **4 to 19** are multiple choice questions

v. **Section C** – questions number **20 to 25** are very short answer

vi. **Section D** – questions number **26 to 32** are short answer

vii. **Section E** – questions number **33 to 37** are long answer

viii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.

ix. Use of calculator is NOT allowed.

Section A

Question 1. The oxidation number of the central atom in a complex is defined as the charge it would carry if all the ligands are removed along with the electron pairs that are shared with the central atom. Similarly, the charge on the complex is the sum of the charges of the constituent parts i.e. the sum of the charges on the central metal ion and its surrounding ligands. Based on this, the complex is called neutral if the sum of the charges of the constituents is equal to zero. However, for an anionic or cationic complex, the sum of the charges of the constituents is equal to the charge on the coordination sphere. Based on the above information, answer the following questions.

Question 2.

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

The oxidation number of the central atom in a complex is defined as the charge it would carry if all the ligands are removed along with the electron pairs that are shared with the central atom. Similarly the charge on the complex is the sum of the charges of the constituent parts Le. the sum of the charges on the central metal ion and its surrounding ligands. Based on this, the complex is called neutral if the sum of the charges of the constituents is equal to zero. However, for an anion or cationic complex, the sum of the charges of the constituents is equal to the charge on the coordination sphere.

Based on the above information, answer the following questions:

(1)

Define ambidentate ligand with an example.

[1 Marks]

Answer: Ambidentate ligand is a ligand that can coordinate to the central metal atom through two different atoms but only one at a time. For example, the ligand NO_2^- can bind through nitrogen or oxygen atom, showing ambidentate behavior as per the definition in the passage.

Key Points: Ambidentate ligand - Coordinates through two different atoms - Example NO2- that binds through N or O

(2)

What type of isomerism is shown by $[Co(NH_3)_5, CL]SO_4$, and $[Co(NH_3)_5\ SO_4]CL$?

[1 Marks]

Answer: Answer: The complexes $[Co(NH_3)_5Cl]SO_4$ and $[Co(NH_3)_5SO_4]Cl$ show ionisation isomerism as explained in the passage. This is because the ion attached outside the coordination sphere switches places with the ion inside the coordination sphere, changing the composition but not the formulas of ions. Ionisation isomerism is a kind of isomerism where the complex ions exchange ligands with counter ions.

Key Points: Ionisation isomerism - ligands inside/outside coordination sphere exchanged - change in ionic composition

(3)

Find the coordination number and oxidation state of chromium in $Na_3 (Cr(C_2O_4)_3]$.

[2 Marks]

Answer: Coordination number: The oxalate ion (C_2O_4) is a bidentate ligand, meaning it binds through two sites. Since there are three oxalate ligands, total coordination number = 3*2 = 6.

Oxidation state of chromium: Sodium (Na) has +1 charge and there are 3 Na^+ ions, giving +3 overall. The complex is neutral, so charge on complex ion is -3. Each oxalate ligand has -2 charge, so total charge from ligands = 3*(-2) = -6. Let oxidation state of Cr be x. Then, x + (-6) = -3 gives x = +3.

Hence, the coordination number is 6 and oxidation state of chromium is +3, as indicated based on the sum of charges from the case passage.

Key Points: Oxalate is bidentate ligand coordination number 6 - Sum of charges on ligands and metal ion equals charge on complex - Oxidation state of chromium is +3

(4)

Define Chelate effect. How it affects the stability of complex?

[2 Marks]

Answer: Chelate effect is the increased stability of a complex ion when a ligand forms more than one bond to the central metal ion, creating a ring structure called a chelate.

This effect increases stability because the ligand binds through multiple atoms, making the complex harder to break apart.

As per the case, the overall charge and bonding affect the complex stability, and chelate ligands help enhance this stability by forming multiple bonds with the metal ion.

Key Points: Chelate effect involves ligands forming multiple bonds with central metal ion - Forms ring structures called chelates - Increases stability of complexes by making dissociation harder

Question 3.

Certain organic compounds are required in small amounts in our diet but their deficiency causes specific disease. These compounds are called vitamins. Most of the vitamins cannot be synthesized in our body but plants can synthesize almost all of them. So they are considered as essential food

factors. However, the bacteria of the gut can produce some of the vitamins required by us. All the vitamins are generally available in our diet. The term 'vitamin' was coined from the words vital amine. since the earlier identified compounds had amino group. Vitamins are classified into two groups depending upon their solubility in water or fat namely fat soluble vitamins and water soluble vitamins.

Answer the following questions :

(1)

What is the other name of vitamin B_6?

[1 Marks]

Answer: The other name of vitamin B_6 is Pyridoxine. It belongs to the group of water soluble vitamins and is essential for various metabolic functions in the body as mentioned in the case about different vitamins required for normal maintenance of health.

Key Points: Vitamin B6 is also called Pyridoxine - It is a water soluble vitamin - Essential for metabolic functions

(2)

Name the vitamin whose deficiency causes increased blood clotting time.

[1 Marks]

Answer: Vitamin K is the vitamin whose deficiency causes increased blood clotting time. It is produced by bacteria in our gut and is essential for proper blood coagulation. A lack of vitamin K leads to bleeding problems as mentioned in the case passage.

Key Points: Vitamin K - Deficiency causes increased blood clotting time - Produced by gut bacteria

(3)

Why can't vitamin C be stored in our body? Name the disease caused by the deficiency of this vitamin.

[2 Marks]

Answer: Vitamin C is a water soluble vitamin, which means it dissolves in water and cannot be stored in our body for long periods as excess amounts are excreted through urine. Because of this, we need to consume it regularly through our diet. Deficiency of vitamin C causes a disease called scurvy, which results in weakness, bleeding gums, and slow healing of wounds. This is explained in the case passage where water soluble vitamins must be supplied regularly since they are not stored in the body.

Key Points: Vitamin C is water soluble - It cannot be stored in the body - Deficiency causes scurvy

(4)

Xerophthalmia is caused by the deficiency of which vitamin? Give two sources of this vitamin.

[2 Marks]

Answer: Xerophthalmia is caused by the deficiency of vitamin A, which is a fat soluble vitamin as mentioned in the case paragraph. Vitamin A is essential for healthy vision and the maintenance of skin and mucous membranes. Two common dietary sources of vitamin A are carrots and green leafy vegetables. Including these in our diet helps prevent diseases caused by vitamin A deficiency such as xerophthalmia.

Key Points: Xerophthalmia is caused by vitamin A deficiency - Vitamin A is a fat soluble vitamin - Sources of vitamin A include carrots and green leafy vegetables

Section B

Question 4.

The specific sequence in which amino acids are arranged in a protein is called its

[1 Marks]

(A) Secondary structure

(B) Tertiary structure

(C) Primary structure

(D) Quaternary structure

Explanation:

The correct answer is 'Primary structure' because the primary structure of a protein refers to the specific sequence of amino acids that make up the protein chain. This sequence is crucial as it determines the protein's unique characteristics and function.

Question 5.

The correct name of the given reaction is

[1 Marks]

$$\mathrm{Ar-N_2^+X^-} \xrightarrow{\mathrm{Cu\ CN/KCN}} \mathrm{Ar-CN + N_2}$$

(A) Sandmeyer's reaction

(B) Gabriel Phthalimide synthesis

(C) Hoffmann bromamide degradation reaction

(D) Carbyl amine reaction

Explanation:

The correct answer is Sandmeyer's reaction. This reaction involves the replacement of the diazonium group by a cyanide ion (CN-) in the presence of cuprous cyanide (CuCN) and is a well-known method for introducing functional groups into aromatic compounds.

Question 6.

Out of the following alkenes, the one which will produce tertiary butyl alcohol on acid catalysed hydration is

[1 Marks]

(A) CH_3-CH=CH-CH_3

(B) $(CH_3)_2C=CH_2$

(C) $CH_3CH_2CH=CH_2$

(D) $CH_3CH=CH_2$

Explanation:

The correct option is $(CH_3)_2C=CH_2$. This alkene, also known as isobutylene, upon acid-catalyzed hydration follows Markovnikov's rule. The hydrogen attaches to the less substituted carbon (the double bond), and the hydroxyl group attaches to the more substituted carbon, resulting in the formation of tertiary butyl alcohol.

Question 7.

Auto-oxidation of chloroform in air and light produces a poisonous gas known as

[1 Marks]

(A) Phosgene

(B) Tear gas

(C) Mustard gas

(D) Phosphine

Explanation:

The correct option is Phosgene. When chloroform undergoes auto-oxidation in the presence of air and light, it can produce phosgene, which is a highly toxic gas. Other options like tear gas, mustard gas, and phosphine are not products of chloroform's auto-oxidation.

Question 8.

Transition metals are known to make interstitial compounds. Formation of interstitial compounds makes the transition metal

[1 Marks]

(A) more metallic

(B) more ductile

(C) more hard

(D) more soft

Explanation:

The correct option is 'more hard'. Interstitial compounds are formed when small atoms fill the interstitial spaces between the larger metal atoms. This can lead to an increase in hardness and strength of the material, making it more difficult to deform compared to the pure metal.

Question 9.

Isotonic solutions have the same

[1 Marks]

(A) volume

(B) osmotic pressure

(C) density

(D) refractive index

Explanation:

The correct option is 'osmotic pressure' because isotonic solutions are defined as solutions that have the same osmotic pressure, which means they exert equal pressure across a semipermeable membrane, preventing water movement in or out of the cells.

Question 10.

Which of the following cell was used in Apollo space programme?

[1 Marks]

(A) Ni-Cd cell

(B) Dry cell

(C) H_2-O_2 fuel cell

(D) Mercury cell

Explanation:

The correct answer is H_2-O_2 fuel cell. The Apollo space program utilized hydrogen-oxygen fuel cells to produce electricity and water for the spacecraft, making them essential for the missions.

Question 11.

The rate of a reaction increases sixteen times when the concentration of the reactant increases four times. The order of the reaction is

[1 Marks]

(A) 2.0

(B) 2.5

(C) 1.5

(D) 0.5

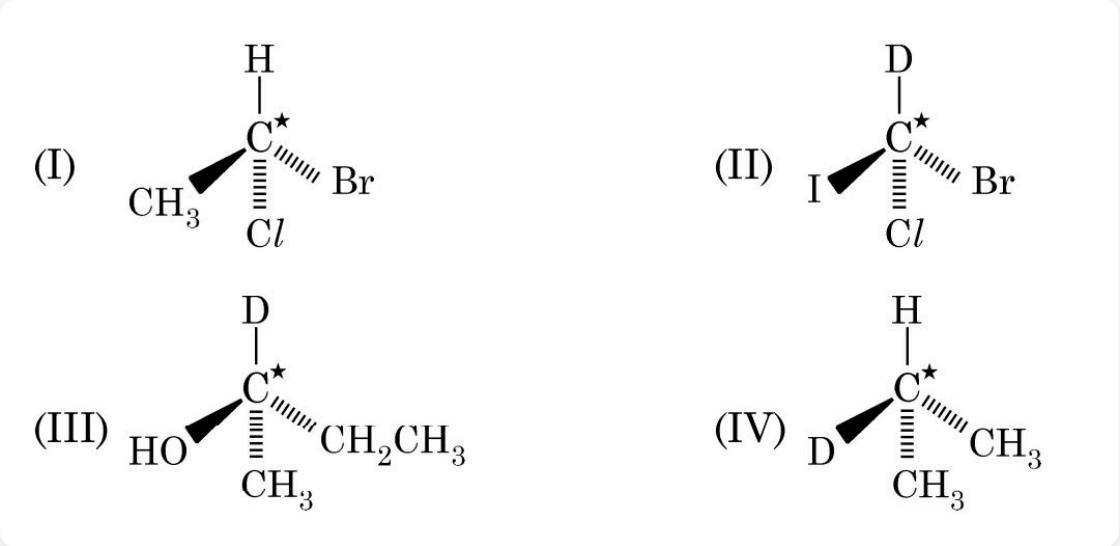
Explanation:

The order of the reaction can be calculated using the rate law. If the concentration is increased by a factor of 4 and the rate increases by a factor of 16, we can use the equation Rate ∝ [A]^n. Here, 4^n = 16. Solving for n gives us n = 2, meaning the order of the reaction is 2.0.

Question 12.

In which of the following molecules, C atom marked with asterisk is chiral?

[1 Marks]



(A) I,II,III,IV

(B) I,II,III,

(C) II, III,IV

(D) I, III, IV

Explanation: The correct answer is III because the C atom marked with an asterisk in molecule III has four different groups attached to it, making it a chiral center. Molecules I, II, and IV either do not have four different substituents around the marked C or have symmetry that prevents chirality. Additionally, the context mentions that structure III has a branched chain, which is more likely to possess asymmetry and chirality compared to the straight chains in I and II.

Question 13.

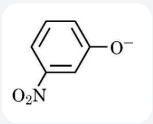
Which of the following species can act as the strongest base?

[1 Marks]

(A) RO^-

(B) OH^-

(C)



(D) $C_6H_5O^-$

Explanation:

RO^- is the strongest base among the options because it is an alkoxide ion, which is a conjugate base of an alcohol. It has a high tendency to accept protons due to the presence of a less electronegative oxygen atom compared to OH^- (hydroxide) and $C_6H_5O^-$ (phenoxide), making it a stronger base.

Question 14.

Dilution affects both conductivity as well as molar conductivity. Effect of dilution on both is as follows

[1 Marks]

(A) both decrease with dilution

(B) both increase with dilution

(C) conductivity increases whereas molar conductivity decreases on dilution

(D) conductivity decreases whereas molar conductivity increases on dilution

Explanation:

The correct option is 'conductivity decreases whereas molar conductivity increases on dilution.' When a solution is diluted, the concentration of ions decreases, which reduces conductivity. However, molar conductivity, which is the conductivity per unit concentration, increases because the ability of ions to move freely increases in a more dilute solution.

Question 15.

Van't Hoff factor for $Na_2SO_4 \cdot 10H_2O$ solution, assuming complete ionization is

[1 Marks]

(A) 3

(B) 13

(C) 2

(D) 1

Explanation:

The correct option is 13. Na_2SO_4 dissociates into 2 Na^+ ions and 1 SO_4^{2-} ion, giving a total of 3 particles for each formula unit. Therefore, for Na_2SO_4, the van't Hoff factor (i) would normally be 3. Additionally, since $Na_2SO_4 \cdot 10H_2O$ includes water of hydration, it contributes an additional 10 water molecules, bringing the total van't Hoff factor to 3 + 10 = 13.

Question 16.

Assertion (A): Zr and Hf are of almost similar atomic radii.

Reason (R): This is due to Lanthanoid contraction.

[1 Marks]

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

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

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

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

Explanation:

Both Assertion (A) and Reason (R) are true, and Reason (R) is the correct explanation of the Assertion (A). The atomic radii of zirconium (Zr) and hafnium (Hf) are similar due to the lanthanoid contraction, which decreases the size of the lanthanide ions and subsequently affects the size of the elements in the same group of the periodic table.

Question 17.

Assertion (A): The units of rate constant of a zero order reaction and rate of reaction are the same

Reason (R): In a zero order reaction, the rate of reaction is independent of the concentration of reactants.

[1 Marks]

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

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

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

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

Explanation:

Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). In a zero order reaction, the rate is constant and the units of the rate constant (k) are the same as the units of rate of reaction (e.g., mol/L/s), but the independence of the rate from reactant concentration does not explain the equality of units.

Question 18.

Assertion (A): Inversion of configuration is observed in SN_2 reaction.

Reason (R): The reaction proceeds with the formation of a carbocation.

[1 Marks]

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

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

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

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

Explanation:

Assertion (A) is true, but Reason (R) is false. The S_2 reaction (bimolecular nucleophilic substitution) indeed leads to an inversion of configuration; however, it does not involve the formation of a carbocation, which is characteristic of S_1 reactions. Therefore, while the assertion about the S_2 reaction is correct, the reasoning does not support it.

Question 19.

Assertion (A): p-methoxyphenol is a stronger acid than p-nitrophenol.

Reason (R): Methoxy group shows +I effect whereas nitro group shows -I effect.

[1 Marks]

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

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

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

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

Explanation:

Assertion (A) is false, but Reason (R) is true. p-Nitrophenol is actually a stronger acid than p-methoxyphenol due to the electron-withdrawing -I effect of the nitro group, which stabilizes the negative charge of the phenoxide ion more effectively than the +I effect of the methoxy group destabilizes it.

Section C

Question 20.

State:

(a) Kohlrausch law of independent migration of ions.

(b) Faraday's first law of electrolysis.

[2 Marks]

Answer: (a) Kohlrausch law of independent migration of ions: The total molar conductivity of an electrolyte at infinite dilution is equal to the sum of the contributions of the individual ions. Mathematically, $\Lambda_m^\circ = \lambda_{cation}^\circ + \lambda_{anion}^\circ$, where λ° is the limiting molar ionic conductivity of each ion.
(b) Faraday's first law of electrolysis: The mass of a substance deposited or liberated at an electrode during electrolysis is directly proportional to the quantity of electricity passed through the electrolyte. It means more the electricity, more the amount of substance produced at the electrode.

Key Points: Kohlrausch law states molar conductivity at infinite dilution - sum of ionic conductivities - Faraday's first law states mass deposited proportional to charge passed - explains electrolysis quantitatively

Question 21. Classify the following sugars into monosaccharides and disaccharides: Galactose, Glucose, Lactose, and Maltose.

[2 Marks]

Answer: Monosaccharides: Galactose and Glucose are monosaccharides because they are single sugar units and cannot be hydrolyzed into simpler sugars.
Disaccharides: Lactose and Maltose are disaccharides because they are made up of two monosaccharide units chemically bonded. Lactose consists of one galactose and one glucose unit, while Maltose consists of two glucose units joined together.

> **Key Points: Galactose is a monosaccharide - Glucose is a monosaccharide - Lactose is a disaccharide composed of galactose and glucose - Maltose is a disaccharide composed of two glucose molecules**

Question 22.

Carry out the following conversions:

(i) Nitrobenzene to Aniline

(ii) Aniline to Phenol.

[2 Marks]

Answer: (i) Nitrobenzene to Aniline: Nitrobenzene on reduction with Sn / HCl or Fe / HCl or Zn / HCl is converted into Aniline ($C_6H_5NH_2$). The nitro group ($-NO_2$) is reduced to an amino group ($-NH_2$).
(ii) Aniline to Phenol: Aniline is first diazotized by reacting with $NaNO_2$ and HCl at 0-5 deg C to form benzenediazonium chloride. Then, on warming with water, diazonium group is replaced by hydroxyl group, producing Phenol (C_6H_5OH).

> **Key Points: Reduction of nitrobenzene produces aniline - Diazotization of aniline forms diazonium salt - Hydrolysis of diazonium salt gives phenol**

Question 23.

(i) Write a chemical test to distinguish between Dimethyl amine and Ethanamine.

(ii) Write the product formed when benzene diazonium chloride is treated with KI.

[2 Marks]

Answer: (i) To distinguish between dimethyl amine and ethanamine, perform Hinsberg test. Ethanamine reacts with Hinsberg reagent (benzene sulfonyl chloride) to form a soluble sulfonamide easily separated on acidification. Dimethyl amine gives an insoluble sulfonamide as it is a secondary amine.
(ii) Benzene diazonium chloride reacts with KI to form iodobenzene and nitrogen gas as per the equation:

$C_6H_5N_2^+Cl^- + KI \rightarrow C_6H_5I + N_2\uparrow + KCl$

The product is **iodobenzene**.

> **Key Points: Hinsberg test distinguishes primary and secondary amines - Ethanamine is primary amine - Dimethyl amine is secondary amine - Benzene diazonium chloride reacts with KI - Product formed is iodobenzene and nitrogen gas**

Question 24.

Show that in case of a first order reaction, the time taken for completion of 99% reaction is twice the time required for 90% completion of the reaction. (log 10 = 1)

[2 Marks]

Answer: Solution:

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

$\ln([R]_0/[R]) = kt$

where $[R]_0$ is the initial concentration and $[R]$ is the concentration at time t.

Let t_{90} be the time for 90% completion, so 10% reactant remains:

$[R] = 0.1 [R]_0$

$\ln([R]_0/0.1 [R]_0) = k t_{90}$

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

Using log 10 = 1, $\ln(10) = 2.303 * 1 = 2.303$

So, $k t_{90} = 2.303$

Let t_{99} be the time for 99% completion, so 1% reactant remains:

$[R] = 0.01 [R]_0$

$\ln([R]_0/0.01 [R]_0) = k t_{99}$

$\ln(100) = k t_{99}$

$\ln(100) = 2.303 * 2 = 4.606$

So, $k t_{99} = 4.606$

Dividing the two equations:

$(k t_{99}) / (k t_{90}) = 4.606 / 2.303 = 2$

Therefore, $t_{99} / t_{90} = 2$

Hence, the time taken for 99% completion is twice the time taken for 90% completion for a first order reaction.

> **Key Points: Integrated rate law for first order - Calculation of time for 90% completion - Calculation of time for 99% completion - Relation $t_{99} = 2 * t_{90}$**

Question 25.

Resistance of a conductivity cell filled with 0.2 mol L^{-1} KCI solution is 200 Ω. If the resistance of the same cell when filled with 0.05 mol L^{-1} KCI solution is 620 Ω, calculate the conductivity and molar conductivity of 0.05 mol L^{-1} KC/ solution. The conductivity of 0.2 mol L^{-1} KCl solution is 0.0248 S cm^{-1}.

[2 Marks]

Answer: Given Data:

Resistance with 0.2 mol L^{-1} KCl, R_1 = 200 Ω

Resistance with 0.05 mol L^{-1} KCl, R_2 = 620 Ω

Conductivity of 0.2 mol L^{-1} KCl, κ_1 = 0.0248 S cm^{-1}

Step 1: Calculate Cell Constant (G*):

Cell constant $G^* = \kappa_1 * R_1 = 0.0248 * 200 = 4.96\ cm^{-1}$

Step 2: Calculate Conductivity (κ_2) of 0.05 mol L^{-1} KCl:

$\kappa_2 = G^* / R_2 = 4.96 / 620 = 0.008$ S cm^{-1}

Step 3: Calculate Molar Conductivity (λ_m):

Molarity, c = 0.05 mol L^{-1}

$\lambda_m = (\kappa_2 / c) * 1000 = (0.008 / 0.05) * 1000 = 160$ S cm^2 mol^{-1}

Final Answer:

Conductivity = 0.008 S cm^{-1}

Molar conductivity = 160 S cm^2 mol^{-1}

Key Points: Resistance and conductivity relation - Calculation of cell constant - Calculation of conductivity and molar conductivity

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Section D

Question 26.

Give the structure of the major product expected from the following reactions:

(a) Reaction of Ethanal with methyl-magnesium bromide followed by hydrolysis.

(b) Hydration of But-1-ene in the presence of dilute sulphuric acid.

(c) Reaction of phenol with bromine water.

[3 Marks]

Answer: (a) Ethanal (CH_3CHO) reacts with methyl-magnesium bromide (CH_3MgBr) which acts as a nucleophile, attacking the electrophilic carbonyl carbon, forming a magnesium alkoxide intermediate. Subsequent hydrolysis converts it to a secondary alcohol, specifically 2-propanol (CH_3-CH(OH)-CH_3).

(b) Hydration of But-1-ene in the presence of dilute sulphuric acid follows Markovnikov's rule where the H^+ adds to the carbon with more hydrogens and OH attaches to the other carbon. The major product is Butan-2-ol (CH_3-CH(OH)-CH_2-CH_3).

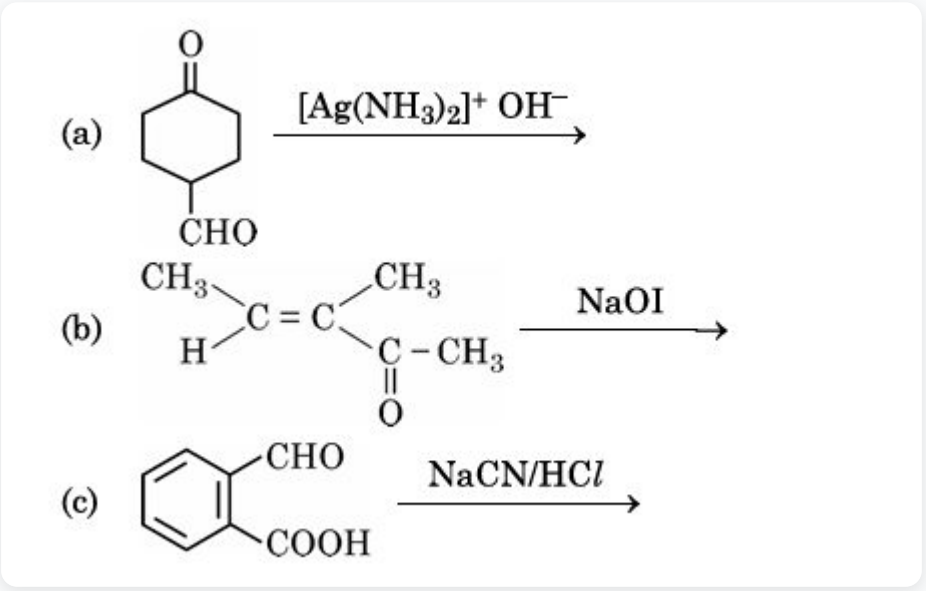
(c) Reaction of phenol with bromine water results in electrophilic aromatic substitution, where bromine substitutes at the ortho and para positions due to activating effect of OH group. The major product is 2,4,6-tribromophenol where three bromine atoms attach to the ortho and para positions of phenol ring, appearing as white precipitate.

Key Points: Reaction of aldehyde with Grignard reagent followed by hydrolysis forms secondary alcohol-Markovnikov addition in alkene hydration-Phenol undergoes electrophilic substitution with bromine giving 2,4,6-tribromophenol

Question 27.

Draw the structures of major product(s) in each of the following reactions

[3 Marks]



Answer: (a) **Mononitration of 3-methylphenol:** 3-methylphenol has an -OH group and a methyl group at position 3 on the benzene ring. The -OH group is an activating ortho/para directing group and the methyl group is also ortho/para directing but less activating compared to -OH. On mononitration with HNO_3/H_2SO_4, the major product is nitration at the position ortho to the -OH group but meta to the methyl group, which is position 2 on the ring. The major product is 2-nitro-3-methylphenol.

(b) **Dinitration:** When dinitration is carried out on 3-methylphenol under harsher conditions, two nitro groups attach preferentially at positions ortho and para to the -OH group since it is a strong activating group. Positions 2 and 4 (with respect to -OH) get nitrated leading to 2,4-dinitro-3-methylphenol as the

major product. The methyl group at position 3 influences substitution pattern but the strong activation by -OH dominates.

In summary, mononitration mainly gives 2-nitro-3-methylphenol whereas dinitration forms 2,4-dinitro-3-methylphenol as the major products. The directing effect of -OH group determines substitution positions in these electrophilic aromatic substitution reactions. Structures can be drawn showing benzene ring with OH at position 1, methyl at position 3 and nitro groups at the substituted positions.

Key Points: 3-methylphenol structure - OH directing effect ortho/para - mononitration gives 2-nitro-3-methylphenol - dinitration gives 2,4-dinitro-3-methylphenol

Question 28.

Calculate the emf of the following cell:

$Ni(s) + 2Ag^{+}(0.01\ M) \rightarrow Ni^{2+}\ (0.1\ M)\ 2Ag(s)$

Given that E°cell= 1.05 V, log 10 =1

[3 Marks]

Answer: The cell reaction is: $Ni(s) + 2Ag^{+}(0.01\ M) \rightarrow Ni^{2+}(0.1\ M) + 2Ag(s)$.
Given E°cell = 1.05 V and using the Nernst equation: Ecell = E°cell - (0.0592/n) * log Q.
Here, n = 2 (number of electrons transferred).
Reaction quotient $Q = [Ni^{2+}]/[Ag^{+}]^2 = 0.1 / (0.01)^2 = 0.1 / 0.0001 = 1000$.
Calculate log Q = log 1000 = 3.
Substitute values: Ecell = 1.05 - (0.0592/2) * 3 = 1.05 - 0.0888 = 0.9612 V.
Therefore, emf of the cell is approximately 0.96 V.

Key Points: Identify cell reaction - Write Nernst equation - Calculate reaction quotient Q - Substitute values to find emf - Final emf = 0.96 V

Question 29.

The rate constant of a reaction quadruples when the temperature changes from 300 K to 320 K. Calculate the activation energy for this reaction. [log2 =0.30, log 4=0.60, 2.303 R =19.15 J K^{-1} mol^{-1}]

[3 Marks]

Answer: Given: k2 / k1 = 4, T1 = 300 K, T2 = 320 K, log 4 = 0.60, 2.303 R = 19.15 J K-1 mol-1
Using Arrhenius equation ratio form:
log(k2 / k1) = (Ea / 2.303 R) * (1 / T1 - 1 / T2)
Substitute values:
0.60 = (Ea / 19.15) * (1/300 - 1/320)

Calculate (1/300 - 1/320): (1/300) = 0.003333 and (1/320) = 0.003125
Difference = 0.000208
So,
0.60 = (Ea / 19.15) * 0.000208
Rearranging:
Ea = 0.60 * 19.15 / 0.000208 = 55240.87 J/mol = 55.24 kJ/mol
Therefore, the activation energy Ea is approximately 55.24 kJ/mol.

Key Points: Arrhenius equation ratio formula - Calculation of reciprocal temperature difference - Correct substitution and simplification to find Ea

Question 30.

A compound X with molecular formula C_3H_9N reacts with $C_6H_5SO_2Cl$ to give a solid, insoluble in alkali. Identify 'X' and give the IUPAC name of the product. Write the reaction involved.

[3 Marks]

Answer: The compound X with the molecular formula C3H9N is propylamine (C3H7NH2). When propylamine reacts with benzenesulfonyl chloride ($C6H5SO_2Cl$), it forms propylbenzenesulfonamide, which is a solid and insoluble in alkali. The reaction involves the nucleophilic attack of the amine on the sulfonyl chloride, resulting in the formation of the sulfonamide product. The balanced reaction is: $C3H9N + C6H5SO_2Cl \rightarrow C3H7SO_2C6H5 + HCl$, where propylbenzenesulfonamide is the final product.

Key Points: Identify propylamine as X; reaction with benzenesulfonyl chloride; product is propylbenzenesulfonamide; reaction produces HCl.

Question 31.

Write the IUPAC names of the following coordination compounds :

(a) $[Co(NH_3)_4Cl(NO_2)]Cl$

(b) $[Ni(NH_3)_6]Cl_2$

(c) $K_3[Cr(C_2O_4)_3]$

(d) $[Co(en)_2Br_2]^+$

[3 Marks]

Answer: (a) The complex ion is $[Co(NH_3)_4Cl(NO_2)]^+$ with one chloride ion outside. The ligands are 4 ammine (NH_3), 1 chlorido (Cl), and 1 nitro (NO_2) ligand. The name is Tetraamminechloridonitro cobalt(III) chloride.
(b) The complex ion is $[Ni(NH_3)_6]^+$ with 2 chloride ions outside the complex ion. The ligand is 6

ammine (NH_3). The metal oxidation state is +2. The name is Hexaammine nickel(II) chloride.
(c) The complex ion is $[Cr(C_2O_4)_3]^{-}$ with 3 potassium ions outside. The ligand is 3 oxalato (C_2O_4) ligands. The metal oxidation state is +3. The name is Potassium trioxalatochromate(III).
(d) The complex ion is $[Co(en)_2Br_2]^{+}$ with overall positive charge. The ligands are 2 ethane-1,2-diamine (en) which are bidentate, and 2 bromido (Br) ligands. The metal oxidation state is +4. The name is Diethane-1,2-diamine dibromidocobalt(IV) ion.

Key Points: Identify ligands and their prefixes - Determine oxidation state of metal ion - Name ligands alphabetically before metal name - Specify charge and counter ions properly

Question 32.

Account for the following:

(a) Haloalkanes react with AgCN to form isocyanide as main product.

(b) Allyl chloride shows high reactivity towardsSn1 reaction.

(c) Haloarenes are extremely lesa reactive towards nucleophilic substitution reactions.

[3 Marks]

Answer: (a) Haloalkanes react with AgCN to form isocyanides because AgCN is covalent in nature, allowing the nitrogen atom in the cyanide group to act as the nucleophile and attack the haloalkane. This leads to isocyanides (isonitriles) where nitrogen is bonded to the alkyl group. In contrast, KCN is ionic and the carbon atom attacks to form alkyl cyanides.
(b) Allyl chloride shows high reactivity towards SN1 reactions because the carbocation intermediate formed after the departure of chloride ion is resonance stabilized. The positive charge is delocalized over the allyl group, making the carbocation more stable and favoring SN1 mechanism.
(c) Haloarenes are less reactive towards nucleophilic substitution due to the strong resonance between the aromatic ring and the halogen. This delocalizes the lone pair of electrons on halogen into the ring, making the C–X bond stronger and less reactive. Also, the planar structure and partial double bond character hinder nucleophilic attack.

Key Points: AgCN forms covalent bond leading to nitrogen attack and isocyanides product - Allyl carbocation is resonance stabilized increasing SN1 reactivity - Haloarenes resonance stabilize halogen lone pairs making C–X bond strong and less reactive

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Section E

Question 33.

Attempt any five of the following:

(a) Ce(III) is easily oxidised to Ce(IV). Comment.

(b) $E°(Mn^{2+}/Mn)$ is -1.18 V. Why is this value highly negative in comparison to neighboring d-block elements?

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

(d) What happens when sodium chromate is acidified ?

(e) Zn, Cd and Hg are soft metals. Why?

(f) Why is permanganate titration not carried out in the presence of HCl?

(g) The lower oxides of transition metals are basic whereas the highest are amphoteric/acidic. Give reason.

[5 Marks]

Answer: (a) Ce(III) is easily oxidised to Ce(IV) because Ce(IV) has a stable electronic configuration due to the empty 4f orbital and the high charge density of Ce(IV) stabilizes the oxidation state. Hence Ce(III) readily loses an electron to form Ce(IV).

(b) $E°(Mn^{2+}/Mn)$ is highly negative (-1.18 V) because manganese in metallic form is very stable and the Mn^{2+} ion has a half-filled d^5 configuration which makes it relatively stable. Also, the large hydration energy of Mn^{2+} does not compensate enough for the energy required to form Mn atom leading to negative reduction potential compared to neighbors.

(c) The element with the lowest enthalpy of atomisation in the 3d series is manganese. This is because Mn has a half-filled d^5 configuration giving extra stability to the atoms and the metallic bonding is weaker, so less energy is needed to break the metal atoms.

(d) When sodium chromate (Na_2CrO_4) is acidified, it forms sodium dichromate ($Na_2Cr_2O_7$) as the yellow chromate ion (CrO_4^{2-}) changes to the orange dichromate ion ($Cr_2O_7^{2-}$) in acidic medium:

$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$.

(e) Zn, Cd and Hg are soft metals because they have completely filled d^{10} electron configuration which results in weak metallic bonding. The filled d-orbitals do not participate in bonding strongly, making these metals softer and with low melting points.

(f) Permanganate titration is not carried out in the presence of HCl because MnO_4^- oxidizes chloride ions (Cl^-) to chlorine gas (Cl_2), which interferes with the titration and gives erroneous results.

(g) Lower oxides of transition metals are basic because in these oxides metal is in lower oxidation states and the oxide ions (O^{2-}) react with water to form hydroxides, showing basic behaviour. Highest oxides have metals in higher oxidation states and show amphoteric or acidic behaviour due to ability to react with both acids and bases or to act as oxidizing agents.

Key Points: Ce(III) oxidised to stable Ce(IV)-Mn E° negative due to stable Mn atom and half-filled d5-Mn has lowest atomisation enthalpy due to weak bonding-HCl acidify chromate to dichromate-Zn,Cd,Hg soft due to filled d10 and weak bonding-Permanganate reacts with HCl producing Cl2 interfering lower oxides basic higher oxides amphoteric/acidic

Question 34.

(i) Ishan's automobile radiator is filled with 1.0 kg of water. How many grams of ethylene glycol (Molar mass 62 g mol^{-1}) must Ishan add to get the freezing point of the solution lowered to-2.8 °C. Kf for water is 1.86 K kg mol^{-1}

(ii) What type of deviation from Raoult's law is shown by ethanol and acetone mixture ? Give reason.

[5 Marks]

Answer: (i) Given:
Mass of water(m solvent) = 1.0 kg
Freezing point depression ΔT_f = 2.8 deg C (since freezing is lowered to -2.8 deg C)
Molal freezing point depression constant of water, K_f = 1.86 K kg mol^{-1}
Molar mass of ethylene glycol = 62 g mol^{-1}

Using formula for freezing point depression:
$\Delta T_f = K_f$ * molality (m)
=> molality m = $\Delta T_f / K_f$ = 2.8 / 1.86 = 1.505 mol kg^{-1}

Molality is moles of solute per kg of solvent,
So, moles of ethylene glycol = molality * mass of solvent = 1.505 * 1.0 = 1.505 mol

Mass of ethylene glycol = moles * molar mass = 1.505 * 62 = 93.31 g

Therefore, Ishan must add approximately 93.31 grams of ethylene glycol.

(ii) The ethanol and acetone mixture shows negative deviation from Raoult's law.
Reason: This is because the intermolecular forces between ethanol and acetone molecules are stronger than the forces present in the pure components. This stronger interaction causes the total vapor pressure of the mixture to be less than the sum of vapor pressures of the individual components, hence negative deviation occurs.

Key Points: Calculation of molality using freezing point depression formula - Determining moles and mass of ethylene glycol required - Ethanol and acetone mixture shows negative deviation due to stronger intermolecular interactions

Question 35.

(i) Boiling point of water at 750 mm Hg pressure is 99.68 °C. How much sucrose (Molar mass = 342 g mol^{-1}) is to be added to 500 g of water such that it boils at 100 °C? (K b for water = 0.52 K kg mol^{-1}).

(ii) State Henry's law and write its any one application

[5 Marks]

Answer: (i) Calculation of amount of sucrose to raise boiling point to 100 degC:

Given:

Initial boiling point T1 = 99.68 degC

Final boiling point T2 = 100 degC

Elevation in boiling point, Delta T b = T2 - T1 = 100 - 99.68 = 0.32 degC

Mass of water, m solvent = 500 g = 0.5 kg

Molal boiling point constant, K b = 0.52 K kg mol-1

Molar mass of sucrose = 342 g mol-1

Using the boiling point elevation formula:

Delta T b = K b * molality (m)

So, molality m = Delta T b / K b = 0.32 / 0.52 = 0.615 mol kg-1

Molality m = moles of solute / mass of solvent in kg

Moles of sucrose = molality * mass of solvent = 0.615 * 0.5 = 0.3075 mol

Mass of sucrose = moles * molar mass = 0.3075 * 342 = 105.1 g

Therefore, about 105.1 g of sucrose should be added to 500 g of water to raise its boiling point to 100 degC.

(ii) Henry's law:

Henry's law states that at a constant temperature, the amount of a gas dissolved in a liquid is directly proportional to the partial pressure of that gas above the liquid.

Mathematically, C = k H * P,

where C is the concentration of the dissolved gas, P is the partial pressure of the gas, and k H is Henry's constant.

Application:

One application of Henry's law is in carbonated beverages where carbon dioxide gas is dissolved in the liquid under high pressure. When the container is opened, pressure decreases and dissolved CO2 escapes as bubbles.

Key Points: Boiling point elevation calculation - Use of molality and Kb to find moles of

solute - Henry's law definition and application in carbonated drinks

Question 36.

An organic compound (A) with the molecular formula C9H10 O forma 2, 4-DNP derivative, reduces Fehling solution and undergoes Cannizzaro reaction. On vigorous oxidation, it gives 1, 2-benzene dicarboxylic acid.

(i) Identify the compound (A) and write its IUPAC name.

(ii) Write the reaction of compound (A) with

(1) 2,4-Dinitrophenyl hydrazine and

(2) Fehling solution

(iii) Write the equation of compound (A) when it undergoes Cannizzaro reaction.

[5 Marks]

Answer: (a) Identification of compound (A) and its IUPAC name: Compound (A) has the molecular formula C9H10O. It forms a 2,4-Dinitrophenylhydrazine (2,4-DNP) derivative, indicating the presence of a carbonyl group (aldehyde or ketone). (A) reduces Fehling solution and undergoes Cannizzaro reaction, which is typical for an aldehyde without an alpha hydrogen. On vigorous oxidation, it gives 1,2-benzene dicarboxylic acid (phthalic acid). These facts suggest (A) is ortho-hydroxybenzaldehyde, whose IUPAC name is 2-hydroxybenzaldehyde.

(b) Reactions of compound (A):
(1) Reaction with 2,4-Dinitrophenyl hydrazine:
2-hydroxybenzaldehyde + 2,4-Dinitrophenylhydrazine --(acidic medium)--> 2,4-Dinitrophenylhydrazone derivative + H_2O
This confirms the presence of the aldehyde group by formation of an orange-red precipitate.

(2) Reaction with Fehling solution:
2-hydroxybenzaldehyde + Fehling solution --(warm)--> 2-hydroxybenzoic acid + Cu_2O (red precipitate)
Here, the aldehyde group is oxidized to the corresponding acid, reducing Cu^{2+} to insoluble red Cu_2O precipitate.

(c) Cannizzaro reaction of compound (A):
Since compound (A) has no alpha hydrogen, it undergoes Cannizzaro reaction in presence of concentrated NaOH:
2 $C_7H_6O_2$ (2-hydroxybenzaldehyde) + NaOH --(conc.)--> $C_7H_6O_3^-$ (2-hydroxybenzoate salt) +

$C_7H_8O_2$ (2-hydroxybenzyl alcohol)

This disproportionation reaction produces an alcohol and a salt of the corresponding acid.

Key Points: Compound (A) is 2-hydroxybenzaldehyde (salicylaldehyde) - Formation of 2,4-DNP derivative confirms carbonyl group - Compound (A) reduces Fehling solution indicating it is an aldehyde - Compound (A) undergoes Cannizzaro reaction because it lacks alpha hydrogen - Oxidation of (A) gives 1,2-benzene dicarboxylic acid (phthalic acid)

Question 37.

(i) Account for the following:

(1) The alpha (a)-hydrogens of aldehydes and ketones are acidic in nature.

(2) Oxidation of aldehydes is easier than ketones

(ii) Arrange the following in:

(1) Decreasing reactivity towards nucleophilic addition reaction propanal, acetone, benzaldehyde.

(2) Increasing order of boiling point:

Propane, Ethanol, Dimethylether, Propanal

(iii) Give simple chemical test to distinguish between Benzoic acid and Benzaldehyde.

[5 Marks]

Answer: (i) (1) Acidity of alpha-hydrogens: The alpha-hydrogens of aldehydes and ketones are acidic because the hydrogen atoms attached to the carbon adjacent to the carbonyl group (C=O) can be removed easily. This is due to the resonance stabilization of the enolate ion formed after deprotonation. The negative charge on the enolate ion is delocalized over the oxygen atom and the alpha carbon, which stabilizes it and increases the acidity of the alpha-hydrogens.

(2) Oxidation of aldehydes is easier than ketones: Aldehydes have a hydrogen atom attached to the carbonyl carbon, making them more susceptible to oxidation into carboxylic acids. Ketones have two alkyl groups attached to the carbonyl carbon, so they do not have this hydrogen and are resistant to oxidation under mild conditions.

(ii) (1) Decreasing reactivity towards nucleophilic addition: Propanal > Benzaldehyde > Acetone. Propanal is an aliphatic aldehyde with less steric hindrance, so it is most reactive. Benzaldehyde has resonance stabilization which reduces its reactivity, but still more reactive than acetone, a ketone, which has greater steric hindrance and electron-donating alkyl groups that reduce the partial positive charge on the carbonyl carbon.

(2) Increasing order of boiling point: Propane < Dimethylether < Propanal < Ethanol. Propane is nonpolar with weakest intermolecular forces. Dimethylether is polar but cannot hydrogen bond.

Propanal has polar carbonyl group increasing intermolecular forces. Ethanol has -OH group and can form hydrogen bonds, thus highest boiling point.

(iii) Chemical test to distinguish Benzoic acid and Benzaldehyde: Benzoic acid gives a positive test with sodium bicarbonate ($NaHCO_3$) by producing effervescence of CO_2 gas due to acid-base reaction. Benzaldehyde does not react with $NaHCO_3$. Also, Tollens test gives positive silver mirror for benzaldehyde but negative for benzoic acid.

Key Points: Alpha hydrogens acidity due to enolate ion resonance stabilization - Aldehydes oxidize easily due to aldehydic hydrogen - Reactivity order based on steric and resonance effects - Boiling points depend on intermolecular forces - Sodium bicarbonate test distinguishes acid and aldehyde

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