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 **40 questions.** All questions are **compulsory.**

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

iii. **Section A** – questions number **1 to 6** are case based questions

iv. **Section B** – questions number **7 to 22** are multiple choice questions

v. **Section C** – questions number **23 to 28** are very short answer

vi. **Section D** – questions number **29 to 35** are short answer

vii. **Section E** – questions number **36 to 40** 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 involvement of (n-1)d electrons in the behaviour of transition elements impart certain distinct characteristics to these elements. Thus, in addition to variable oxidation states, they exhibit paramagnetic behaviour, catalytic properties and tendency for the formation of coloured ions. The transition metals react with a number of non-metals like oxygen, nitrogen and halogens. KMnO4 and K2Cr2O7 are common examples. The two series of inner transition elements, lanthanoids and actinoids, constitute the f-block of the periodic table. In the lanthanoids, there is regular decrease in atomic size with increase in atomic number due to the imperfect shielding effect of 4f-orbital electrons which causes contraction.

Question 2.

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Question 5.

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

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The two series of inner transition elements, lanthanoids and actinoids, constitute the f-block of the periodic table. In the lanthanoids, there is regular decrease in atomic size with increase in atomic number due to the imperfect shielding effect of 4f-orbital electrons which causes contraction.

(1)

Why do transition metals and their compounds act as good catalysts ?

[1 Marks]

Answer: Answer: Transition metals and their compounds act as good catalysts because they have partly filled d orbitals that allow them to exhibit variable oxidation states. This helps in the adsorption of reactant molecules on their surface, facilitating bond breaking and formation of intermediate species, speeding up chemical reactions, as explained in the case passage.

Key Points: Partly filled d orbitals-Variable oxidation states-Adsorption of reactants leading to faster reactions

(2)

What is the cause of contraction in the atomic size of lanthanoids ?

[1 Marks]

Answer: Answer: The contraction in atomic size of lanthanoids is caused by the imperfect shielding effect of 4f-electrons. As the atomic number increases, the 4f-electrons do not effectively shield the increasing nuclear charge, resulting in stronger attraction of electrons towards the nucleus and thus regular decrease in atomic size, as explained in the case passage.

Key Points: Lanthanide contraction - Imperfect shielding by 4f-electrons - Increase in effective nuclear charge with atomic number

(3)

In aqueous media, which is a stronger reducing agent Cr^{2+} or Fe^{2+} and why ?

[2 Marks]

Answer: Cr2+ is a stronger reducing agent than Fe2+ in aqueous media because Cr2+ has a greater tendency to lose electrons and get oxidised to Cr3+. This is due to the fact that Cr2+ has a less stable electronic configuration and a higher oxidation state variability compared to Fe2+. According to the case passage, transition elements exhibit variable oxidation states which influence their chemical behaviour. Therefore, Cr2+ easily donates electrons making it a better reducing agent than Fe2+.

Key Points: Cr2+ is stronger reducing agent than Fe2+ - Cr2+ has greater tendency to oxidise due to less stable electronic configuration - Variable oxidation states affect reducing strength as per case passage

(4)

Define lanthanoid contraction. How does it affect the atomic radii of the third transition series and the second transition series ?

[2 Marks]

Answer: Lanthanoid contraction is the progressive decrease in the atomic radii of lanthanoid elements with increasing atomic number due to poor shielding effect of 4f electrons. This causes the atoms in the third transition series to have atomic sizes similar to or even smaller than those of the corresponding elements of the second transition series, despite being in a higher period. This contraction leads to slight decrease in atomic radii of third transition series elements compared to the second series, affecting their chemical properties as mentioned in the case passage.

Key Points: Definition of lanthanoid contraction - Caused by poor shielding of 4f electrons leading to decrease in atomic radii - Leads to third transition series having atomic radii similar to or smaller than second series

Question 6. Proteins are the most abundant biomolecules of the living system. Proteins are the polymers of about twenty different -amino acids which are linked by peptide bonds. Ten amino acids are called essential amino acids. In zwitter ionic form, amino acids show amphoteric behaviour as they react both with acids and bases. On the basis of their molecular shape, proteins are classified

into two types : Fibrous and Globular proteins. Structure and shape of proteins can be studied at four different levels i.e., primary, secondary, tertiary and quaternary, each level being more complex than the previous one. The secondary or tertiary structure of proteins get disturbed on change of pH or temperature and they are not able to perform their functions. This is called denaturation of proteins.

(1) What are essential amino acids ?

[1 Marks]

Answer: Essential amino acids are the ten amino acids that our body cannot synthesise on its own and hence must be obtained through our diet. This fact is highlighted in the case where it states that these amino acids are called essential because they must be provided through diet. Without these essential amino acids, the body cannot make complete proteins necessary for growth and repair.

Key Points: Essential amino acids cannot be synthesised by the body - Must be obtained from diet - Important for making proteins

(2) What is meant by zwitter ionic form of amino acids ?

[1 Marks]

Answer: The zwitter ionic form of amino acids means that amino acids have both a positive and a negative charge on the same molecule at the same time. In this form, the amino group (–NH2) gains a proton and becomes $–NH3^{+}$ while the carboxyl group (–COOH) loses a proton and becomes $–COO^{-}$. This form helps amino acids to show amphoteric behavior, reacting with both acids and bases as mentioned in the case.

Key Points: Amino acids have both positive and negative charges simultaneously - Amino group gains proton forming $–NH3^{+}$ - Carboxyl group loses proton forming $–COO^{-}$ - Shows amphoteric behavior reacting with acids and bases

(3)

(i) Give one example each for Fibrous protein and Globular protein.

(ii) What type of linkages hold monomers of proteins together?

[2 Marks]

Answer: (i) One example of fibrous protein is keratin and one example of globular protein is insulin, as mentioned in the passage.
(ii) The monomers of proteins, which are amino acids, are held together by peptide bonds. These peptide bonds link amino acids to form polypeptides, which make up proteins.

Key Points: Fibrous protein example keratin - Globular protein example insulin - Peptide bonds link amino acids

(4)

(i) What is the structural feature which characterises a reducing sugar ?

(ii) What is the structural difference between nucleoside and nucleotide?

[2 Marks]

Answer: (i) A reducing sugar has a free aldehyde group or a free ketone group that can reduce other compounds. This is usually due to the presence of a free -CHO group or a free -C=O group in its open chain form.
(ii) A nucleoside consists of a nitrogenous base linked to a sugar (ribose or deoxyribose), but a nucleotide has an additional phosphate group attached to the sugar along with the nitrogenous base. Thus, nucleotide = nucleoside + phosphate group.

Key Points: Reducing sugar has free aldehyde or ketone group - Nucleoside has nitrogenous base and sugar only - Nucleotide has nitrogenous base, sugar and phosphate group

Section B

Question 7.

Which of the following does not show variable oxidation states?

[1 Marks]

(A) Cu

(B) Mn

(C) Sc

(D) Fe

Explanation:

Scandium (Sc) does not show variable oxidation states. It primarily exhibits a +3 oxidation state, while manganese (Mn), copper (Cu), and iron (Fe) can exhibit multiple oxidation states due to their ability to lose different numbers of electrons. This is typical in transition metals, whereas Sc is a d-block element that generally shows a fixed oxidation state.

Question 8.

The type of isomerism shown by the complex $[CoCl_2(en)_2]^+$ is:

[1 Marks]

(A) Ionisation isomerism

(B) Coordination isomerism

(C) Linkage isomerism

(D) Geometrical isomerism

Explanation: The complex [CoCl2(en)2]+ contains different ligands (chloride ions and ethylenediamine, en) around a central cobalt ion. Since it is a heteroleptic complex with coordination number 6, different spatial arrangements of ligands are possible leading to geometrical isomerism (cis/trans forms). Other types of isomerism like linkage, coordination, or ionisation isomerism are not applicable in this case because the ligands do not differ in bonding mode or composition beyond spatial arrangement. Hence, the complex shows geometrical isomerism.

Question 9.

Which of the following is diamagnetic in nature?

[Atomic number : Co = 27]

[1 Marks]

(A) Co_3^+, octahedral complex with strong field ligand

(B) Co_3^+, octahedral complex with weak field ligand

(C) Co_3^+, in a tetrahedral complex

(D) Co_3^+, in a square planar complex

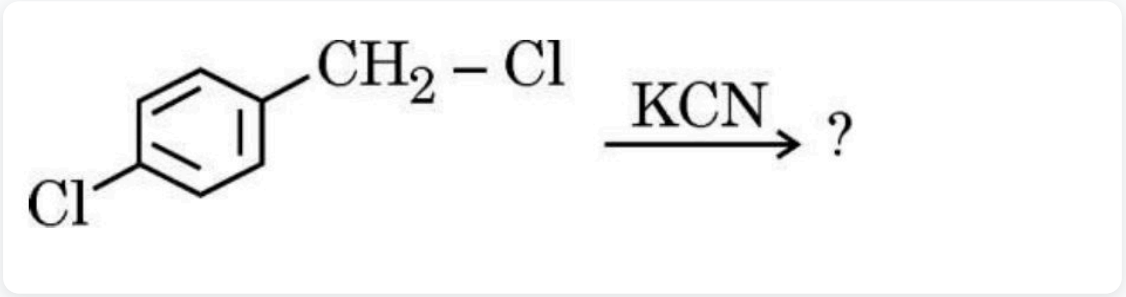
Explanation: Cobalt in +3 oxidation state has electronic configuration $3d^6$. In an octahedral complex with a strong field ligand (such as NH_3 or CO), the ligand field causes pairing of all six electrons in the lower energy t_2g orbitals, resulting in no unpaired electrons. This makes the complex diamagnetic. In contrast, weak field ligands or tetrahedral geometries do not cause complete pairing, leading to paramagnetism. Square planar complexes can also be diamagnetic but are rare for Co^{3+}. Therefore, the octahedral complex of Co^{3+} with a strong field ligand is diamagnetic.

Question 10.

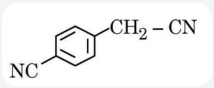
Consider the following reaction:

The major product of the reaction is:

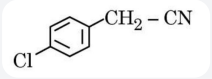
[1 Marks]



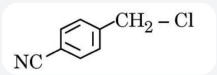
(A)



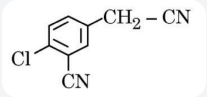
(B)



(C)



(D)



Explanation:

The starting compound is p-chlorobenzyl chloride (a benzene ring with one Cl on the ring and a $–CH_2Cl$ side chain).

With KCN, the reaction proceeds by SN2 at the benzylic $–CH_2Cl$ position (benzyl halides are very reactive in SN2).
The aryl Cl on the ring does not get substituted under these conditions.

So only this change happens:
$–CH_2Cl \rightarrow –CH_2CN$

The ring chlorine remains unchanged.

Therefore, the major product is p-chlorobenzyl cyanide.

Question 11.

Which one of the following compounds has the lowest pK_a value?

[1 Marks]

(A) m-Nitrophenol

(B) p-Cresol

(C) p-Nitrophenol

(D) 2,4,6-Trinitrophenol

Explanation:

The compound with the lowest pKa value is 2,4,6-Trinitrophenol. This is because it has three nitro groups that strongly enhance its acidity by stabilizing the negative charge of the conjugate base through resonance. In comparison, the other compounds have fewer electron-withdrawing groups, leading to higher pKa values.

Question 12.

$(CH_3)_2CH\text{-}O\text{-}CH_3$ when treated with HI gives:

[1 Marks]

(A) $(CH_3)_2CH$ - OH + CH_3 -I

(B) $(CH_3)_2CH$ -I + CH_3OH

(C) $(CH_3)_2CH$ -I + CH_3 -I

(D) $(CH_3)_2CH$ - OH + CH_3OH

Explanation:

The correct answer is $(CH_3)_2CH - OH + CH_3 - I$. When $(CH_3)_2CH\text{-}O\text{-}CH_3$ (an ether) reacts with HI, it acts as an acid and generates an oxonium ion. The iodide ion then acts as a nucleophile, attacking the less hindered carbon (the carbon connected to the -O- group), resulting in the formation of isopropyl alcohol ($(CH_3)_2CH - OH$) and methyl iodide ($CH_3 - I$).

Question 13.

Which of the following compounds on treatment with benzene sulphonyl chloride forms an alkali-soluble precipitate?

[1 Marks]

(A) CH_3CONH_2

(B) $(CH_3)_3N$

(C) $(CH_3)_2NH$

(D) $CH_3CH_2NH_2$

Explanation:

The correct option is CH_3CONH_2 (acetanilide). Upon treatment with benzene sulphonyl chloride, acetanilide forms a sulphonamide which is soluble in alkali. The other compounds do not form precipitates that are alkali-soluble.

Question 14.

The order of increasing basicities of CH_3NH_2 (I), $(CH_3)_2NH$ (II), $(CH_3)_3N$ (III) and $C_6H_5NH_2$ (IV) in aqueous media is:

[1 Marks]

(A) IV < III < I < II

(B) I < II < III < IV

(C) II < III < I < IV

(D) II < I < IV < III

Explanation:

The correct order of increasing basicities is IV < III < I < II. Aniline (IV) has a phenyl group that decreases its basicity due to resonance. Dimethylamine (II) is more basic than methylamine (I) because the two methyl groups provide stronger +I effect than one methyl group. Trimethylamine (III)

is the most basic due to the +I effect from the three methyl groups, which greatly enhance its ability to accept protons.

Question 15.

The vitamin which plays an important role in coagulating blood is:

[1 Marks]

(A) Vitamin A

(B) Vitamin E

(C) Vitamin D

(D) Vitamin K

Explanation:

Vitamin K is essential for the blood coagulation process, as it is required for the synthesis of certain proteins that are necessary for blood clotting. Without adequate vitamin K, the body cannot produce these proteins effectively, leading to increased bleeding and difficulty in clotting.

Question 16.

When a catalyst increases the rate of a chemical reaction, then the rate constant (k):

[1 Marks]

(A) may increase or decrease depending on the order of the reaction

(B) increases

(C) remains constant

(D) decreases

Explanation:

The correct answer is 'remains constant.' A catalyst speeds up a reaction by providing an alternative pathway with a lower activation energy, but it does not change the intrinsic rate constant (k) of the reaction, which is determined by the nature of the reactants and the temperature.

Question 17.

A 1% solution of solute 'X' is isotonic with 6% solution of sucrose (molar mass = 342 g mol^{-1}). The molar mass of solute 'X' is

[1 Marks]

(A) 34·2 g mol^{-1}

(B) 3·42 g mol^{-1}

(C) 114 g mol^{-1}

(D) 57 g mol^{-1}

Explanation:

The correct answer is 3.42 g mol^{-1} because 1% mass means 1 gram in 100 grams of solution. Therefore, to find the mass for 1% of a substance with a molar mass of 342 g mol^{-1}, the calculation is (1/100) * 342 = 3.42 g mol^{-1}.

Question 18.

During the electrolysis of aqueous NaCl, the cathodic reaction is:

[1 Marks]

(A) Oxidation of H_2O

(B) Reduction of H_2O

(C) Oxidation of Cl^- ion

(D) Reduction of Na^+ ion

Explanation:

The correct answer is the 'Reduction of H_2O'. During the electrolysis of aqueous sodium chloride, at the cathode (negative electrode), water is reduced to form hydrogen gas and hydroxide ions. The reduction of Na^+ ions is not favored since the reduction potential for water is lower than that for Na^+. Therefore, the primary cathodic reaction is the reduction of water.

Question 19.

Assertion (A): Addition of ethylene glycol to water lowers its freezing point.

Reason (R): Ethylene glycol is insoluble in water due to lack of its ability to form hydrogen bonds with water molecules.

[1 Marks]

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

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

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

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

Explanation:

Assertion (A) is true because the addition of ethylene glycol to water indeed lowers its freezing point, a phenomenon known as freezing point depression. However, Reason (R) is false. Ethylene glycol is actually soluble in water and can form hydrogen bonds with water molecules, which contributes to its ability to lower the freezing point of the mixture.

Question 20.

Assertion (A): Order of reaction and molecularity are always same for complex reactions.

Reason(R): Order is determined experimentally and molecularity is applicable only for elementary reactions.

[1 Marks]

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

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

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

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

Explanation:

Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). The assertion is false because the order of a reaction can differ from its molecularity for complex reactions. The reason is true as order is indeed determined experimentally, while molecularity is applicable only to elementary reactions.

Question 21.

Assertion (A): The boiling point of ethanol is higher than that of dimethyl ether.

Reason (R): Ethanol molecules are associated through hydrogen bonding whereas in dimethyl ether, it is not possible.

[1 Marks]

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

(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) 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). Ethanol has a higher boiling point compared to dimethyl ether due to the presence of hydrogen bonding in ethanol, which requires more energy to break compared to the weaker van der Waals forces in dimethyl ether.

Question 22.

Assertion (A): Aniline does not undergo Friedel-Crafts reaction.

Reason (R): Friedel-Crafts reaction is an electrophilic substitution reaction.

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

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

Explanation:

Assertion (A) is true because aniline, which contains a strong electron-donating amino group, deactivates the aromatic ring toward electrophilic substitution, preventing the Friedel-Crafts reaction from occurring. Reason (R) is also true as Friedel-Crafts reaction is indeed an electrophilic substitution reaction. However, Reason (R) does not explain why aniline does not undergo this reaction, so the correct answer is: Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

Section C

Question 23. Define molal depression constant. How is it related to enthalpy of fusion?

[2 Marks]

Answer: Molal depression constant, also known as freezing point depression constant or cryoscopic constant, is a property of a solvent that indicates how much its freezing point drops when one mole of solute is dissolved in one kilogram of the solvent (1 molal solution).
It is related to the enthalpy of fusion because K_f is proportional to the ratio of the gas constant (R) times the square of the freezing point of the pure solvent (T_f^2) to the enthalpy of fusion ($\u0394H_{fusion}$) of the solvent. Mathematically, $K_f = (R * T_f^2) / \u0394H_{fusion}$. Thus, a solvent with a higher enthalpy of fusion will have a lower molal depression constant and vice versa.

Key Points: Definition of molal depression constant - It depends on the solvent - Related to enthalpy of fusion through the formula K_f = (R * T_f^2) / DeltaH_fusion

Question 24.

What type of deviation is shown by ethanol and acetone mixture? Give reason.What type of azeotropic mixture is formed by that deviation ?

[2 Marks]

Answer: The ethanol and acetone mixture shows a positive deviation from Raoult's law. This occurs because the intermolecular attractions between ethanol and acetone are weaker than those in the pure components. Consequently, when mixed, the vapor pressure of the solution is higher than predicted by Raoult's law. The azeotropic mixture formed by this deviation is classified as a maximum boiling azeotrope, where the boiling point of the mixture is higher than that of the individual components.

Key Points: Positive deviation-Raoult's law-intermolecular attractions-weaker mixture-vapor pressure-higher than predicted-maximum boiling azeotrope.

Question 25.

(a) In a reaction, if the concentration of reaction 'X' is tripled rate of reaction becomes twenty-seven times? What is the order of the reaction .

(b) State a condition under which a bimolecular reaction is kinetically a first-order reaction. Give an example of such a reaction.

[2 Marks]

Answer: (a) Let the rate law be Rate = $k [X]^n$. When concentration of X is tripled, rate becomes 27 times.
So, $(3)^n = 27 = 3^3$. Therefore, n = 3.
Hence, the order of the reaction is 3 (third order).

(b) A bimolecular reaction is kinetically first-order when one reactant's concentration is in large excess and remains nearly constant.
In such case, rate depends effectively on the concentration of the other reactant only.
Example: The hydrolysis of an ester in acid is bimolecular but appears as first-order because acid concentration is constant.
Rate = k [ester][H_3O^+], if [H_3O^+] is constant, rate = k' [ester], which is first-order.

Key Points: Order n found from rate change and concentration change - Reaction order is 3 as 3^n = 27 - Bimolecular reaction appears first-order when one reactant concentration is constant - Example: acid catalyzed ester hydrolysis - Rate depends on one reactant only under such condition

Question 26.

Complete the following ionic equations:

(a) $2Mno^-_4 + 5SO_3^{2-} + 6H^+ \rightarrow$

(b) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+}$

[2 Marks]

Answer: (a) $2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2MnO_2(s) + 5SO_4^{2-} + 3H_2O$
(b) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

Explanation:
In (a), permanganate ion (MnO_4^-) is reduced to manganese dioxide (MnO_2) and sulfite ion (SO_3^{2-}) is oxidized to sulfate ion (SO_4^{2-}). Acidic medium is represented by H^+. The equation is balanced for atoms and charges.
In (b), dichromate ion ($Cr_2O_7^{2-}$) is reduced to chromium ion (Cr^{3+}) and ferrous ion (Fe^{2+}) is oxidized to ferric ion (Fe^{3+}) in acidic medium. The atoms and charges are balanced properly.

Key Points: Balance atoms and charges - Identify oxidation and reduction half reactions - Use H+ to represent acidic medium

Question 27.

(a) Which halogen compound will react faster in S_n2 reactions, and why?

CH_3- CH_2 -I or CH_3 - CH_2 - Br

(b) Why is chloroform stored in closed dark coloured bottles?

[2 Marks]

Answer: (a) CH_3-CH_2-I reacts faster than CH_3-CH_2-Br in S_N2 reactions because iodine is a better leaving group than bromine due to its larger size and weaker carbon-iodine bond. This makes the substitution easier.
(b) Chloroform is stored in closed dark coloured bottles to prevent its decomposition by light and air. Light can cause chloroform to react and form toxic substances like phosgene. The dark bottle blocks light, and the closed container limits air exposure, thus increasing its stability.

Key Points: Iodine is a better leaving group than bromine - CH3CH2I undergoes S N 2 faster than CH3CH2Br - Chloroform decomposes on exposure to light and air - Stored in dark bottles to block light - Closed containers prevent air oxidation

Question 28.

Give the reaction of glucose with the following :

(a) HCN

(b) Conc. HNO_3

[2 Marks]

Answer: (a) Glucose reacts with hydrogen cyanide (HCN) to form a cyanohydrin. The aldehyde group (-CHO) of glucose adds HCN across the carbonyl group, resulting in the formation of glucose cyanohydrin.
(b) Glucose reacts with concentrated nitric acid (Conc. HNO_3) and gets oxidised to produce glucaric acid (saccharic acid). Both the aldehyde group and the primary alcohol group at the end are oxidised to carboxylic acid groups.

Key Points: Glucose forms cyanohydrin with HCN - Conc. HNO3 oxidises glucose to glucaric acid - Aldehyde and primary alcohol groups get oxidised in this reaction

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Section D

Question 29.

A solution is prepared by dissolving 5 g of a non-volatile solute in 200 g of water. It has a vapour pressure of 31·84 mm Hg at 300 K. Calculate the molar mass of the solute.

(Vapour pressure of pure water at 300 K = 32 mm Hg)

[3 Marks]

Answer: Given: Mass of solute, m_solute = 5 g
Mass of solvent (water), m_solvent = 200 g = 0.2 kg
Vapour pressure of solution, P_solution = 31.84 mm Hg
Vapour pressure of pure solvent, P_solvent = 32 mm Hg

Step 1: Calculate the lowering of vapour pressure, ΔP = P_solvent - P_solution = 32 - 31.84 = 0.16 mm Hg

Step 2: Use Raoult's law relation for vapour pressure lowering:
ΔP / P_solvent = mole fraction of solute, x_solute

So, x_solute = 0.16 / 32 = 0.005

Step 3: Let the molar mass of the solute be M (g/mol). Number of moles of solute = n_solute = 5 / M
Number of moles of solvent (water), n_solvent = mass / molar mass = 200 / 18 = 11.11 mol

Step 4: Mole fraction of solute, x_solute = n_solute / (n_solute + n_solvent) ≈ n_solute / n_solvent (since n_solute is very small)
So, 0.005 = (5 / M) / 11.11

Step 5: Solve for M:
5 / M = 0.005 * 11.11 = 0.05555
M = 5 / 0.05555 ≈ 90 g/mol

Answer: The molar mass of the solute is approximately 90 g/mol.

Key Points: Use of Raoult's law - Calculation of vapour pressure lowering - Calculation of mole fraction and molar mass

Question 30.

A first-order reaction is 25 complete in 40 minutes. Calculate the value of rate constant. In what time will the reaction be 80 % complete ?

Given : log 2 = 0·30, log 3 = 0·48, log 4 = 0·60, log 5 = 0·69

[3 Marks]

Answer: (a) Given that the reaction is 25 % complete in 40 minutes means 75 % of the reactant remains. Let initial concentration be C_0 and concentration after 40 min be C. Then, C = 0.75 C_0.
For a first order reaction, the formula is ln(C) = ln(C_0) - k t or log C = log C_0 - (k t / 2.303).
Using concentrations: log (C_0 / C) = (k t) / 2.303.
Here, log (C_0 / C) = log (1 / 0.75) = log (4/3) = log 4 - log 3 = 0.60 - 0.48 = 0.12.
So, (k * 40) / 2.303 = 0.12 => k = (2.303 * 0.12) / 40 = 0.006909 min^{-1}.

(b) To find time for 80 % completion, 20 % reactant remains, so C = 0.20 C_0.
log (C_0 / C) = log (1 / 0.20) = log 5 = 0.69.
Using same equation: (k * t) / 2.303 = 0.69 => t = (2.303 * 0.69) / k = (2.303 * 0.69) / 0.006909 = 230 minutes approx.

Hence, the rate constant k = 0.006909 min^{-1} and the time for 80 % completion is approximately 230 minutes.

> **Key Points: Understanding first order reaction formula - Using logarithmic relationship between concentration and time - Calculating rate constant and time for given percentage completion**

Question 31.

(a) What type of nucleophilic substitution (SN1 or SN2) occurs in the hydrolysis of 2-Bromo butane to form (±)-Butan-2-ol ? Give reason.

(b) What happens when chlorobenzene and methyl chloride are treated with sodium metal in dry ether ?

[3 Marks]

Answer: (a) The hydrolysis of 2-Bromo butane to form (±)-Butan-2-ol occurs via **SN1 mechanism**. This is because 2-Bromo butane is a secondary alkyl halide and forms a relatively stable carbocation intermediate after the bromide ion leaves. The planar carbocation allows the nucleophile (water) to attack from either side, producing a racemic mixture (±) of Butan-2-ol.
(b) When chlorobenzene and methyl chloride are treated with sodium metal in dry ether, the sodium metal acts as a reducing agent leading to a Wurtz type coupling reaction. Methyl chloride undergoes coupling to form ethane (C_2H_6). However, chlorobenzene does not easily participate in Wurtz reaction

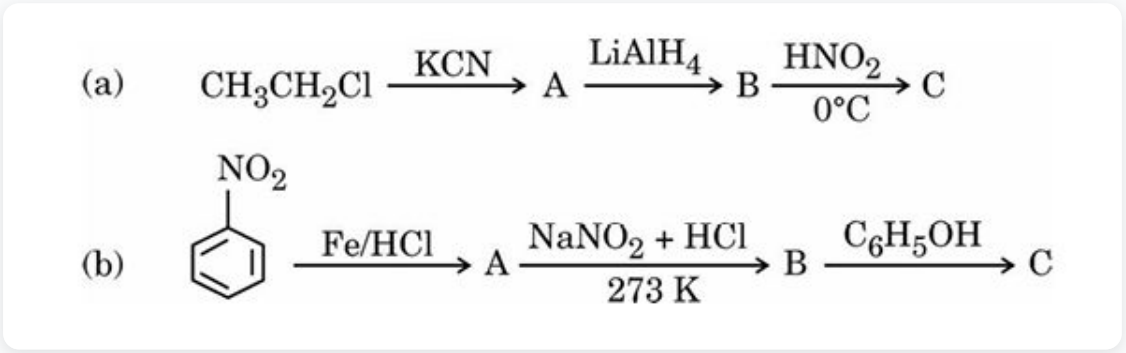
due to the strong C-Cl bond in the aromatic ring; hence it remains mostly unreacted. Thus, the reaction mainly produces ethane and sodium chloride as byproduct with unreacted chlorobenzene.

Key Points: (a) Hydrolysis of 2-Bromo butane proceeds via SN1 mechanism - Formation of carbocation intermediate - Racemic mixture of Butan-2-ol formed due to planar carbocation (b) Sodium metal reduces methyl chloride to form ethane via Wurtz reaction - Chlorobenzene is unreactive due to strong C-Cl bond in aromatic ring - Reaction performed in dry ether prevents side reactions

Question 32.

Give the structures of A, B and C in the following reactions :

[3 Marks]



Answer:

(a)

CH_3CH_2Cl —KCN→ A —$LiAlH_4$→ B —HNO_2 (0°C)→ C

1. **CH_3CH_2Cl + KCN → A**
   KCN does **SN2 substitution** → Cl is replaced by CN.
   A = CH_3CH_2CN (propionitrile / ethyl cyanide)

2. **A —$LiAlH_4$→ B**
   $LiAlH_4$ reduces nitrile **–CN → $–CH_2NH_2$** (primary amine).
   B = $CH_3CH_2CH_2NH_2$ (n-propylamine)

3. **B —HNO_2 (0°C)→ C**
   Primary aliphatic amine + nitrous acid → **alcohol** (via diazonium, which is unstable).
   C = $CH_3CH_2CH_2OH$ (1-propanol)

✅ Answers (a):

- **A = CH_3CH_2CN**
- **B = $CH_3CH_2CH_2NH_2$**

- **C = $CH_3CH_2CH_2OH$**

(b)

Starting compound: **Nitrobenzene ($C_6H_5–NO_2$)**

1. **$C_6H_5–NO_2$ —Fe/HCl→ A**
   Fe/HCl reduces **$–NO_2$ to $–NH_2$**
   A = Aniline ($C_6H_5–NH_2$)

2. **A —$NaNO_2$ + HCl, 273 K→ B**
   Aniline undergoes **diazotization** → forms benzene diazonium chloride.
   B = $C_6H_5–N_2^+Cl^-$ (benzene diazonium chloride)

3. **B —C_6H_5OH→ C**
   Diazonium salt couples with phenol → **azo coupling** (para position major).
   C = p-hydroxyazobenzene
   Structure: **$HO–C_6H_4–N=N–C_6H_5$ (para)**

✅ Answers (b):

- **A = Aniline ($C_6H_5NH_2$)**
- **B = Benzene diazonium chloride ($C_6H_5N_2^+Cl^-$)**
- **C = p-Hydroxyazobenzene (azo dye)**

Key Points:

(a) Ethyl chloride reacts with KCN to form propionitrile (A), which on reduction with $LiAlH_4$ gives propylamine (B), and with nitrous acid at 0°C gives propanol (C).
(b) Nitrobenzene is reduced by Fe/HCl to aniline (A), which on diazotization forms benzene diazonium chloride (B).
This diazonium salt couples with phenol to give p-hydroxyazobenzene (C

Question 33.

(a) Write the equations of the reactions involved in the following :

(i) Reimer-Tiemann reaction

(ii) Kolbe's reaction

(b) Name the reagent used in the bromination of phenol to form 2,4,6-Tribromophenol.

[3 Marks]

Answer: (a) (i) Reimer-Tiemann reaction: Phenol reacts with chloroform ($CHCl_3$) in the presence of aqueous sodium hydroxide (NaOH) to form salicylaldehyde (2-hydroxybenzaldehyde). The reaction introduces a –CHO group at the ortho position of phenol.

$C_6H_5OH + CHCl_3 + 3NaOH \rightarrow C_6H_4(OH)CHO + 3NaCl + 2H_2O$

(a) (ii) Kolbe's reaction: Phenol when heated with sodium hydroxide and carbon dioxide under pressure forms salicylate salt, which upon acidification gives salicylic acid.

$C_6H_5ONa + CO_2 \rightarrow C_6H_4(OH)COONa$

$C_6H_4(OH)COONa + HCl \rightarrow C_6H_4(OH)COOH + NaCl$

(b) The reagent used for bromination of phenol to form 2,4,6-Tribromophenol is bromine water (Br_2 in H_2O). When phenol is treated with bromine water at room temperature, 2,4,6-Tribromophenol is formed as a white precipitate.

> **Key Points: Reimer-Tiemann reaction involves phenol, chloroform, and NaOH forming salicylaldehyde - Kolbe's reaction involves phenol, NaOH, CO2 giving salicylic acid - Bromine water is reagent used for bromination of phenol to give 2,4,6-Tribromophenol**

Question 34.

How will you bring about the following conversions ?

(a) Benzoic acid to Benzaldehyde

(b) Ethanal to Propanone

(c) Acetophenone to Benzoic acid

(d) Bromobenzene to 1-Phenylethanol

[3 Marks]

Answer: (a) Benzoic acid to Benzaldehyde: First, convert benzoic acid to its acid chloride using $SOCl_2$, then reduce it with lithium tri-tert-butoxyaluminum hydride ($LiAlH(OtBu)_3$) to form benzaldehyde.

(b) Ethanal to Propanone: Perform an aldol condensation by treating ethanal with dilute NaOH, then carry out oxidation with dilute acid to get propanone.

(c) Acetophenone to Benzoic acid: Oxidise acetophenone using alkaline $KMnO_4$ and heat. The methyl side chain is cleaved, yielding benzoic acid.

(d) Bromobenzene to 1-Phenylethanol: React bromobenzene with magnesium in dry ether to form phenylmagnesium bromide (Grignard reagent), then treat with acetaldehyde followed by acidified workup to form 1-phenylethanol.

Key Points: Benzoic acid to benzaldehyde via acid chloride and selective reduction - Aldol condensation and oxidation to convert ethanal to propanone - Oxidation of acetophenone side chain to benzoic acid - Grignard reagent formation and reaction with acetaldehyde to produce 1-phenylethanol

Question 35.

The conductivity of 0·2 M solution of KCl is $2{\cdot}48\ 10^{-2}$ S cm^{-1}. Calculate its molar conductivity and degree of dissociation (α).

Given :

$\lambda°_{k^+} = 73.5\ S\ cm^2\ mol^{-1}$

$\lambda°cl^- = 76.5\ S\ cm^2\ mol^{-1}$

[3 Marks]

Answer: Given:

Concentration, c = 0.2 mol L^{-1}

Conductivity, κ = 2.48 * 10^{-2} S cm^{-1}

$\lambda°_{K+} = 73.5\ S\ cm^2\ mol^{-1}$, $\lambda°_{Cl-} = 76.5\ S\ cm^2\ mol^{-1}$

(a) Molar conductivity (Λ_m) = κ / c

= (2.48 * 10^{-2}) / 0.2 = 0.124 S cm^2 mol^{-1}

(b) Molar conductivity at infinite dilution, $\Lambda°_m = \lambda°_{K+} + \lambda°_{Cl-} = 73.5 + 76.5 = 150\ S\ cm^2\ mol^{-1}$

(c) Degree of dissociation, $\alpha = \Lambda_m / \Lambda°_m$

= 0.124 / 150 = 0.000827 or approximately 0.083%

Conclusion: Molar conductivity of 0.2 M KCl solution is 0.124 S cm^2 mol^{-1} and the degree of dissociation is approximately 0.083%. This shows that KCl is almost completely dissociated but the low molar conductivity is due to high concentration.

Key Points: Molar conductivity calculation - Molar conductivity at infinite dilution - Degree of dissociation calculation

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Section E

Question 36.

(i) Calculate emf of the following cell at 25ºC :

Zn (s) $|Zn^{2+}$ (0·001M)| Cd^{2+} (0·1 M) Cd (s)

Given:E °zn^{2+}/zn= -0·76 V, E°cd^{2+}/Cd = - 0·40 V [log 10 = 1]

(ii) State faraday 's second law of electrolysis How will the ph of aqueous NaCl solution be affected when it is electrolyzed?

[5 Marks]

Answer: (i) Given cell: Zn (s) | Zn^{2+} (0.001 M) || Cd^{2+} (0.1 M) | Cd (s)
Standard electrode potentials are: E°(Zn^{2+}/Zn) = -0.76 V, E°(Cd^{2+}/Cd) = -0.40 V
The cell potential $E_{cell} = E_{cathode} - E_{anode}$
Cathode is Cd since it has less negative E°, anode is Zn
Standard emf, $E°_{cell}$ = (-0.40) - (-0.76) = 0.36 V
Using Nernst equation at 25 deg C:
$E = E° - (0.0592/2) * \log([Zn^{2+}]/[Cd^{2+}])$
Substitute values:
$E = 0.36 - (0.0592/2) * \log(0.001/0.1) = 0.36 - 0.0296 * \log(0.01)$
Since log(0.01) = -2,
$E = 0.36 - 0.0296 * (-2) = 0.36 + 0.0592 = 0.4192$ V
Therefore, emf of the cell is approximately 0.42 V.

(ii) Faraday's Second Law of Electrolysis states that when the same quantity of electricity passes through different electrolytes, the masses of different substances deposited or liberated are proportional to their chemical equivalent weights.
When aqueous NaCl solution is electrolyzed, at cathode hydrogen gas is evolved and at anode chlorine gas is produced. Water can also decompose affecting pH.
The pH of the solution will become acidic due to the formation of HCl in the solution as chlorine dissolves and reacts with water producing HCl and HClO.
Hence, the pH of aqueous NaCl decreases and solution becomes acidic during electrolysis.

Key Points: Calculation of emf using Nernst equation- Identification of cathode and anode based on standard electrode potentials- Statement of Faraday's second law of electrolysis- Effect of electrolysis of NaCl on pH due to formation of acidic species

Question 37.

(i) Calculate the $\Delta_rG°$ and log Kc for the following cell reaction :

Fe (s) + Ag^+ (aq) ⇌ Fe^{2+} (aq) + Ag (s)

Given: E° fe^{2+}/fe = -0.44V, E°Ag^{+}/Ag= +0.80V, 1F = 96500 C mol^{-1}

(ii) Write any two advantages of the fuel cells over primary and secondary batteries ?

(iii) How many Faradays are required for the oxidation of 1 mole of H_2O to O_2 ?

[5 Marks]

Answer: (i) The cell reaction is: Fe (s) + Ag^{+} (aq) ⇌ Fe^{2+} (aq) + Ag (s).
Given electrode potentials are: E° Fe^{2+}/Fe = -0.44 V, E° Ag^{+}/Ag = +0.80 V.
To find E° cell, use: E° cell = E° cathode - E° anode.
Here, Ag^{+}/Ag is cathode (reduction), Fe/Fe^{2+} is anode (oxidation).
So, E° cell = 0.80 V - (-0.44 V) = 1.24 V.
Number of electrons transferred, n = 2 (Fe goes from 0 to +2 oxidation state).
Calculate ΔrG° using formula: ΔrG° = - nFE° cell = - 2 * 96500 * 1.24 = -239720 J/mol or -239.72 kJ/mol.
Calculate log Kc using: ΔrG° = - 2.303 RT log Kc.
At 298 K, R = 8.314 J/mol K,
So, log Kc = nFE° cell / (2.303 RT) = (2 * 96500 * 1.24) / (2.303 * 8.314 * 298) ≈ 20.8.

(ii) Advantages of fuel cells over primary and secondary batteries:
1. Fuel cells can continuously produce electricity as long as fuel and oxidant are supplied, unlike batteries which store limited energy.
2. Fuel cells have higher efficiency and produce less pollution compared to conventional batteries.

(iii) Oxidation of water: 2 $H_2O \rightarrow O_2 + 4\ H^{+} + 4\ e^{-}$.
Thus, 4 moles of electrons are involved per mole of O_2 formed.
Therefore, for oxidation of 1 mole of H_2O to O_2, 4 Faradays of electricity are required.

Key Points: Calculate E° cell by subtracting standard potentials - Use ΔrG° = - nFE° cell to find Gibbs free energy change - Use ΔrG° = - 2.303 RT log Kc to find equilibrium constant - Fuel cells have continuous energy supply and higher efficiency - 4 Faradays are needed for oxidation of 1 mole of water to oxygen

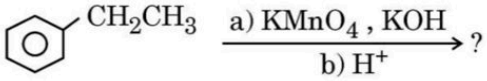
Question 38.

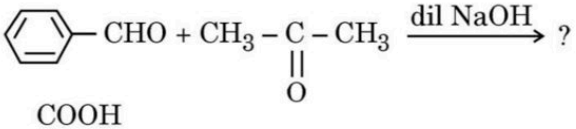
(i) Write the major product(s) in the following reactions :

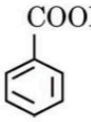
(ii) Give simple chemical tests to distinguish between the following pairs of compounds :

[5 Marks]

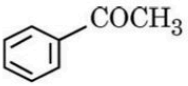
(i) Write the major product(s) in the following reactions :

(1)  $\xrightarrow[\text{b) } H^+]{\text{a) } KMnO_4\text{ , KOH}}$?

(2)  $\xrightarrow{\text{dil NaOH}}$?

(3)  $\xrightarrow{Br_2 / FeBr_3}$?

(ii) Give simple chemical tests to distinguish between the following pairs of compounds :

(1)  and 

(2) Pentanal and Pentan-3-one

Answer:

(i) Write the major product(s)

(1) Ethylbenzene + $KMnO_4$ / KOH, then H^+

Strong oxidation of any alkyl side chain on benzene → **benzoic acid**.

Product: C_6H_5COOH (Benzoic acid)

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(2) Benzaldehyde (C_6H_5CHO) + Acetone (CH_3COCH_3) with dil. NaOH

This is a **Claisen–Schmidt (aldol) condensation**.

Major product: **Benzylidene acetone**

Structure: **C_6H_5–CH=CH–CO–CH_3** (α,β-unsaturated ketone)

(3) Benzoic acid + Br_2 / $FeBr_3$

–COOH is a **meta-directing, deactivating** group.

Product: m-Bromobenzoic acid (3-bromobenzoic acid)

(ii) Give simple chemical tests to distinguish

(1) $C_6H_5COCH_3$ (acetophenone) and $C_6H_5COCH_2CH_3$ (propiophenone)

Iodoform test (I_2/NaOH):

- **Acetophenone ($C_6H_5COCH_3$)** → **Positive** (yellow CHI_3 precipitate)
- **Propiophenone ($C_6H_5COCH_2CH_3$)** → **Negative**

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(2) Pentanal and Pentan-3-one

Tollens' test or Fehling's test:

- **Pentanal (aldehyde) → Positive** (silver mirror / red precipitate)
- **Pentan-3-one (ketone) → Negative**

Key Points:

(i)

1. Benzoic acid

2. C_6H_5–CH=CH–CO–CH_3 (benzylidene acetone)

3. m-Bromobenzoic acid

(ii)

1. Iodoform test: acetophenone positive, propiophenone negative

2. Tollens'/Fehling's test: pentanal positive, pentan-3-one negative

Question 39.

(i) Give reasons for the following :

(1) In semicarbazide, only one NH_2 group is involved in the formation of semicarbazone.

(2) Acetaldehyde is more reactive than acetone towards addition of HCN.

(ii) (1) Arrange the following in decreasing order of their acidic strength :

CH_3COOH, O_2N CH_2 COOH, HCOOH

(2) Name the reagent in the following reaction :

CH_3- CH = CH-CH_2-CN ⟶ CH_3- CH = CH- CH_2 CHO

(iii) Write the reaction involved in Hell-Volhard-Zelinsky reaction.

[5 Marks]

Answer: (i)(1) In semicarbazide, only the terminal NH_2 group attached to the carbonyl carbon reacts with the aldehyde or ketone to form semicarbazone because it is more nucleophilic and accessible. The other NH groups are involved in resonance with the carbonyl group, reducing their nucleophilicity.
(2) Acetaldehyde is more reactive than acetone towards the addition of HCN because acetaldehyde has only one alkyl group which exerts less electron-donating effect, making its carbonyl carbon more

electrophilic and thus more reactive. In contrast, acetone has two alkyl groups that donate electrons and decrease the carbonyl carbon's reactivity.
(ii)(1) The acidic strength in decreasing order is: $O_2NCH_2COOH > HCOOH > CH_3COOH$. This is because the nitro group (O_2N-) is strongly electron withdrawing and stabilizes the conjugate base of O_2NCH_2COOH the most, increasing its acidity. Formic acid (HCOOH) is more acidic than acetic acid (CH_3COOH) due to the absence of electron-donating alkyl groups.
(2) The reagent that converts CH_3- CH = CH-CH_2-CN to CH_3- CH = CH- CH_2 CHO is DIBAL-H (Diisobutylaluminium hydride). It selectively reduces nitriles to aldehydes.
(iii) Hell-Volhard-Zelinsky reaction involves the alpha-halogenation of carboxylic acids using phosphorus tribromide (PBr_3) and bromine (Br_2). For example: R-CH_2-COOH + Br_2 + PBr_3 → R-CHBr-COOH which upon hydrolysis forms alpha-bromo acid. This reaction helps in introducing a halogen atom at the alpha-position of carboxylic acids.

Key Points: Only terminal NH_2 group in semicarbazide forms semicarbazone - Acetaldehyde more reactive due to less electron donation and more electrophilic carbonyl - Acidic strength order influenced by electron withdrawing groups - DIBAL-H is reagent for nitrile to aldehyde conversion - Hell-Volhard-Zelinsky reaction involves alpha-halogenation of carboxylic acids using PBr_3 and Br_2

Question 40.

Attempt any five of the following:

(a) Write the IUPAC name of the complex : $[Co(H_2O)(CN)(en)_2]^{2+}$

(b) Why is geometrical isomerism not possible in tetrahedral complexes having two different types of unidentate ligands coordinated with the central metal ion ?

(c) Arrange the following complex ions in increasing order of their crystal field splitting energy (Δ_o) :

$[Co(NH_3)_6]^{3+}$, $[CoF_6]^{3-}$, $[Co(CN)_6]^{3-}$

(d) Write the hybridization and magnetic character of the complex $[Ni(CO)_4]$ on the basis of valence bond theory. [Atomic No. : Ni = 28]

(e) Out of $[CoF_6]^{3-}$ and $[Co(C_2O_4)_3]^{3-}$, which one complex is :

(i) more stable ?

(ii) the high spin complex ?

(f) What is the difference between an ambidentate ligand and bidentate ligand ?

(g) Write the electronic configuration of d^5 in terms of t_2g and eg in an

octahedral field when :

(i) $\Delta_o > P$, and (ii) $\Delta_o < P$

[5 Marks]

Answer: (a) The complex $[Co(H_2O)(CN)(en)_2]^{2+}$ contains one aqua, one cyano, and two ethylenediamine (en) ligands. According to IUPAC rules, ligands are named alphabetically before the metal and their numbers indicated by prefixes. The IUPAC name is **diaquacyanoethylenediaminecobalt(III) ion**. However, since only one aqua and one cyano, and two en, it should be named as **aqua cyanido bis(ethylenediamine)cobalt(III) ion**. The oxidation state of Co is +3.

(b) Geometrical isomerism is not possible in tetrahedral complexes with two different types of unidentate ligands because tetrahedral complexes have all ligands arranged symmetrically at the corners of a tetrahedron, resulting in no cis or trans arrangements. Due to rapid ligand interchange and high symmetry, distinct geometrical isomers do not exist.

(c) The crystal field splitting energy (Δ_o) depends on the nature of ligands according to the spectrochemical series. Among NH_3, F^-, and CN^-, the order of increasing ligand field strength is $F^- < NH_3 < CN^-$. Therefore, increasing order of Δ_o is $[CoF_6]^{3-} < [Co(NH_3)_6]^{3+} < [Co(CN)_6]^{3-}$.

(d) In $[Ni(CO)_4]$, Ni has atomic number 28 with electronic configuration [Ar] $3d^8 4s^2$. CO is a strong field ligand and causes pairing of electrons in Ni. The hybridization is dsp^2, forming four equivalent hybrid orbitals for bonding with four CO ligands. The complex is diamagnetic as all electrons are paired.

(e) (i) $[Co(C_2O_4)_3]^{3-}$ is more stable because oxalate ($C_2O_4^{2-}$) is a bidentate ligand which forms stable chelate rings with Co, increasing stability.
(ii) $[CoF_6]^{3-}$ is the high spin complex because F^- is a weak field ligand causing less pairing and higher number of unpaired electrons.

(f) An ambidentate ligand can coordinate to the metal through two different atoms but only uses one atom at a time, for example SCN^- (can bind through S or N). A bidentate ligand has two donor atoms that coordinate simultaneously to the metal forming a chelate, for example ethylenediamine (en).

(g) For d^5 configuration in an octahedral field:
(i) When $\Delta_o > P$ (high crystal field splitting energy > pairing energy), electrons pair in lower t_{2g} orbitals first: electronic configuration is $t_{2g}^5\ eg^0$ (low spin).
(ii) When $\Delta_o < P$, electrons occupy t_{2g} and eg orbitals singly to minimize pairing: configuration is $t_{2g}^3\ eg^2$ (high spin).

Key Points: IUPAC naming of complex ligands - Geometrical isomerism absent due to tetrahedral symmetry - Crystal field splitting depends on ligand strength - [Ni(CO)4] has dsp2 hybridization and is diamagnetic - Chelate effect increases stability - Ambidentate vs bidentate ligand difference - Electronic configurations depend on Δo and pairing energy