CBSE Class 12 Chemistry 2024 — Set 3 — Answer Key

English Medium

Time Allowed: 3 Hours

General Instructions:

1. This is an answer key — each question is shown with its correct answer and a step-by-step explanation.
2. Questions appear in the original paper order.

Q.1

Which of the following does not show variable oxidation states ?

(a) Fe

(b) Cu

(c) Mn

(d) Sc <<

Explanation:

Sc (Scandium, Z=21) has electronic configuration [Ar]$3d^1 4s^2$.

It loses all three electrons to form Sc^{3+} only and does not show variable oxidation states.

Fe, Cu, and Mn all exhibit multiple oxidation states.

Q.2

The type of isomerism shown by the complex $[CoCl2(en)2]^+$ is :

(a) Ionisation isomerism

(b) Geometrical isomerism <<

(c) Linkage isomerism

(d) Coordination isomerism

Explanation:

$^+$ shows geometrical isomerism.

The two Cl ligands can be cis (adjacent) or trans (opposite) to each other in the octahedral complex, giving cis and trans isomers.

Q.3

Which of the following is diamagnetic in nature ? [Atomic number : Co = 27]

(a) Co^{3+}, octahedral complex with strong field ligand <<

(b) Co^{3+}, octahedral complex with weak field ligand

(c) Co^{3+}, in a square planar complex

(d) Co^{3+}, in a tetrahedral complex

Explanation:

Co^{3+} has configuration $[Ar]3d^6$.

In an octahedral complex with a strong field ligand, crystal field splitting energy (Δo) > pairing energy (P), so all 6 d-electrons pair up in the t2g level: $t2g^6eg^0$.

No unpaired electrons → diamagnetic.

With weak field ligands or in tetrahedral/square planar arrangements, unpaired electrons remain.

Q.4

Consider the following reaction :

4-Cl–C_6H_4–CH_2–Cl —(KCN)→ ?

(p-chlorobenzyl chloride treated with KCN)

The major product of the reaction is :

(a) 4-NC–C_6H_4–CH_2–CN (ring Cl and side-chain Cl both replaced by CN)

(b) 4-NC–C_6H_4–CH_2–Cl (only ring Cl replaced by CN)

(c) 4-Cl–C_6H_4–CH_2–CN (only side-chain Cl replaced by CN) <<

(d) Cl–C_6H_3(CN)–CH_2–CN (side-chain Cl replaced and an extra CN on the ring next to Cl)

Explanation:

Substrate: p-chlorobenzyl chloride.

The benzylic C–Cl is very reactive towards SN2 by CN^- (stabilised transition state), while the aryl C–Cl has partial double-bond character and does not undergo nucleophilic substitution under these conditions.

So only the side-chain Cl is replaced: 4-Cl–C_6H_4–CH_2–CN → (C).

Q.5

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

(a) p-Cresol

(b) p-Nitrophenol

(c) m-Nitrophenol

(d) 2,4,6-Trinitrophenol <<

Explanation:

Lower pKa means stronger acid.

2,4,6-Trinitrophenol (picric acid) has three nitro groups (all electron-withdrawing) at ortho and para positions, making the phenoxide ion highly stabilised by resonance and induction.

This makes it the strongest acid among the four (pKa ≈ 0.38).

Order of acidity: 2,4,6-trinitrophenol > p-nitrophenol > m-nitrophenol > p-cresol.

Q.6

(CH3)2CH–O–CH3 when treated with HI gives :

(a) (CH3)2CH–I + CH3OH

(b) (CH3)2CH–OH + CH3–I <<

(c) (CH3)2CH–I + CH3–I

(d) (CH3)2CH–OH + CH3OH

Explanation:

Mixed ether with a secondary and a primary (methyl) alkyl group: HI protonates the oxygen and I^- attacks the less hindered carbon by SN2.

The CH_3–O bond breaks, giving CH_3I and $(CH_3)_2CHOH$.

So the answer is (B).

(The more substituted group is cleaved only when it is tertiary, via SN1.)

Q.7

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

(a) CH3CONH2

(b) (CH3)3N

(c) (CH3)2NH

(d) CH3CH2NH2 <<

Explanation:

Primary amines (1°) react with benzenesulphonyl chloride (C6H5SO2Cl) to form N-alkyl benzenesulphonamide, which is soluble in alkali (due to acidic NH).

CH3CH2NH2 is a primary amine and forms an alkali-soluble product.

(CH3)3N (tertiary amine) does not react.

(CH3)2NH (secondary amine) forms a product insoluble in alkali.

CH3CONH2 is an amide, not an amine.

Q.8

The order of increasing basicities of CH3NH2 (I), (CH3)2NH (II), (CH3)3N (III) and C6H5NH2 (IV) in aqueous media is :

(a) IV < III < I < II <<

(b) II < I < IV < III

(c) I < II < III < IV

(d) II < III < I < IV

Explanation:

In aqueous medium, basicities are determined by inductive effect, steric effect, and solvation.

C6H5NH2 is least basic (lone pair delocalised into ring).

Among alkylamines: (CH3)2NH > CH3NH2 > (CH3)3N in aqueous medium because (CH3)3N is poorly solvated due to steric hindrance.

Order: IV < III < I < II.

Q.9

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

(a) Vitamin A

(b) Vitamin E

(c) Vitamin D

(d) Vitamin K <<

Explanation:

Vitamin K is essential for the synthesis of prothrombin and other clotting factors required for blood coagulation.

Deficiency of Vitamin K leads to increased bleeding time.

Q.10

When a catalyst increases the rate of a chemical reaction, then the rate

constant (k) :

(a) remains constant

(b) decreases

(c) increases <<

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

Explanation:

A catalyst lowers the activation energy (Ea) of a reaction.

By the Arrhenius equation k = Ae^(−Ea/RT), a decrease in Ea causes an increase in k.

So the rate constant increases when a catalyst is used.

Q.11

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

(a) 34·2 g mol^{-1}

(b) 57 g mol^{-1} <<

(c) 114 g mol^{-1}

(d) 3·42 g mol^{-1}

Explanation:

For isotonic solutions, osmotic pressures are equal: π1 = π2, so C1 = C2 (molarities are equal).

Molarity = (% w/v × 10) / M.

For sucrose: C2 = (6 × 10) / 342 = 60/342 = 0.1754 M.

For solute: C1 = (1 × 10) / M = 10/M.

Setting equal: 10/M = 60/342 → M = (10 × 342)/60 = 3420/60 = 57 g mol^{-1}.

Q.12

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

(a) Oxidation of Cl^- ion

(b) Reduction of Na^+ ion

(c) Oxidation of H2O

(d) Reduction of H2O <<

Explanation:

At cathode (reduction occurs): In aqueous NaCl, both Na^+ and H_2O are present.

H_2O is preferentially reduced over Na^+ because the reduction potential of H_2O (–0.83 V) is more positive than that of Na^+ (–2.71 V).

Cathode reaction: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ (i.e., reduction of H_2O).

Q.13

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.

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

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

Explanation:

Assertion (A) is true: ethylene glycol is an antifreeze and lowers freezing point (colligative property).

Reason (R) is false: ethylene glycol ($HO–CH_2–CH_2–OH$) is miscible with water and readily forms hydrogen bonds with water molecules due to its –OH groups.

It is soluble in water, not insoluble.

Hence A is true, R is false.

Q.14

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.

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

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

Explanation:

Assertion (A) is false: for complex (multi-step) reactions, order and molecularity need not be the same — order is an experimentally determined quantity while molecularity applies only to elementary steps.

Reason (R) is true: order is determined experimentally from rate law, and molecularity is defined only for elementary reactions (single-step reactions).

Q.15

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.

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

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

Explanation:

Both A and R are true, and R correctly explains A.

Ethanol (bp 78.4°C) has a higher boiling point than dimethyl ether (bp −24°C).

Ethanol molecules form intermolecular hydrogen bonds (O–H···O) due to the –OH group, requiring more energy to separate.

Dimethyl ether has no –OH, so cannot form intermolecular H-bonds.

R is the correct explanation.

Q.16

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

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

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

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

Explanation:

Assertion (A) is true: aniline does not undergo Friedel-Crafts reaction because the amino group acts as a Lewis base and coordinates with the Lewis acid catalyst (AlCl3), forming a salt (C6H5NH2·AlCl3) which deactivates the ring.

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

However, R does not correctly explain A — aniline's inability is due to salt formation with AlCl3, not merely because it is electrophilic substitution.

Q.17

(a) Define molal depression constant. How is it related to enthalpy of fusion ?

Answer: Molal depression constant (Kf or cryoscopic constant) is defined as the depression in freezing point when 1 mole of a non-volatile, non-electrolyte solute is dissolved in 1 kg of solvent. It is related to enthalpy of fusion by: $K_f = (R \times T_f^2 \times M_1) / (1000 \times \Delta_{fus}H)$, where R = gas constant, Tf = freezing point of pure solvent (K), M1 = molar mass of solvent (g mol^{-1}), $\Delta_{fus}H$ = enthalpy of fusion of solvent (J mol^{-1}).

Explanation:

Kf depends only on the nature of the solvent, not the solute.

For water, Kf = 1.86 K kg mol^{-1}.

The relation $K_f = RT^2M/(1000\Delta_{fus}H)$ shows that Kf increases with higher freezing point and lower enthalpy of fusion.

OR

Q.17

(b) [OR] What type of deviation is shown by ethanol and acetone mixture ? Give reason. What type of azeotropic mixture is formed by that deviation ?

Answer: Ethanol and acetone mixture shows positive deviation from Raoult's law.
Reason: In pure ethanol, molecules are associated by H-bonds. When acetone is added, acetone molecules come between ethanol molecules and break some H-bonds. The new ethanol–acetone interactions (H-bond between –OH and C=O) are weaker than the original ethanol–ethanol H-bonds. This weakens intermolecular forces, increasing vapour pressure above the ideal value. As a result, a minimum boiling azeotrope (also called positive azeotrope) is formed.

Explanation:

Positive deviation: Pobs > Pideal.

Minimum boiling azeotrope: the mixture has a lower boiling point than either pure component.

Example: ethanol–acetone mixture (bp of azeotrope ≈ 56°C at a specific composition, lower than acetone bp 56.1°C or ethanol bp 78.4°C).

Q.18

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

Answer: 3 (third order)

Explanation:

Rate = k[A]^n.

When [A] is tripled: Rate' = k[3A]^n = 3^n × k[A]^n = 3^n × Rate.

Given Rate' = 27 × Rate, so 3^n = 27 = 3^3.

Therefore n = 3.

The reaction is third order.

Q.18(b)

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

Answer: A bimolecular reaction is kinetically first order (pseudo first order) when

one of the reactants is present in such large excess that its concentration remains essentially constant throughout the reaction. Example: Hydrolysis of ethyl acetate ($CH_3COOC_2H_5$) in acidic aqueous medium — $CH_3COOC_2H_5 + H_2O \rightarrow CH_3COOH + C_2H_5OH$. Water is present in excess, so its concentration is constant. Rate = k'[$CH_3COOC_2H_5$], making it pseudo first order.

Explanation:

The rate law for the bimolecular reaction A + B → products is Rate = k[A][B].

If [B] >> [A] and [B] ≈ constant = [B]0, then Rate = k'[A] where k' = k[B]0.

This is pseudo first order kinetics.

Q.19

Complete the following ionic equations :

(a) $2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow$

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

Answer: (a) $2MnO_4^- + 5SO_3^{2-} + 6H^+ \rightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$

(b) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$

Explanation:

(a) MnO_4^- is reduced from +7 to +2 (gain of $5e^-$ each).

SO_3^{2-} is oxidised from +4 to +6 in SO_4^{2-} (loss of $2e^-$ each).

LCM of 5 and 2 gives: $2MnO_4^-$ (total $10e^-$ gained) + $5SO_3^{2-}$ (total $10e^-$ lost).

Balance O with H_2O and H^+: products are $2Mn^{2+} + 5SO_4^{2-} + 3H_2O$.

(b) $Cr_2O_7^{2-}$ oxidises Fe^{2+} to Fe^{3+}.

Cr goes from +6 to +3 (gain $3e^-$ each, 2 Cr = $6e^-$).

$6Fe^{2+}$ each lose $1e^-$ (total $6e^-$).

Balance: $2Cr^{3+} + 6Fe^{3+} + 7H_2O$.

Q.20

(a) Which halogen compound in the following pair will react faster in SN2 reactions and why ?

$CH_3–CH_2–I$ OR $CH_3–CH_2–Br$

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

Answer: (a) CH3–CH2–I (iodoethane) will react faster in SN2 reactions. Reason: In SN2 reactions, the rate depends on the leaving group ability. I^- is a better leaving group than Br^- because C–I bond is weaker (longer bond, lower bond dissociation energy) and iodide ion is more stable (larger, more polarisable). Therefore iodoethane undergoes SN2 faster.

(b) Chloroform (CHCl3) is stored in closed, dark-coloured bottles because in the presence of air and light, it undergoes slow oxidation to form phosgene (COCl2), which is a highly toxic gas. CHCl3 + (1/2)O2 → COCl2 + HCl. Dark bottles prevent photochemical oxidation.

Explanation:

SN2 rate order for alkyl halides with same alkyl group: RI > RBr > RCl > RF (based on leaving group ability).

Phosgene (COCl2) is a war gas and extremely toxic; hence storage precaution is essential.

Q.21

Give reaction of glucose with the following :

(a) HCN

(b) Conc. HNO3

Answer: (a) Glucose reacts with HCN by nucleophilic addition across the aldehyde group: CH2OH(CHOH)4CHO + HCN → CH2OH(CHOH)4CH(OH)CN (glucose cyanohydrin). The product is a cyanohydrin with one extra carbon.

(b) Glucose reacts with conc. HNO3 (oxidation) to give glucaric acid (saccharic acid): CH2OH(CHOH)4CHO + HNO3(conc.) → HOOC(CHOH)4COOH + H2O. Both the aldehyde (–CHO) and primary alcohol (–CH2OH) groups are oxidised to carboxylic acid (–COOH).

Explanation:

(a) HCN adds to the carbonyl (–CHO) of glucose — the CN^- acts as nucleophile and attacks the electrophilic carbon of the aldehyde.

(b) Concentrated HNO3 is a strong oxidising agent;

it oxidises both the terminal –CHO and –CH2OH groups to –COOH, giving the dicarboxylic acid glucaric acid.

Q.22

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)

Answer: 89.5 g mol^{-1} (≈ 90 g mol^{-1})

Explanation:

$(P° - P)/P = w_2M_1/(M_2w_1)$

$(32 - 31.84)/31.84 = (5 \times 18)/(M_2 \times 200)$

$0.16/31.84 = 90/(200\ M_2)$

$M_2 = (90 \times 31.84)/(200 \times 0.16) = 2865.6/32 \approx 89.5$ g mol^{-1}, i.e. about 90 g mol^{-1}.

Q.23

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

Given : $\Lambda°(K^+) = 73{\cdot}5$ S cm^2 mol^{-1}, $\Lambda°(Cl^-) = 76{\cdot}5$ S cm^2 mol^{-1}

Answer: Molar conductivity $\Lambda m = 124$ S cm^2 mol^{-1}; Degree of dissociation $\alpha = 0.827$ (82.7%)

Explanation:

Step 1: Calculate molar conductivity.

$\Lambda m = \kappa \times 1000 / c$

$\kappa = 2.48 \times 10^{-2}$ S cm^{-1}, $c = 0.2$ mol L^{-1}

$\Lambda m = (2.48 \times 10^{-2} \times 1000) / 0.2 = 24.8 / 0.2 = 124$ S cm^2 mol^{-1}

Step 2: Calculate limiting molar conductivity.

$\Lambda°m(KCl) = \Lambda°(K^+) + \Lambda°(Cl^-) = 73.5 + 76.5 = 150$ S cm^2 mol^{-1}

Step 3: Degree of dissociation.

α = Λm / Λ°m = 124 / 150 = 0.827 (82.7%)

Q.24

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

Answer: $k = 6.9 \times 10^{-3}$ min^{-1}; time for 80% completion = 230 min

Explanation:

$k = (2.303/t) \log([A]_0/[A]) = (2.303/40) \log(100/75) = (2.303/40) \log(4/3)$

$\log(4/3) = \log 4 - \log 3 = 0.60 - 0.48 = 0.12$

$k = (2.303 \times 0.12)/40 = 6.9 \times 10^{-3}$ min^{-1}

For 80% completion [A] = 20: $t = (2.303/k) \log 5 = (2.303 \times 0.69)/(6.9 \times 10^{-3}) \approx 230$ min.

Q.25

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

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

Answer: (a) SN1. 2-Bromobutane is a secondary halide; in aqueous (polar protic) medium it ionises to a planar 2° carbocation, which water attacks from both faces equally, giving racemic (±)-butan-2-ol.

(b) Wurtz–Fittig reaction: $C_6H_5Cl + CH_3Cl + 2Na \rightarrow C_6H_5–CH_3 + 2NaCl$ (toluene).

Explanation:

(a) Racemisation (±) shows the reaction goes through a planar carbocation intermediate →

SN1.

(SN2 would give only the inverted product.)

(b) An aryl halide and an alkyl halide coupled with Na in dry ether = Wurtz–Fittig reaction;

product is toluene (methylbenzene).

Q.26

(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.

Answer: (a)(i) Reimer-Tiemann reaction: phenol + $CHCl_3$ + aq. NaOH, then H^+ → salicylaldehyde (o-hydroxybenzaldehyde):

$C_6H_5OH + CHCl_3 + 3NaOH \rightarrow o\text{-}HOC_6H_4CHO + 3NaCl + 2H_2O$

The electrophile is dichlorocarbene $:CCl_2$, generated from $CHCl_3$ and NaOH.

(a)(ii) Kolbe's reaction: sodium phenoxide + CO_2 (≈ 400 K, 4–7 atm), then H^+ → salicylic acid (2-hydroxybenzoic acid):

$C_6H_5ONa + CO_2 \rightarrow o\text{-}HOC_6H_4COONa \rightarrow (H^+)\ o\text{-}HOC_6H_4COOH$

(b) Bromine water (Br_2/H_2O): all three ortho/para positions are brominated, giving 2,4,6-tribromophenol as a white precipitate.

Explanation:

(a)(i) The electrophile is dichlorocarbene ($:CCl_2$) generated in situ;
it attacks the ortho position of the phenoxide ion.
(a)(ii) The phenoxide ion is attacked by CO_2 at the ortho position;
acidification gives salicylic acid.
(b) In aqueous medium the –OH group activates the ring so strongly that all three ortho/para positions are substituted (in CS_2 or CCl_4 only mono-bromination occurs).

Q.27

How will you bring about the following conversions ? (any three)

(a) Benzoic acid to Benzaldehyde

(b) Ethanal to Propanone

(c) Acetophenone to Benzoic acid

(d) Bromobenzene to 1-Phenylethanol

Answer: (a) Benzoic acid → benzaldehyde: $C_6H_5COOH + SOCl_2 \rightarrow C_6H_5COCl$; then H_2, Pd–$BaSO_4$ (Rosenmund reduction) → C_6H_5CHO.

(b) Ethanal → propanone: $CH_3CHO + CH_3MgBr$, then $H_3O^+ \rightarrow CH_3CH(OH)CH_3$ (propan-2-ol); oxidise with CrO_3/PCC (or $K_2Cr_2O_7/H_2SO_4$) → CH_3COCH_3.

(c) Acetophenone → benzoic acid: $C_6H_5COCH_3 + NaOI$ (I_2/NaOH), warm → $C_6H_5COONa + CHI_3$; acidify with $H^+ \rightarrow C_6H_5COOH$.

(d) Bromobenzene → 1-phenylethanol: $C_6H_5Br + Mg$ (dry ether) → C_6H_5MgBr; + CH_3CHO, then $H_3O^+ \rightarrow C_6H_5CH(OH)CH_3$.

Explanation:

Any three conversions are to be answered.

(a) acid chloride then Rosenmund reduction;

(b) Grignard addition then oxidation of the secondary alcohol;

(c) iodoform (haloform) reaction of the methyl ketone;

(d) Grignard addition to ethanal.

Q.28

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

(a) $CH_3CH_2Cl \xrightarrow{KCN} A \xrightarrow{LiAlH_4} B \xrightarrow{HNO_2\ (0°C)} C$

(b) $C_6H_5NO_2$ (nitrobenzene) $\xrightarrow{Fe/HCl} A \xrightarrow[NaNO_2 + HCl\ (273\ K)]{} B \xrightarrow{C_6H_5OH} C$

Answer: Reaction (a): A = CH_3CH_2CN (propionitrile/propanenitrile); B = $CH_3CH_2CH_2NH_2$ (propan-1-amine / n-propylamine); C = $CH_3CH_2CH_2OH$ (propan-1-ol).

Reaction (b): A = $C_6H_5NH_2$ (aniline); B = $C_6H_5N_2^+Cl^-$ (benzenediazonium chloride); C = p-HO–C_6H_4–N=N–C_6H_5 (p-hydroxyazobenzene, an azo dye).

Explanation:

Reaction (a): $CH_3CH_2Cl + KCN \rightarrow CH_3CH_2CN$ (A; SN2 substitution, nitrile formed).

$CH_3CH_2CN + LiAlH_4 \rightarrow CH_3CH_2CH_2NH_2$ (B; reduction of nitrile to primary amine).

$CH_3CH_2CH_2NH_2 + HNO_2$ (0°C) →

$CH_3CH_2CH_2OH + N_2 + H_2O$ (C; primary aliphatic amine reacts with HNO_2 to give alcohol via diazonium salt which immediately decomposes).

Reaction (b): Nitrobenzene + Fe/HCl → $C_6H_5NH_2$ (A; reduction of $–NO_2$ to $–NH_2$).

$C_6H_5NH_2 + NaNO_2 + HCl$ at 273 K → $C_6H_5N_2^+Cl^-$ (B; diazotisation).

$C_6H_5N_2^+Cl^- + C_6H_5OH$ (phenol) →

p-HO–C_6H_4–N=N–C_6H_5 (C; coupling reaction of diazonium salt with phenol at para position to give p-hydroxyazobenzene, an orange azo dye).

Q.29(a)

(Case Study — Transition Elements & Inner Transition Elements)

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 (a): Why do transition metals and their compounds act as good catalysts ?

Answer: Transition metals and their compounds act as good catalysts because: (1) They have variable oxidation states, which allows them to form unstable intermediate compounds with the reactants, facilitating alternate reaction pathways with lower activation energies. (2) They have large surface area

(especially in finely divided form) that can adsorb reactant molecules, increasing the effective concentration at the surface (heterogeneous catalysis).

Explanation:

The ability to exhibit variable oxidation states is the key reason.

Examples: Fe in Haber process ($N_2 + 3H_2 \rightarrow 2NH_3$), V_2O_5 in Contact process ($SO_2 \rightarrow SO_3$), MnO_2 in decomposition of $KClO_3$.

Q.29(b)

(Case Study — Transition Elements) Question (b): What is the cause of contraction in the atomic size of lanthanoids ?

Answer: The contraction in atomic size of lanthanoids (lanthanoid contraction) is caused by the imperfect (poor) shielding effect of the 4f-orbital electrons. As atomic number increases across the lanthanoid series, electrons are added to the 4f-subshell. The 4f electrons are poor shielders of nuclear charge from each other due to the shape of f-orbitals. The increasing nuclear charge (Zeff) is not effectively screened, so the effective nuclear charge felt by the outermost electrons increases, pulling the electron cloud closer and decreasing atomic radius.

Explanation:

This is unique to lanthanoids (4f filling).

The same effect (imperfect shielding) also occurs in actinoids (5f filling) giving actinoid contraction.

Q.29(c)

(Case Study — Transition Elements) Question (c): Define lanthanoid contraction. How does it affect the atomic radii of the third transition series and the second transition series ?

Answer: Lanthanoid contraction: The steady decrease in atomic size (ionic radii) of the lanthanoid elements (La to Lu) with increasing atomic number, due to

imperfect shielding of 4f electrons.

Effect on transition series atomic radii:

- The lanthanoids come between the second (4d) and third (5d) transition series in the periodic table.
- Due to lanthanoid contraction, the radii of the third transition series elements (5d series, e.g., Hf to Pt) are almost equal to those of the corresponding second transition series elements (4d series, e.g., Zr to Pd).
- Despite being in the next period (with an extra filled shell), the third transition series elements have nearly the same atomic radii as their second-series counterparts. For example: Zr = 160 pm, Hf = 159 pm (almost identical).
- This makes the elements of the second and third transition series similar in properties (e.g., Zr/Hf are very hard to separate chemically).

Explanation:

Without lanthanoid contraction, the 5d elements would be significantly larger than the 4d elements (as expected going down a group).

The lanthanoid contraction nearly perfectly compensates for the expected increase in size.

OR

Q.29(c)

(Case Study — Transition Elements) Question (c) [OR]: In aqueous media, which is a stronger reducing agent Cr^{2+} or Fe^{2+} and why ?

Answer: Cr^{2+} is a stronger reducing agent than Fe^{2+} in aqueous media.

Reason: The standard reduction potentials are:

Cr^{3+}/Cr^{2+}: $E^\circ = -0.41$ V

Fe^{3+}/Fe^{2+}: $E^\circ = +0.77$ V

A more negative reduction potential means the species is more easily oxidised (stronger reducing agent). Cr^{2+} has a much more negative E° than Fe^{2+}, so Cr^{2+} is readily oxidised to Cr^{3+} and is a stronger reducing agent.

Explanation:

Reducing agent: the species that gets oxidised.

Lower (more negative) E° for the Mn+/M(n-1)+ couple →

M(n-1)+ is more easily oxidised →

stronger reducing agent.

Cr^{2+} ($E° = -0.41$ V) vs Fe^{2+} ($E° = +0.77$ V) confirms Cr^{2+} is the stronger reducing agent.

Q.30(a)

(Case Study — Proteins and Biomolecules)

Proteins are the most abundant biomolecules of the living system. Proteins are the polymers of about twenty different α-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.

Question (a): What are essential amino acids ?

Answer: Essential amino acids are those amino acids that cannot be synthesised by the human body and must be obtained from food (diet). There are ten essential amino acids. Examples: valine, leucine, isoleucine, phenylalanine, tryptophan, methionine, threonine, lysine, histidine, arginine.

Explanation:

Non-essential amino acids can be synthesised in the body.

Essential amino acids must be supplied through the diet.

Deficiency leads to various metabolic disorders.

Q.30(b)

(Case Study — Proteins) Question (b): What is meant by zwitter ionic form of amino acids ?

Answer: Zwitter ionic form (also called dipolar ion or zwitterion) refers to the form of amino acids in which the molecule carries both a positive charge and a negative charge simultaneously, with an overall neutral charge. The amino group (–NH2) accepts a proton to become $–NH_3^+$ (positively charged) and the carboxyl group (–COOH) loses a proton to become $–COO^-$ (negatively charged). So the molecule is: $^+NH_3–CHR–COO^-$. In this form, amino acids show amphoteric behaviour — they can react with both acids (the $–COO^-$ accepts H^+) and bases (the $–NH_3^+$ donates H^+).

Explanation:

Zwitter ion exists predominantly in the solid state and aqueous solution at the isoelectric point (pH = pI).

The pH at which zwitter ion concentration is maximum is the isoelectric point.

Q.30(c)

(Case Study — Proteins) Question (c)(i): Give one example each for Fibrous protein and Globular protein.

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

Answer: (c)(i) Fibrous protein example: Keratin (found in hair, nails, wool, feathers) or Myosin (muscle fibre) or Collagen (tendons). Globular protein example: Insulin (regulates blood glucose), Haemoglobin (carries oxygen in blood), or Albumin (in egg white).

(c)(ii) The monomers (α-amino acids) of proteins are held together by peptide bonds (also called amide bonds). A peptide bond is formed between the –COOH group of one amino acid and the –NH2 group of the adjacent amino acid with the elimination of a water molecule: –CO–NH– linkage.

Explanation:

(c)(i) Fibrous proteins: long polypeptide chains arranged in fibres;
insoluble in water;
structural role.
Globular proteins: compact spherical/ellipsoidal shape;
soluble in water;
physiological functions (enzymes, hormones, antibodies).
(c)(ii) Peptide bond: –CO–NH– bond formed by condensation (–COOH + H2N– → –CO–NH– + H2O).

OR

Q.30(c)

(Case Study — Proteins) Question (c) [OR] (i): What is the structural feature which characterises a reducing sugar ?
(c)(ii): What is the structural difference between nucleoside and nucleotide ?

Answer: (c)(i) A reducing sugar is characterised by the presence of a free (unblocked) aldehydic group (–CHO) or a free hemiacetal/hemiketal group (anomeric –OH that can open to give –CHO or ketone). These free carbonyl groups can reduce Fehling's solution or Tollen's reagent. All monosaccharides (glucose, fructose, galactose) are reducing sugars. Sucrose is a non-reducing sugar because both anomeric carbons are involved in the glycosidic bond.

(c)(ii) Nucleoside = Nitrogenous base + Pentose sugar (ribose or deoxyribose). Nucleotide = Nitrogenous base + Pentose sugar + Phosphate group. The structural difference is that a nucleotide has a phosphate group esterified to the 5'-OH of the sugar, whereas a nucleoside lacks the phosphate group.

Explanation:

(i) Reducing sugars: glucose (open chain has –CHO), fructose (open chain has –C=O but can tautomerise).
Sucrose: no free anomeric –OH, so non-reducing.
(ii) Nucleotides are the monomeric units of nucleic acids (DNA, RNA).
Nucleosides are formed by hydrolysis of nucleotides (removal of phosphate).

Q.31(a)

(a)(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]

(a)(ii) State the second law of Faraday's electrolysis. How will the pH of an aqueous NaCl solution be affected when it is electrolysed ?

Answer: (a)(i) $E°cell = E°(cathode) - E°(anode) = E°(Cd^{2+}/Cd) - E°(Zn^{2+}/Zn) = (-0.40) - (-0.76) = 0.36$ V

Using Nernst equation (n = 2 for both Zn^{2+}/Zn and Cd^{2+}/Cd half-cells):

$Ecell = E°cell - (0.0591/n) \times \log([Zn^{2+}]/[Cd^{2+}])$

$Ecell = 0.36 - (0.0591/2) \times \log(0.001/0.1)$

$\log(0.001/0.1) = \log(0.01) = \log(10^{-2}) = -2$ [since log 10 = 1]

$Ecell = 0.36 - (0.02955) \times (-2) = 0.36 + 0.0591 = 0.4191 \approx 0.42$ V

(a)(ii) Faraday's second law: When the same quantity of electricity is passed through different electrolytes, the masses of the substances deposited/liberated are directly proportional to their chemical equivalents (equivalent weights).

Effect on pH of aqueous NaCl on electrolysis:

Anode: $2Cl^- \rightarrow Cl2 + 2e^-$

Cathode: $2H2O + 2e^- \rightarrow H2 + 2OH^-$

OH^- ions are produced at the cathode, increasing the concentration of OH^- in the solution, which makes the solution alkaline. Therefore, the pH of the aqueous NaCl solution increases (becomes greater than 7).

Explanation:

(i) $E°cell = E°(Cd^{2+}/Cd) - E°(Zn^{2+}/Zn) = -0.40 - (-0.76) = 0.36$ V; n = 2.

$Ecell = 0.36 - (0.0591/2) \log([Zn^{2+}]/[Cd^{2+}]) = 0.36 - 0.02955 \times \log(10^{-2}) = 0.36 + 0.0591 = 0.4191$ V ≈ 0.42 V.

(ii) Faraday's second law: for the same quantity of electricity, masses deposited are proportional to equivalent masses.

On electrolysis of aqueous NaCl, OH^- accumulates at the cathode ($2H_2O + 2e^- \rightarrow H_2 + 2OH^-$), so pH increases.

Q.31(b)

(b)(i) [OR] Calculate the ΔrG° and log Kc for the following cell reaction :
$Fe(s) + Ag^+(aq) \rightarrow Fe^{2+}(aq) + Ag(s)$
Given : $E^\circ(Fe^{2+}/Fe) = -0{\cdot}44$ V, $E^\circ(Ag^+/Ag) = +0{\cdot}80$ V, 1 F = 96500 C mol^{-1}

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

(b)(iii) How many Faradays are required for the oxidation of 1 mole of H2O to O2 ?

Answer: (b)(i) $E^\circ cell = E^\circ(cathode) - E^\circ(anode) = E^\circ(Ag^+/Ag) - E^\circ(Fe^{2+}/Fe) = 0.80 - (-0.44) = 1.24$ V

n = 2 ($Fe \rightarrow Fe^{2+} + 2e^-$; $2Ag^+ + 2e^- \rightarrow 2Ag$)

$\Delta rG^\circ = -nFE^\circ cell = -2 \times 96500 \times 1.24 = -239{,}320$ J $mol^{-1} = -239.32$ kJ mol^{-1}

$\log Kc = nE^\circ cell / 0.0591 = (2 \times 1.24) / 0.0591 = 2.48 / 0.0591 = 41.96 \approx 41.96$

(b)(ii) Advantages of fuel cells over batteries:

1. Fuel cells have higher efficiency (no heat loss as in combustion; direct conversion of chemical energy to electrical energy).
2. Fuel cells do not cause pollution — when H2/O2 fuel cells are used, water is the only by-product.
3. Fuel cells can operate continuously as long as fuel is supplied (unlike batteries that discharge and need recharging).

(b)(iii) Oxidation of H2O to O2: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

1 mole H2O loses $2e^-$ (since 2 moles H2O give $4e^-$). Therefore oxidation of 1 mole H2O requires 2 Faradays.

Explanation:

(i) $E°_{cell} = 0.80 - (-0.44) = 1.24$ V, n = 2.

$\Delta_r G° = -nFE° = -2 \times 96500 \times 1.24 = -239320$ J mol^{-1} ≈ −239.3 kJ mol^{-1}.

log Kc = nE°/0.0591 = 2.48/0.0591 ≈ 42 (41.96 with 0.0591; 42.03 with 0.059).

(ii) Fuel cells are more efficient, non-polluting and work continuously while fuel is supplied.

(iii) $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$, so 1 mol H_2O needs 2 F.

Q.32(a)

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

(1) $C_6H_5CH_2CH_3$ —(a) $KMnO_4$, KOH; (b) $H^+ \rightarrow$?

(2) $C_6H_5CHO + CH_3COCH_3$ —dil. NaOH→ ?

(3) C_6H_5COOH —$Br_2/FeBr_3 \rightarrow$?

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

(1) $C_6H_5COCH_3$ and $C_6H_5COCH_2CH_3$

(2) Pentanal and Pentan-3-one

Answer: (a)(i)

(1) Benzoic acid, C_6H_5COOH (side-chain oxidation of the ethyl group).

(2) $C_6H_5CH{=}CH{-}CO{-}CH_3$ (benzalacetone, 4-phenylbut-3-en-2-one): Claisen–Schmidt (crossed aldol) condensation followed by dehydration.

(3) m-Bromobenzoic acid (3-bromobenzoic acid): –COOH is meta-directing.

(a)(ii)

(1) Iodoform test: acetophenone ($C_6H_5COCH_3$, a methyl ketone) warmed with I_2/NaOH gives a yellow precipitate of CHI_3; propiophenone ($C_6H_5COCH_2CH_3$) does not.

(2) Tollens' test: pentanal gives a silver mirror; pentan-3-one does not (Fehling's solution: red precipitate with pentanal only).

Explanation:

Ethylbenzene → benzoic acid with $KMnO_4$/KOH then H^+.

Benzaldehyde (no α-H) + acetone under dil.

NaOH gives the crossed aldol condensation product.

In benzoic acid the –COOH group deactivates the ring and directs the incoming Br to the meta position.

Acetophenone has the $CH_3CO–$ group and answers the iodoform test; propiophenone lacks it.

Aldehydes reduce Tollens' reagent; ketones do not.

Q.32(b)

(b)(i) [OR] Give reasons for the following :

(1) In semicarbazide, only one NH2 group is involved in the formation of semicarbazone.

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

(b)(ii)(1) Arrange the following in decreasing order of their acidic strength :
CH3COOH, O2N–CH2–COOH, HCOOH

(b)(ii)(2) Name the reagent in the following reaction :
CH3–CH=CH–CH2–CN → CH3–CH=CH–CH2–CHO

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

Answer: (b)(i)(1) Semicarbazide, $H_2N–CO–NH–NH_2$, has two $–NH_2$ groups. The one attached to the C=O group is part of an amide: its lone pair is delocalised over the C=O, so it is not nucleophilic. Only the $–NH_2$ of the $–NH–NH_2$ end is free to attack the carbonyl carbon, so only it forms the semicarbazone.

(b)(i)(2) Acetaldehyde has one $–CH_3$ group and acetone two. Less steric hindrance and a smaller +I effect make the carbonyl carbon of acetaldehyde more electrophilic and more easily attacked by CN^-.

(b)(ii)(1) $O_2N–CH_2–COOH$ > HCOOH > CH_3COOH. The $–NO_2$ group (strong –I

effect) stabilises the carboxylate ion and increases acidity; –CH_3 (+I effect) destabilises the carboxylate ion and decreases acidity.

(b)(ii)(2) DIBAL-H (diisobutylaluminium hydride) at low temperature, followed by H_2O (alternatively Stephen reduction: $SnCl_2$/HCl, then H_3O^+). The C=C bond is not affected.

(b)(iii) Hell–Volhard–Zelinsky reaction: a carboxylic acid having α-H reacts with Cl_2 or Br_2 in the presence of a little red phosphorus to give the α-halo acid, e.g. $CH_3COOH + Br_2 \xrightarrow{\text{red P}} BrCH_2COOH + HBr$.

Explanation:

(i)(1) Resonance of the amide-type NH_2 with C=O removes its nucleophilicity.

(i)(2) Steric and electronic effects both favour acetaldehyde.

(ii)(1) Electron-withdrawing groups raise acid strength, electron-donating groups lower it.

(ii)(2) Nitrile →
aldehyde needs a partial-reduction reagent such as DIBAL-H; H_2/Raney Ni would also reduce C=C.

(iii) HVZ gives α-halo acids.

Q.33(a)

(Attempt any five) (a) Write the IUPAC name of the complex : $[Co(H2O)(CN)(en)2]^{2+}$

Answer: Aquacyanobis(ethane-1,2-diamine)cobalt(III) ion

Explanation:

Ligands in alphabetical order: aqua (H_2O), cyano (CN^-), ethane-1,2-diamine (en).

Prefix: bis for the two en ligands.

Central metal: Co.

Oxidation state of Co: let it be x.

Charge: $[Co(H2O)(CN)(en)2]^{2+}$.

H_2O = neutral, CN^- = −1, en = neutral × 2.

$x + 0 + (-1) + 0 = +2 \rightarrow x = +3$.

So Co(III).

IUPAC name: aquacyanobis(ethane-1,2-diamine)cobalt(III) ion.
(Note: the complex carries 2+ overall charge.)

Q.33(b)

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

Answer: Geometrical isomerism is not possible in tetrahedral complexes of the type [MA2B2] because all four positions in a tetrahedron are equivalent to each other. In a tetrahedral geometry, any two positions are adjacent to each other (there is no 'trans' position opposite to each other, unlike in octahedral/square planar complexes). Therefore, there is no distinction between cis and trans arrangements — any arrangement of the two A and two B ligands gives the same compound. Hence no geometrical isomers exist.

Explanation:

Geometrical isomerism arises when two different arrangements of ligands are possible (cis/trans).
In an octahedron or square plane, positions can be cis (adjacent, 90°) or trans (opposite, 180°).
In a tetrahedron, all bond angles are ~109.5° and all positions are equivalent — no position is 'opposite' another — so cis/trans distinction does not arise.

Q.33(c)

(Attempt any five) (c) Arrange the following complex ions in increasing order of their crystal field splitting energy (Δo) :
$[Co(NH3)6]^{3+}$, $[CoF6]^{3-}$, $[Co(CN)6]^{3-}$

Answer: Increasing order of Δo: $[CoF6]^{3-} < [Co(NH3)6]^{3+} < [Co(CN)6]^{3-}$

Explanation:

Crystal field splitting energy (Δo) depends on the field strength of ligands (spectrochemical series).
CN^- is a strong field ligand (highest Δo), NH3 is a moderate field ligand, and F^- is a

weak field ligand (lowest Δo).

Spectrochemical series order: F^- < NH_3 < CN^-.

So Δo increases: $[CoF_6]^{3-}$ < $[Co(NH_3)_6]^{3+}$ < $[Co(CN)_6]^{3-}$.

Q.33(d)

(Attempt any five) (d) Write the hybridization and magnetic character of the complex [Ni(CO)4] on the basis of valence bond theory. [Atomic No. : Ni = 28]

Answer: Hybridization: sp^3; Magnetic character: Diamagnetic

Explanation:

Ni (Z = 28): [Ar] $3d^8\ 4s^2$. In $[Ni(CO)_4]$, Ni is in the 0 oxidation state.

CO is a strong-field ligand, so the 4s electrons pair into 3d → $3d^{10}\ 4s^0$.

The empty 4s and three 4p orbitals hybridise (sp^3) and accept four lone pairs from CO →

tetrahedral.

All electrons are paired → diamagnetic.

Q.33(e)

(Attempt any five) (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 ?

Answer: (i) $[Co(C_2O_4)_3]^{3-}$ is more stable. Oxalate ($C_2O_4^{2-}$) is a bidentate ligand forming chelate rings, which confers extra stability (chelate effect) compared to $[CoF_6]^{3-}$ where F^- is a monodentate ligand.

(ii) $[CoF_6]^{3-}$ is the high spin complex. F^- is a weak field ligand (small Δo), so Δo < P (pairing energy), and electrons occupy both t2g and eg orbitals giving maximum unpaired electrons (high spin). $C_2O_4^{2-}$ is a stronger field ligand than F^-, giving larger Δo, resulting in lower spin character.

Explanation:

(i) $[Co(C_2O_4)_3]^{3-}$ is more stable: oxalate is a bidentate chelating ligand (chelate effect), whereas F^- is monodentate.

(ii) $[CoF_6]^{3-}$ is the high-spin complex: F^- is a weak-field ligand ($\Delta o < P$), giving $t_2g^4e_g^2$ with 4 unpaired electrons.

Oxalate is a stronger-field ligand than F^-, so $[Co(C_2O_4)_3]^{3-}$ is low spin (t_2g^6).

Q.33(f)

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

Answer: Ambidentate ligand: A ligand that can donate lone pairs from two different donor atoms but bonds to the metal through only ONE donor atom at a time. Examples: SCN^- (can bond via S or via N), $NO2^-$ (can bond via N as nitro or via O as nitrito), CN^- (can bond via C or via N).

Bidentate ligand: A ligand that has two donor atoms and simultaneously bonds to the metal through BOTH donor atoms, forming a ring (chelate). Examples: ethylenediamine (en) [bonds via two N atoms], oxalate ($C2O4^{2-}$) [bonds via two O atoms], acetylacetonate (acac).

Key difference: Ambidentate ligand uses only one donor atom at a time (two possible sites); bidentate ligand uses both donor atoms simultaneously.

Explanation:

Ambidentate: mono-dentate in practice, but has two possible donor sites (creates linkage isomers).

Bidentate: truly bi-dentate — occupies two coordination sites simultaneously and forms 5- or 6-membered chelate rings.

Q.33(g)

(Attempt any five) (g) Write the electronic configuration of d^5 in terms of t2g and eg in an octahedral field when :

(i) $\Delta o > P$, and (ii) $\Delta o < P$

Answer: (i) $\Delta o > P$ (strong field, low spin): $t2g^5\ eg^0$ — 1 unpaired electron.

(ii) $\Delta o < P$ (weak field, high spin): $t2g^3\ eg^2$ — 5 unpaired electrons.

Explanation:

(i) When $\Delta o > P$, pairing costs less energy than promotion, so all 5 electrons enter the lower t2g set: $t2g^5\ eg^0$ (low spin, 1 unpaired e^-), e.g. $[Fe(CN)_6]^{3-}$.

(ii) When $\Delta o < P$, electrons occupy all five d orbitals singly before pairing: $t2g^3\ eg^2$ (high spin, 5 unpaired e^-), e.g. $[FeF_6]^{3-}$.