5
CHAPTER
Co-ordination Compounds

Level - 1 CORE SUBJECTIVE QUESTIONS

MULTIPLE CHOICE QUESTIONS (MCQs) (1 Mark)

1. **Option (D) is correct.**

   Explanation: EDTA^{4-} is a hexadentate ligand because it has six donor atoms.

2. **Option (A) is correct.**

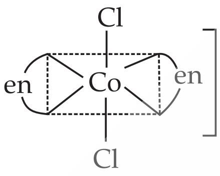
   Explanation: CO^{3+} with strong field ligand is likely to be diamagnetic.

3. **Option (A) is correct.**

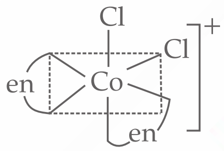
   Explanation: Oxalate is a bidentate ligand act as chelating agents because the two donor atoms allow the ligand to bind more tightly to the metal ion.

4. **Option (B) is correct.**

   Explanation:



Trans-form



Cis-form

5. **Option (C) is correct.**

   Explanation: The highest excitation energy will be observed in $[Co(CN)_6]^{3-}$ because CN$^-$ is the strongest ligand. Stronger ligands create large crystal field splitting which corresponds to higher excitation energy.

6. **Option (C) is correct.**

   Explanation: Polyderlate ligand form more stable complexes than unidentate ligands.

7. **Option (A) is correct.**

   Explanation: The magnetic moment of substance increases with the number of unpaired electrons.

Ion	No.of unpaired electrons
Fe^{2+}	4
Co^{2+}	3
Cr^{3+}	3
Ni^{2+}	2

8. **Option (C) is correct.**

   Explanation: The geometry of the complex ion with dsp^2 hybridisation is square planar.

9. **Option (B) is correct.**

   Explanation: In the compounds $[Co(NH_3)_5NO_2]Cl_2$ the oxidation state of Cobalt is +3 and here five NH_3 ligand and a NO_2 ligand are attached to the central atom.

10. **Option (B) is correct.**

    Explanation: Overall charge of metal is +4 it is balanced by two Cl^- ions, by two NO_3^- ions, and ethane 1, 2-diamine in a neutral ion.

11. **Option (C) is correct.**

    Explanation: Ionisation isomers have same molecular formula but produce different ions in solution when ionized.

    $[Co(SO_4)\,(NH_3)_5]Br \rightarrow [Co(SO_4)\,(NH_3)_5]^+ + Br^-$

    $[Co(Br)\,(NH_3)_5]SO_4 \rightarrow [Co(Br)\,(NH_3)_5]^{2+} + SO_4^{2-}$

12. **Option (B) is correct.**

    Explanation: In metal carbonyls, oxidation state of metal is zero.

13. **Option (C) is correct.**

    $[Fe\,(C_2O_4)_3]^{3-}$

$$\begin{aligned} x + (-2 \times 3) &= -3 \\ x - 6 &= -3 \\ x &= -3 + 6 \\ x &= +3 \end{aligned}$$

    In other given compounds metal show + 2 oxidation state.

14. **Option (B) is correct.**

    Explanation:

$$[Co(NH_3)_5\,NO_3]SO_4 \rightleftharpoons [Co(NH_3)_5NO_3]^{2+} + SO_4^{2-}$$

$$[Co(NH_3)_5SO_4]NO_3 \rightleftharpoons [Co(NH_3)_5SO_4]^+ + NO_3^-$$

15. **Option (B) is correct.**

    Explanation: NH_4^+ does not have a lone pair of electrons that it can donate to a central metal atom. and behave as ligand.

16. **Option (A) is correct.**

    Explanation:

    $[Fe(C_2O_4)_3]^{3-}$ is a chelate because three $C_2O_4^{2-}$ ions act as chelating ligand being a bidentate ligand it binds the metal ion at two points forming a stable chelate ring.

17. Option (B) is correct.

Explanation:

$[Ni(NH_3)_6]Cl_2 \rightarrow [Co(NH_3)_6]^{2+} + 2Cl^-$ 3 ions are produced.

18. Option (B) is correct.

Explanation: Here nickel in +2 oxidation state with 2 unpaired e^- So, $n = 2$

$$\mu_s = \sqrt{n(n+2)}$$
$$= \sqrt{2(2+2)}$$
$$= \sqrt{8}$$
$$\mu_s = 2.82 \text{ B.M.}$$

19. Option (B) is correct.

Explanation: Ionisation isomerism is shown when the counter ion (outside the coordination sphere) can act as a ligand and displace a ligand within the coordination sphere. This produces different ions in solution.

$$[Co(NH_3)_5Br]\,SO_4 \rightleftharpoons [Co(NH_3)_5Br]^{2+} + SO_4^{2-}$$

$$[Co(NH_3)_5SO_4]Br \rightleftharpoons [CO(NH)_5SO_4]^- + Br^-$$

20. Option (B) is correct.

Explanation: $[Co(NH_3)_4(H_2O)_2]\,Cl_3$

$$x + (0 \times 4) + (0 \times 2) + (-1 \times 3) = 0$$
$$x + 0 + 0 + (-3) = 0$$
$$x - 3 = 0$$
$$x = +3$$

ASSERTION-REASON QUESTIONS (1 Mark)

1. **Option (A) is correct.**

   Explanation: EDTA forms stable chelate complexes with Pb^{2+} metal ions, hence it is used for treating Pb poisoning and other heavy metal poisoning.

2. **Option (A) is correct.**

   Explanation: The cyanide ion (CN^-) is a strong-field ligand which causes a large splitting of the iron(II) ion's *d*-orbitals (crystal field splitting), leading to a low-spin complex.

   In this case, the six valence *d*-electrons of Fe(II) pair up in the lower energy t_{2g} orbitals. No unpaired electrons are left making complex diamagnetic.

   However, H_2O is a weak-field ligand which causes a smaller splitting of the *d*-orbitals, resulting in a high-spin complex. Here, the six *d*-electrons of Fe(II) occupy both the lower energy t_{2g} orbitals and the higher energy orbitals, resulting in four unpaired electrons making the complex paramagnetic.

3. **Option (D) is correct.**

   Explanation: *Trans* $[CrCl_2(OX)_2]^{3-}$ does not exhibits optical isomerism due to its trans arrangement. Trans $[CrCl_2(OX)_2]^{3-}$ has plane of symmetry and its mirror image is not superimposable. Optical isomerism is common in octahedral complexes with bidentate ligands, as they form chelate rings.

4. **Option (A) is correct.**

   Explanation: EDTA (Ethylene diaminetetra acetic acid) is a hexadentate ligand because it can form six coordination bonds with a metal ion. The molecule contains two amine (nitrogen) groups and four corboxylate (oxygen) groups, providing a total of six donor for metal ion coordination.

5. **Option (C) is correct.**

   Explanation: The complex dissociate to give Cl^-.

   The complex ionises in the solution to produce a $[Co(NH_3)_5SO_4]^+$ ion and a Cl^- ion. The sulphate (SO_4) is coordinated within the complex, hence is a part of the cation. The chloride ion (Cl^-) is the counter ion, which is an anion and is located outside the coordination sphere.

VERY SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. (i) Tetra amminechloridonitritecobalt (III)chloride

(ii) Dichloridobis(ethane-1, 2-diamine)platinum(IV) ion.

(iii) (1) Low spin tetrahedral complexes are not formed because the crystal field stabilisation energy (Δ_t) is lower than the pairing energy (P). This means that electron pairing in the *d*-orbital is not possible As a result the complex will have a large number of unpaired electrons and will be paramagnetic with high spin.

(2) $[Co(NH_3)_6]^{3+}$ is an inner orbital complex because it uses the inner *d*-orbitals for hybridisation whereas $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex because it uses the outer *d*-orbitals for hybridisation d^2sp^3 and sp^3d^2 hybridisation involving inner and outer *d*-orbitals respectively.

2. (a) Potassium diaquadioxalatochromate(III) hydrate.

3. (i) Pentaamminenitrito-O-cobalt(III) ion

(ii) Potassium tetrachloridonickelate(II)

4. (i) NH_4^+ species cannot act as a ligand because it does not have lone pair of electron.

(ii) pentaamminenitrito -O-cobalt(III)chloride

5. (i) When a di-or polydentate ligand uses its two or more donor atoms simultaneously to bind a single metal ion, it is said to be a chelate ligand. Such complexes are called chelate complexes.

For example: $[CoCl_2(en)_2]^+$

(ii) Co-ordination compound in which the central metal atom/ion is co-ordinated to more than one kind of ligand is called heteroleptic complex. Example: $[Pt\,(NH_3)_2Cl_2]$

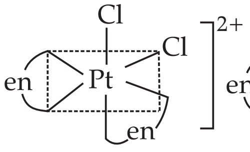
6. (a) The complex ion $[Ti(H_2O)_6]^{3+}$ is coloured because it has an unpaired electron in its 3*d* subshell which allows it to undergo a *d-d* transition when it absorbs visible light.

(b) Potassium tris(oxalato) chromate (III)

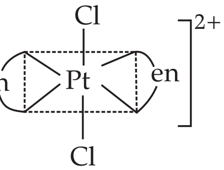
SHORT ANSWER TYPE QUESTIONS

(3 Marks)

1. (i)



Cis-form



Trans-form

(ii) $t_{2g}^3 e_g^1$

(iii) A unidentate ligand is a ligand that can donate only one pair of electrons to the central metal atom in a co-ordination complex. Example : Chloride ion (Cl^-)

2. (i) Tetraamminechloridonitrito-N-cobalt(III)chloride.

(ii) Hexaamminenickel(II)chloride

(iii) Potassiumtris(oxalato)chromate(III)

(iv) Dibromidobis(ethane-1-,2-diamine)cobalt(II).

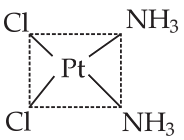
3. (i) $K_2[Zn(OH)_4]$

(ii) $[Cr(NH_3)_3Cl_3] < [Cr(NH_3)_5Cl]Cl_2 < [Cr(NH_3)_6]Cl_3$

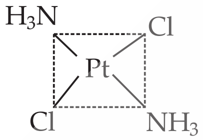
(iii) (1) Linkage isomerism

(2) optical isomerism

4. (i)



Cis



trans

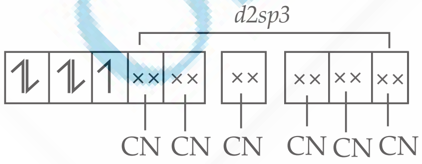
(ii) $t_{2g}^4 e_g^0$

(iii) In complex $[Ni(H_2O)_6]^{2+}$, H_2O is a weak ligand. So they don't cause electron pairing. This results in *d-d* transition and show green colour. Whereas in $[Ni(CN)_4]^{2-}$, CN^- is a strong ligand causes pairing of electrons. This means no unpaired electrons so there is no *d-d-* transition and the solution is colourless.

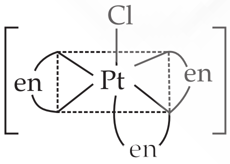
5. (i) d^2sp^3

$Fe = [Ar]\ 4s^2\ 3d^6$

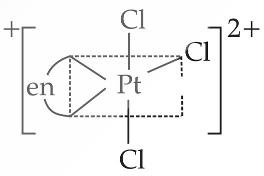
As CN^- is a strong ligand causes pairing of electrons.



(ii)



Cis-form



Trans-form

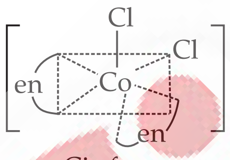
(iii) $[NiCl_4]^{2-}$ is paramagnetic because it has 2 unpaired electrons whereas $[Ni(CO)_4]$ does not a any unpaired electron means all the electrons are paired hence, it is diamagnetic in nature.

(iv) Linkage isomerism

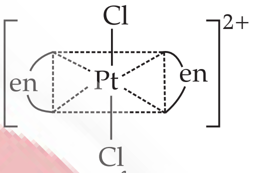
Example of ambidentate ligand is NO_2

nitro *nitro*

6. (i)



Cis-form



trans-form

The trans isomer of $[Co(en)_2Cl_2]^{2+}$ is not optically active because of the plane of symmetry

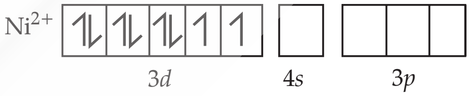
(ii) Hybridisation –sp^3d^2. The ground state electronic configuration of Co^{3+} is $[Ar]\ 3d^6$.

In $[CoF_6]^{3-}$, the cobalt ion utilises six orbitals (one 4*s*, three 4*p*, and two 4*d*) to form six hybrid sp^3d^2 orbitals to which six fluoride ligands bind, leaving one unpaired electron.

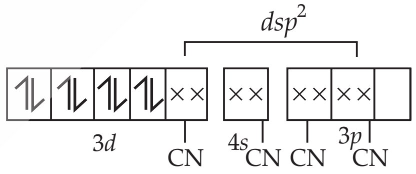
Magnetic behaviour: paramagnetic

7. (i) If $\Delta_o > P$, it becomes more energetically favourable for the fourth electron to occupy a t_{2g} orbital with configuration $t_{2g}{}^5\ eg^O$

(ii) In $[Ni(CN)_4]^{2-}$, nickel is in a +2 oxidation state and the ion has electronic configuration $3d^8$. The hybridisation is shown below.

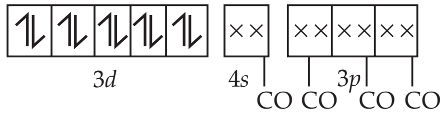


dsp^2 hybridisation



Shape – Square planer mgnetic behavior: Diamagnetic

whereas in case of $[Ni(CO)_4]$ Ni is in zero oxidation state and show sp^3 hybridisation due to which its geometry is tetrahedral.



Shape-Tetrahedral

Magnetic behaviour -diamagnetic

LONG ANSWER TYPE QUESTIONS (5 Marks)

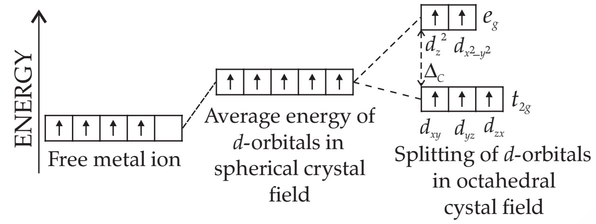
1. (A) (i) Test tube C

$$10I^- + 2MnO_4^- + 16H^+ \xrightarrow{\text{violet vapours}} 5I_2 + 2Mn^{2+} + 8H_2O$$

(ii) Test tube A

$$C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow \underset{\text{extinguishes burning matchstick}}{10CO_2} + 2Mn^{2+} + 8H_2O$$

(B) (i)



Since crystal field splitting energy is less than the pairing energy the electrons will occupy all the available orbitals.

(ii) Sp^3d^2, Since $\Delta_0 < P$ it will form an outer orbital complex as the electrons in the 3*d* orbital will not pair up.

(iii) Optical isomerism.

OR

(A) A = Co^{2+}
B = 3
C = d^2sp^3
D = Paramagnetic
E = sp^3
F = Tetrahedral

2. (i) $\Delta_t = \frac{4}{9}\Delta_o$

(ii) Dichloridobis(ethane -1, 2-diamine)platinum(iv) nitrate

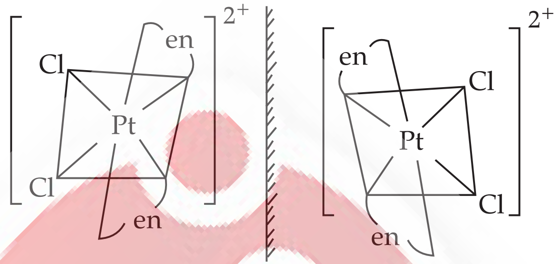
(iii) Geometry -Tetrahedral; Magnetic behaviour -Diamagnetic

(iv) Co-ordinate isomersim

$$[Co(NH_3)_6]\,[Cr(CN)_6] \xrightarrow{\text{Co-ordinate isomer}} [Cr(NH_3)_6][Co(CN)_6]$$

(v) On the basis of crystal field theory for a d^4 ion if Δ_o < P, then the complex is a high spin complex formed by the association of weak field fourth electron enters one of the e_g oribtals thereby exhibiting the electronic configuration t_{2g}^3 eg^1.

(vi) $[Co(NH_3)_4\,Cl_2]^+$ is heteroleptic because it contain two different types of ligands ie. NH_3 and Cl^-



3. (i) Aquacyanidobis-(ethane-1-,2 -diamine)cobalt(III) ion.

(ii) It is because the relative positions of four ligand attached to the central metal atom are the same with respect to each other.

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

(iv) sp^3, diamagnetic

(v) (1) $[Co(C_2O_4)_3]^{3-}$. This complex is formed by chelating ligand that's why it is more stable than $[CoF_6]^{3-}$.

(2) $[CoF_6]^{3-}$ is formed by weak ligand which is not able to pair up the electron that's why $[CoF_6]^{3-}$ will form high spin complex.

(vi) Ligand that having two doner atoms but only one doner atom is attached to metal during complex formation is known as ambidentale ligand whereas bidentate ligand has two donor atoms and both can donate lone pair of electrons simultaneously to one central metal ion during formation of complex.

(vii) (1) $t_{2g}^5 e_g^0$

(2) $t_{2g}^3 e_g^2$

Level - 2 ADVANCED COMPETENCY FOCUSED QUESTIONS

MULTIPLE CHOICE QUESTIONS (MCQs) (1 Mark)

1. **Option (B) is correct.**
Explanation: For octahedral complexes with weak legand P is greater than Δ_o

2. **Option (A) is correct.**
Explanation: Repulsion between the ligands, and d_{xy}, d_{yz}, d_{zx} is more than that in octahedral complexes.

3. **Option (B) is correct.**
Explanation: Conductivity ratio in $[Co(NH_3)_6]^{3+}\,3Cl^-$ will be 1 : 3.
For conductivity ratio 1 : 1 the complex should be $[Co(NH_3)_4Cl_2]^+Cl^-$.

4. Option (C) is correct
Explanation: EDTA (Ethylenediaminetetraacetic acid) is a hexadentate ligand, meaning it can bind to metal ions at six sites. In hard water, the hardness is mainly due to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. EDTA forms very stable and soluble complexes with these metal ions, effectively removing them from the solution. This prevents scale formation and allows soaps and detergents to work efficiently.

5. Option (C) is correct
Explanation: Cisplatin is a coordination compound with the formula $[PtCl_2(NH_3)_2]$. It is one of the most

effective chemotherapy drugs used to treat various types of cancer, such as testicular, ovarian, bladder, and lung cancers. The compound binds to DNA in cancer cells and prevents replication, ultimately leading to cell death.

6. Option (B) is correct
   Explanation: The brown ring test is a qualitative test used to detect nitrate ions (NO_3^-) in a solution. In this test, freshly prepared $FeSO_4$ (ferrous sulphate) solution is added to the nitrate solution, followed by careful addition of concentrated H_2SO_4 along the sides of the test tube. A brown ring forms at the junction of the two liquids due to the formation of a complex compound:
   $[Fe(H_2O)_5(NO)]^{2+}$
   This brown ring is a complex of Fe^{2+} and NO^+ (nitrosonium ion).

7. Option (A) is correct
   Explanation: When a solution of potassium ferrocyanide, $K_4[Fe(CN)_6]$, is added to ferric ions (Fe^{3+}), a deep blue precipitate forms. This precipitate is known as Prussian blue, a complex compound with the formula:
   $Fe_4[Fe(CN)_6]_3$
   The reaction is used in qualitative analysis to test for Fe^{3+} ions.

ASSERTION-REASON QUESTIONS (1 Mark)

1. Option (A) is correct
   Explanation: Assertion is true. EDTA is widely used in chelation therapy to remove heavy metals like lead (Pb^{2+}) from the bloodstream. It is administered as calcium disodium EDTA to safely bind and eliminate lead ions.
   Reason is also true. EDTA is a hexadentate ligand, meaning it can bind to a metal ion at six coordination sites, forming a very stable chelate complex. This stability helps pull toxic metal ions out of biological systems and excrete them safely.

2. Option (A) is correct
   Explanation: Assertion is true. In $[Fe(CN)_6]^{4-}$, Fe is in the +2 oxidation state (Fe^{2+}), with $3d^6$ configuration. CN^- is a strong field ligand, causing pairing of electrons in the lower-energy t_{2}g orbitals → no unpaired electrons → diamagnetic. In $[Fe(H_2O)_6]^{2+}$, H_2O is a weak field ligand, and no pairing occurs, leaving four unpaired electrons → paramagnetic.
   Reason is also true. Cyanide (CN^-) is a strong field ligand according to the spectrochemical series. It causes a large crystal field splitting (Δ_0), so electrons pair up in the t_{2}g orbitals instead of occupying higher energy eg orbitals.

3. Option (A) is correct
   Explanation: Assertion is true. Cisplatin, with the formula $[PtCl_2(NH_3)_2]$, is widely used in chemotherapy for treating various cancers such as testicular, ovarian, and bladder cancer.
   Reason is also true. Cisplatin has a square planar geometry. The two chloride ligands can be replaced by water inside the body, forming aqua complexes that bind to the nitrogen bases (especially guanine) of DNA. This cross-links the DNA strands, blocking replication and ultimately killing cancer cells.

4. Option (C) is correct
   Explanation: Assertion is true. In $[Ni(CO)_4]$, Ni is in the zero oxidation state (Ni^0), with electron configuration [Ar] $3d^8\ 4s^2$. CO is a strong field ligand, and in this complex, it causes pairing of electrons in $3d$ orbitals. All $3d$ electrons pair up, leaving no unpaired electrons → Diamagnetic. The complex is tetrahedral, as CO is a neutral monodentate ligand and the coordination number is 4.
   Reason is false. The complex has Ni in the 0 oxidation state, not Ni^{2+}.

5. Option (A) is correct
   Explanation: Assertion is true. Most transition metal complexes are coloured due to the presence of partially filled *d*-orbitals which allow certain wavelengths of visible light to be absorbed.
   Reason is also true. In a complex, the degenerate *d*-orbitals split into two sets (e.g., t_{2}g and eg in octahedral fields). When light hits the complex, electrons jump from lower to higher energy *d*-orbitals (a *d*–*d* transition), absorbing specific wavelengths. The remaining wavelengths are reflected or transmitted, and this gives the complex its observed colour.

6. Option (A) is correct
   Explanation: Assertion is true. Chelating ligands (like EDTA or ethylenediamine) can form multiple bonds to a single metal ion, making the resulting complex more stable than one formed by equivalent monodentate ligands.
   Reason is also true. Chelating ligands form five- or six-membered rings with the central metal atom, which are thermodynamically more stable due to reduced entropy loss per metal-ligand bond formed, and entropic advantage over multiple unidentate ligands.

VERY SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. Sample solution $[CoCl_2(en)_2]^+$ in test tube B can rotate plane ploarised light.

   The spatial arrangement of two didenate ligands ethylene diamine and two Cl monodentate ligands around the metal ion is such that it makes the molecule unsymmetrical. Such molecules are optically active i.e. it can rotate plane polarised light.

2. (i) Solution of $FeSO_4(NH_4)_2SO_4.6H_2O$ in Test Tube 'A' will turn into red.

   (ii) $FeSO_4(NH_4)_2SO_4.6H_2O$ solution in Test Tube 'A' is a double salt and it ionises fully in aqueous solution. The Fe^{2+} ions in solution reacts with KSCN and give red colour due to formation of $FeSCN^{2+}$ complex.

But $K_3[Fe(C_2O_4)_3]$ is a complex. It cannot ionise fully in aqueous solution. The Fe^{3+} ion remain intact in sphere. Therefore, it does not react with KSCN to give red colour.

3. When a few drops of aqueous ammonia are added to a solution containing Cu^{2+} ions, a light blue precipitate of $Cu(OH)_2$ is first formed. On adding excess NH_3, the precipitate dissolves, forming a deep blue coloured tetraaminecopper(II) complex.

$Cu^{2+}{}_{(aq)} + 4NH_{3(aq)} \rightarrow [Cu(NH_3)_4]^{2+}(aq)$

4. One coordination compound used in silver electroplating is $[Ag(CN)_2]^-$ (Diamminesilver(I) complex formed from AgCN or $AgNO_3$ and KCN)

$[Ag(CN)_2]^-$ is preferred in silver electroplating because it ensures uniform deposition, better quality coating, and controlled release of silver ions, unlike simple silver salts.

5. The natural coordination compound that transports oxygen in the human body is Haemoglobin.

The central metal ion in haemoglobin is iron (Fe^{2+}). Fe^{2+} is coordinated to a porphyrin ring (a tetradentate ligand). It binds reversibly to oxygen (O_2) in the lungs, forming oxyhemoglobin.

In tissues, Fe^{2+} releases the oxygen where it's needed, converting back to deoxyhemoglobin.

6. Coordination compounds improve dye fixation and colour fastness in textiles.

Chromium (Cr^{3+}) is widely used to form metal–dye complexes, which enhance the durability and vibrancy of dyed fabrics.

7. One important coordination complex used as a catalyst in industry is Wilkinson's Catalyst – $[RhCl(PPh_3)_3]$ (Triphenylphosphine rhodium(I) chloride complex).

It is used in the hydrogenation of alkenes:

$$RCH{=}CH_2 + H_2 \xrightarrow{[RhCl_9PPh_3)_3]} RCH_2CH_3$$

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1. (i) The colour of a salt arises due to two main factors.

1. Influence of ligands present in a salt.
2. Presence of incomplete *d*-subshells.

Both potassium and sodium lack *d*-orbitals. So, when light falls on such complexes no excitation of electrons occurs to higher energy levels to absorb or emit light of a certain wavelength. Hence, such salts are white in colour.

(ii) A complex having molar conductivity similar to AB_2 should release 3 ions in the solution. Thus, the probable formula of the complex will be:

$[Cr(H_2O)_5\,Cl]\,Cl_2$ or $[Cr(H_2O)Cl]^{+2} + 2Cl^-$

2. The formula of the isomer is $[Cr(H_2O)_5Cl]Cl_2$

Since two mole AgCl is produced hence 2 chloro groups are present as primary valencies.

In complex $[Cr\,(H_2O)_6]Cl_3$ six aqua ligands make direct bond with Cr metal ion thus complex is octahedral.

Whereas in complex $[Cr(H_2O)_5Cl]Cl_2.H_2O$ only 5 aqua and one Cl ligands make direct bond with metal. This complex is also octahedral. The remaining one aqua is present as water of crystallisation.

3. **(i)** One coordination compound used in the detection of cyanide ions in water is potassium ferricyanide – $K_3[Fe(CN)_6]$.

(ii) Potassium ferricyanide reacts with cyanide ions to form a stable coordination complex. This interaction causes a distinct colour change (usually forming a blue or green precipitate, depending on conditions), which helps detect the presence of toxic metal ions like Fe^{3+} or Cu^{2+} that form coloured complexes with CN^-.

(iii) This method is preferred over traditional tests because:

(1) It is highly specific and sensitive to even small amounts of toxic ions.

(2) It gives immediate visual results due to colour changes.

(3) It allows for on-site testing without the need for sophisticated instruments.

4. **(i)** A coordination complex used in catalytic converters is platinum-based complexes, such as $[PtCl_4]^{2-}$, often supported on a ceramic surface. Rhodium and palladium complexes are also commonly used.

(ii) These metal complexes act as heterogeneous catalysts in catalytic converters. They accelerate redox reactions that convert harmful gases in automobile exhaust into less toxic substances, thus helping reduce air pollution.

(iii) They help convert:

(1) Carbon monoxide (CO) into carbon dioxide (CO_2)

(2) Nitrogen oxides (NO and NO_2) into nitrogen gas (N_2)

(3) Unburnt hydrocarbons (HCs) into carbon dioxide and water

5. **(i)** Coordination compounds known as metal complexes of ruthenium, such as polypyridyl complexes, are used in light sensors and dye-sensitised solar cells (DSSCs).

(ii) These compounds exhibit photoactive properties — they can absorb visible light and undergo metal-to-ligand charge transfer (MLCT). This property allows them to convert light energy into electrical energy efficiently.

(iii) An example is $[Ru(bipy)_3]^{2+}$ (tris(bipyridine) ruthenium(II)), which is commonly used as a photosensitiser in DSSCs due to its stability, strong absorption in the visible region, and efficient electron transfer capabilities.

6. **(i)** Optical isomerism in coordination compounds arises when a complex can exist in two non-superimposable mirror image forms (enantiomers), even though they have the same connectivity of atoms. This typically occurs in octahedral complexes with bidentate ligands (e.g., ethylenediamine).

(ii) An example is $[Co(en)_3]^{3+}$ (tris(ethylenediamine) cobalt(III)), which exhibits optical isomerism. The two enantiomers are dextrorotatory (+) and levorotatory (–) forms.

(iii) This property is important in drug design because different enantiomers of a drug may have different biological activities — one may be therapeutic while the other could be inactive or even harmful. Hence, understanding and controlling optical activity is crucial in pharmaceuticals.

CASE BASED QUESTIONS (2 Marks)

1. (i) The complex $[CoF_6]^{3-}$ is paramagnetic because it has weak ligand F^- that do not cause pairing of electron. So, in $[CoF_6]^{-3}$ there are four unpaired *e*– present and due to this it is paramagnetic.

(ii) The co-ordination number of Co in $[Co(en)_2Cl_2]^+$ is six (6) because it is surrounded by six donor sites.

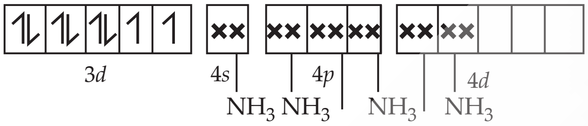
(iii) (a) (1) Diamminedichloridoplatinum(IV)ion

(2) Complex $[Co(NH_3)_6]^{3+}$ is an inner orbital complex because of participation of $(n-1)$ *d* orbitals.

OR

(b) shape-octahedral; hybridisation – sp^3d^2

sp^2d^2 hydridisation



2. (i) Ambidentate ligands are those ligands which have two atom but only one donor atom is attached to metal during complex formation Example $\leftarrow NO_2$ and $\leftarrow ONO$

(ii) They show ionisation isomerism.

(iii) (a) When a bidentate or a polydentate ligand contains donor atoms positioned in such a way that they co-ordinate with the central metal ion and a five or six membered ring is formed the effect is known as the chelate effect.

Complexes containing chelate rings are more stable than complex without rings due to high (+) entropy change.

OR

(b) Coordination number of chromium is 6 and oxidation number is + 3. in $Na_3[Cr(C_2O_4)_3]$

As oxalate is a bidentate ligand- coordination no. of Cr is+3.

Na oxidation no. is +3

Oxalate ion carries – 2

Cr oxidation no. is *x*

$+3 + x + (-2 \times 3) = 0$ as the complex is neutral.

Hence, $x = +3$

3. (i) $[Ni(H_2O)_6]Cl_2$

Secondary valency of Ni is 6.

(ii) $[Co(NH_3)_5Cl]SO_4$ is the ionisation isomer of $[Co(NH_3)_5(SO_4)]Cl$

IUPAC name of $[Co(NH_3)_5Cl]SO_4$ is pentaammine chloridocobalt(III)sulphale.

(iii) (a) (1) $[Ni(CO)_4]$: Tetrahedral geometry and diamagnetic

(2) $[Fe(CN)_6]^{3-}$: Octahedral geometry and paramagnetic

OR

(b) (1) Because Δ_t is not sufficient for the pairing of electrons.

Crystal field splitting energy (CFSE) in tyetrahedral complexes is not sufficinet for pairing of electrons.

(2) NH_3 being a strong field ligand can pair up the electrons to form d^2sp^3 but cannot pair up in Ni^{2+} as two vacant *d*-orbitals of $(n-1)$ shell are not available. Therefore, sp^3d^2 is formed.

4. (i) $[Pt\ Cl_2(NH_3)_2]$

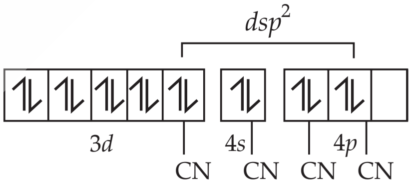
(ii) Secondary valency of $[Co(en)_3]^{3+}$ is 6

(iii) (1) $Fe_4[Fe(CN)_6]_3$

(2) Pentaamminechloridocobalt(III)chloride

OR

(iii) Hybridisation: dsp^2



Magnetic behaviour -Diamagnetic

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. (i) Cisplatin $[PtCl_2(NH_3)_2]$ is a coordination compound used as an anti-cancer drug.

It works by binding to the DNA in cancer cells through its square planar geometry, preventing replication of DNA and thus inhibiting cell division, leading to cell death.

(ii) EDTA (Ethylenediaminetetraacetic acid) is a hexadentate ligand that forms stable chelate complexes with heavy metal ions like Pb^{2+}, Hg^{2+}, and Cd^{2+}. It binds tightly to the metal ions, rendering them non-toxic and allowing them to be safely excreted from the body.

(iii) IUPAC name: Potassium hexacyanoferrate(II)

Role: It is used in analytical chemistry to detect Fe^{3+} ions by forming Prussian blue, a deep blue coloured complex $[Fe_4[Fe(CN)_6]_3]$, used in qualitative analysis.

(iv) Coordination complexes are coloured due to *d–d* transitions. When white light falls on a complex, certain wavelengths are absorbed as electrons in the *d*-orbitals jump to higher energy levels (due to crystal field splitting), and the remaining light is transmitted or reflected, giving the compound its observed colour.

(v) In electroplating, coordination compounds like $[Ag(CN)_2]^-$ and $[Au(CN)_2]^-$ are used because they release metal ions slowly and uniformly, allowing for smooth, even deposition of metal on the object. This helps prevent roughness or pitting and provides greater control over the thickness and quality of the coating.

2. (i) Platinum-based complexes (e.g., $[PtCl_6]^{2-}$) are commonly used. Other metals include rhodium and palladium complexes.

(ii) Catalytic converters help convert toxic gases into less harmful ones using coordination compounds as catalysts:

$2CO + O_2 \rightarrow 2CO_2$ (carbon monoxide to carbon dioxide)

$2NO \rightarrow N_2 + O_2$ (nitric oxide to nitrogen and oxygen)

$CxHy + O_2 \rightarrow CO_2 + H_2O$ (unburnt hydrocarbons to CO_2 and water)

(iii) The chelate effect enhances the stability of metal-ligand complexes. In environmental detoxification:

(1) Chelating agents like EDTA bind strongly to toxic heavy metals (e.g., Pb^{2+}, Hg^{2+}),
(2) Form non-toxic, water-soluble complexes,
(3) Facilitating their removal from water and soil systems efficiently.

(iv) $[Ni(CO)_4]$ (nickel tetracarbonyl) is used in the Mond process for the purification of nickel.

Another example: $[RhCl(PPh_3)_3]$ (Wilkinson's catalyst) is used in hydrogenation of alkenes.

(v) Transition metal complexes offer:

(1) Higher selectivity and efficiency,
(2) Lower energy consumption, and
(3) Can function under milder conditions, reducing unwanted side reactions and energy costs compared to traditional solid catalysts.

3. (i) Haemoglobin – an iron-based coordination complex that carries oxygen.

Vitamin B_{12} – a cobalt-containing coordination compound essential for DNA synthesis and nerve function.

(ii) Iron (Fe^{2+}) in haemoglobin forms a coordination complex with the porphyrin ring and binds reversibly with O_2. This reversible binding enables transport of oxygen from the lungs to tissues and release where needed.

(iii) Vitamin B_{12} (cyanocobalamin) contains Co^{3+} as the central metal ion coordinated with nitrogen atoms of a corrin ring. It acts as a coenzyme in enzymatic reactions, particularly in methylation and DNA synthesis.

(iv) Coordination compounds are ideal for biological transport of gases or ions because:

(1) They allow selective and reversible binding of small molecules (like O_2, CO_2).
(2) Provide a stable and protected environment around metal ions to prevent unwanted reactions.
(3) The geometry and ligand arrangement control specificity and function.

(v) Free metal ions (like Fe^{2+} or Cu^{2+}) are highly reactive and toxic in biological systems. They could cause oxidative damage or interfere with enzymatic functions. Complexation ensures safe storage, transport, and reactivity control of metal ions.

4. (i) When aqueous ammonia (NH_3) is added to a solution containing Cu^{2+} ions, a deep blue coloured tetraamminecopper(II) complex is formed:

$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$

This intense blue colour confirms the presence of Cu^{2+}.

(ii) In the brown ring test, nitrate ions (NO_3^-) are reduced by Fe^{2+} in the presence of H_2SO_4 to form nitrosyl ion (NO^+), which then forms a brown-coloured coordination complex with Fe^{2+}:

$[Fe(H_2O)_6]^{2+} + NO^+ \rightarrow [Fe(H_2O)_5(NO)]^{2+}$

This brown ring confirms the presence of nitrates.

(iii) When Fe^{3+} ions react with potassium ferrocyanide ($K_4[Fe(CN)_6]$), a deep blue coloured precipitate of Prussian blue forms:

$4Fe^{3+} + 3[Fe(CN)_6]_4^{-} \rightarrow Fe_4[Fe(CN)_6]_3(s)$

(iv) EDTA is a hexadentate ligand that forms stable complexes with Ca^{2+} and Mg^{2+} ions, which are responsible for water hardness. In titration, EDTA binds to all $\frac{Ca^{2+}}{Mg^{2+}}$ ions, and the endpoint is indicated by a colour change using indicators like Eriochrome Black T.

(v) These methods preferred are over simple precipitation tests because of:

(1) Higher sensitivity and specificity
(2) Detects ions even at trace levels
(3) No interference from other common ions
(4) Forms stable, well-defined coloured complexes
(5) Useful for quantitative and qualitative analysis