

Term-II

COORDINATION COMPOUNDS

Syllabus

- Coordination compounds - Introduction, ligands, coordination number, colour, magnetic properties and shapes, IUPAC nomenclature of mononuclear coordination compounds. Bonding, Werner's theory, VBT, and CFT.



STAND ALONE MCQs

[1 Mark each]

Q. 1. The oxidation of Ni in $[\text{Ni}(\text{CO})_4]$ is

- (A) 0 (B) 2
(C) 3 (D) 4

A&E [CBSE Delhi Set-I 2020]

Ans. Option (A) is correct.

Explanation: CO is a neutral ligand and its oxidation state is zero. Since the overall charge on the complex is zero too, hence oxidation state of Ni is 0.

AI Q. 2. Which of the following will give a white precipitate upon reacting with AgNO_3 ?

- (A) $\text{K}_2[\text{Pt}(\text{en})_2\text{Cl}_2]$ (B) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$
(C) $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ (D) $[\text{Fe}(\text{H}_2\text{O})_3\text{Cl}_3]$

R [CBSE Delhi Set-II 2020]

Ans. Option (C) is correct.

Explanation: $\text{AgNO}_3 + [\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3 \rightarrow \text{AgCl}$
ppt should be below $\text{AgCl} + \text{NO}_3^-$
Since Cl is outside the coordination sphere, it can react with AgNO_3 forming the white AgCl precipitate.

Q. 3. The formula of the complex triamminetri(nitrito-O) Cobalt (III) is

- (A) $[\text{Co}(\text{ONO})_3(\text{NH}_3)_3]$ (B) $[\text{Co}(\text{NO}_2)_3(\text{NH}_3)_3]$
(c) $[\text{Co}(\text{ONO}_2)_3(\text{NH}_3)_3]$ (D) $[\text{Co}(\text{NO}_2)(\text{NH}_3)_3]$

U [CBSE Delhi Set-III 2020]

Ans. Option (A) is correct.

Explanation: $[\text{Co}(\text{ONO})_3(\text{NH}_3)_3]$

Q. 4. How many ions are produced from the complex $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ in solution?

- (A) 4 (B) 2
(C) 3 (D) 5

A [CBSE O.D. Set-1 2020]

Ans. Option (C) is correct.

Explanation:



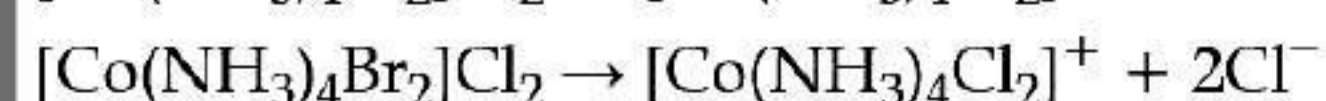
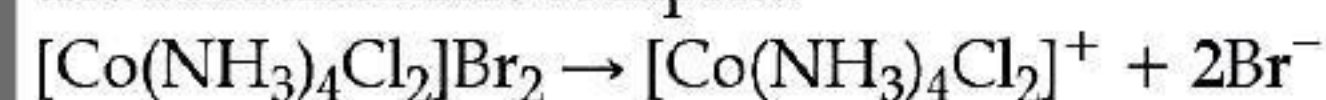
AI Q. 5. The pair $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Br}_2$ and $[\text{Co}(\text{NH}_3)_4\text{Br}_2]\text{Cl}_2$ will show

- (A) Linkage isomerism
(B) Hydrate isomerism
(C) Ionization isomerism
(D) Coordinate isomerism

U [CBSE O.D. Set-I 2020]

Ans. Option (C) is correct.

Explanation: Ionization isomers have identical central ion and the other ligands except for a ligand that has exchanged places with an anion or neutral molecule that was originally outside the coordination complex.



Q. 6. The coordination number of 'Co' in the complex $[\text{Co}(\text{en})_3]^{3+}$ is

- (A) 3 (B) 6
(C) 4 (D) 5

A&E [CBSE O.D. Set-II 2020]

Ans. Option (B) is correct.

Explanation: Coordination number is the number of ligands joined to the central metal ion or atom. Since ethylenediamine is a bidentate ligand, Co has coordination number of 6.

Q. 7. Which of the following is the most stable complex?

- (A) $[\text{Fe}(\text{CO})_5]$ (B) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$
(C) $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ (D) $[\text{Fe}(\text{CN})_6]^{3-}$

[A&E] [CBSE O.D. Set-III 2020]

Ans. Option (C) is correct.

Explanation: $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ acts as the chelating ligands. because $\text{C}_2\text{O}_4^{2-}$ is a bidentate ligand.

[AI] Q. 8. What type of isomerism is shown by the pair $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ and $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$?

- (A) Ionisation isomerism
(B) Coordination isomerism
(C) Solvate isomerism
(D) Linkage isomerism

[A&E] [CBSE O.D. Set-III 2020]

Ans. Option (C) is correct.

Explanation: Solvate / Hydrate isomerism
Solvate or hydrate isomers have the same composition but differ with respect to the number of solvent ligand molecules as well as the counter ion in the crystal lattice.

[AI] Q. 9. Ambidentate ligands like NO_2^- and SCN^- are:

- (a) unidentate
(b) didentate
(c) polydentate
(d) has variable denticity

OR

The formula of the coordination compound Tetraammineaquachloridocobalt(III) chloride is

- (A) $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}]\text{Cl}_2$
(B) $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}]\text{Cl}_3$
(C) $[\text{Co}(\text{NH}_3)_2(\text{H}_2\text{O})\text{Cl}]\text{Cl}_2$
(D) $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}]\text{Cl}$ [R] [CBSE SQP 2021]

Ans. Option (A) is correct.

Explanation: Tetraammineaquachloridocobalt (III) chloride is $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}]\text{Cl}_2$.

Central atom – Cobalt(III)

Coordination sphere ligands-

Tetraammine - 4 NH_3 groups neutral ligand

Aqua - 1 H_2O groups neutral ligand

Chlorido -1 Cl group, negatively charged ligand, one negative charge

Counter ion- Chloride ions, 2

Since Cobalt is 3+, one valency is satisfied with Cl in coordination sphere and 2 by chlorine counter ions.

Hence, the formula of the coordination compound is $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}]\text{Cl}_2$.

Q. 10. The crystal field splitting energy for octahedral (Δ_o) and tetrahedral (Δ_t) complexes is related as

- (A) $\Delta_t = \frac{2}{9}\Delta_o$ (B) $\Delta_t = \frac{5}{9}\Delta_o$
(C) $\Delta_t = \frac{4}{9}\Delta_o$ (D) $\Delta_t = 2\Delta_o$

[R] [CBSE O.D. Set-II 2020]

Ans. Option (C) is correct.

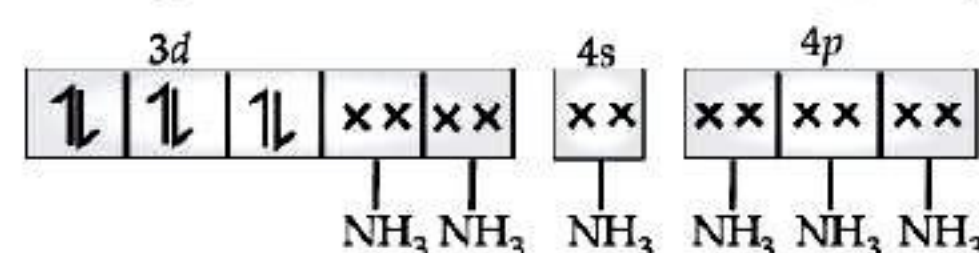
Explanation: $\Delta_t = \frac{4}{9}\Delta_o$

Q. 11. Atomic number of Mn, Fe and Co are 25, 26, 27 respectively. Which of the following inner orbital octahedral complex ions are diamagnetic?

- (A) $[\text{Co}(\text{NH}_3)_6]^{3+}$ (B) $[\text{Mn}(\text{CN})_6]^{3-}$
(C) $[\text{Fe}(\text{CN})_6]^{3-}$ (D) None of the above

Ans. Option (A) is correct.

Explanation: Molecular orbital electronic configuration of Co^{3+} in $[\text{Co}(\text{NH}_3)_6]^{3+}$ is



Number of unpaired electron = 0
Magnetic property = Diamagnetic

[AI] Q. 12. The colour of the coordination compounds depends on the crystal field splitting. What will be the correct order of absorption of wavelength of light in the visible region, for the complexes, $[\text{Co}(\text{NH}_3)_6]^{3+}$, $[\text{Co}(\text{CN})_6]^{3-}$, $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$.

- (A) $[\text{Co}(\text{CN})_6]^{3-} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+}$
(B) $[\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$
(C) $[\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$
(D) $[\text{Co}(\text{CN})_6]^{3-} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+}$

Ans. Option (C) is correct.

Explanation: Δ_o values follow the order : $[\text{Co}(\text{H}_2\text{O})_6]^{3+} < [\text{Co}(\text{NH}_3)_6]^{3+} < [\text{Co}(\text{CN})_6]^{3-}$ and therefore, absorption wavelength follows the order :

$[\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$

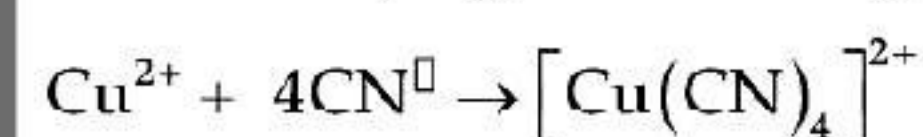
Q. 13. Which of the following complexes formed by Cu^{2+} ions is most stable?

- (A) $\text{Cu}^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+}$, $\log K = 11.6$
(B) $\text{Cu}^{2+} + 4\text{CN}^- \rightarrow [\text{Cu}(\text{CN})_4]^{2-}$, $\log K = 27.3$
(C) $\text{Cu}^{2+} + 2\text{en} \rightarrow [\text{Cu}(\text{en})_2]^{2+}$, $\log K = 15.4$
(D) $\text{Cu}^{2+} + 4\text{H}_2\text{O} \rightarrow [\text{Cu}(\text{H}_2\text{O})_4]^{2+}$, $\log K = 8.9$

Ans. Option (D) is correct.

Explanation: The greater the value of $\log K$, the greater will be stability of complex compound formed.

For reaction, $\log K$ has the highest value.



$$K = \frac{[\text{Cu}(\text{CN})_4]^{2-}}{[\text{Cu}^{2+}][\text{CN}^-]^4} \text{ and } \log K = 27.3$$

- Q. 14.** The CFSE for octahedral $[\text{CoCl}_6]^{4-}$ is $18,000 \text{ cm}^{-1}$.
The CFSE for tetrahedral $[\text{CoCl}_4]^{2-}$ will be
(A) $18,000 \text{ cm}^{-1}$ (b) $16,000 \text{ cm}^{-1}$
(C) $8,000 \text{ cm}^{-1}$ (d) $20,000 \text{ cm}^{-1}$.

Ans. Option (C) is correct.

Explanation: CFSE for tetrahedral complex is

$$\Delta_t = \frac{4}{9} \Delta_o$$

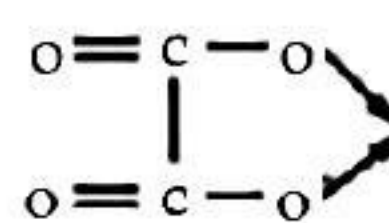
$$\Delta_t = \frac{4}{9} \times 18,000 = 8,000 \text{ cm}^{-1}$$

- AI Q. 15.** Amongst the following, the most stable complex is

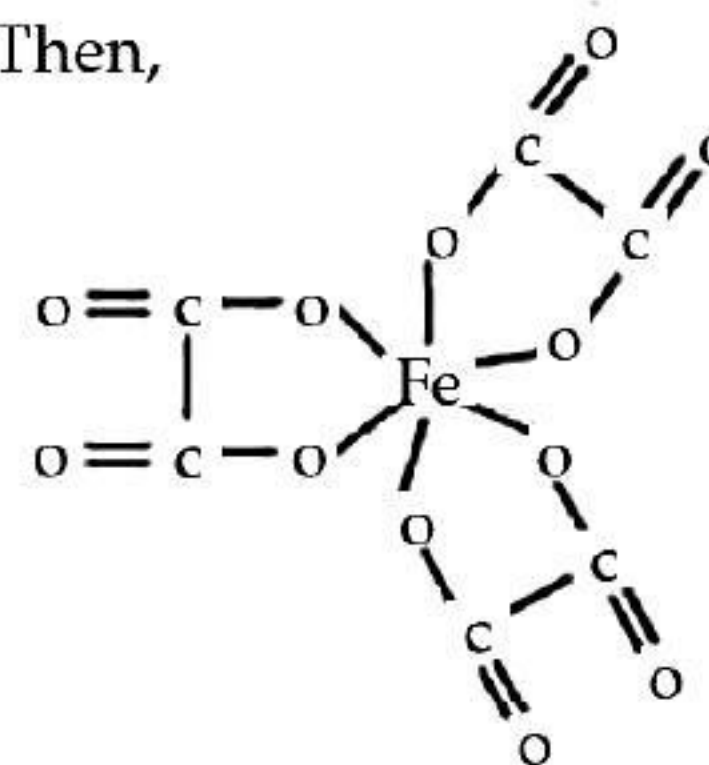
- (A) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ (B) $[\text{Fe}(\text{NH}_3)_6]^{3+}$
(C) $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ (D) $[\text{FeCl}_6]^{3-}$

Ans. Option (C) is correct.

Explanation: We know that the stability of a complex increases by chelation. Therefore, the most stable complex is $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$.



Then,



- Q. 16.** How many ions are produced from the complex $\text{Co}(\text{NH}_3)_6\text{Cl}_2$ in solution?

- (A) 6 (B) 4
(C) 3 (D) 2

Ans. Option (D) is correct.

Explanation: The given complex can be written as $[\text{Co}(\text{NH}_3)_6]\text{Cl}_2$.

Thus, $[\text{Co}(\text{NH}_3)_6]^+$ along with two Cl^- ions are produced.



ASSERTION AND REASON BASED MCQs

[1 Mark each]

Directions: In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.

- (A) Both A and R are true and R is the correct explanation of A
(B) Both A and R are true but R is NOT the correct explanation of A
(C) A is true but R is false
(D) A is false and R is true

- Q. 1. Assertion (A):** Toxic metal ions are removed by the chelating ligands.

Reason (R): Chelate complexes tend to be more stable.

Ans. Option (A) is correct.

Explanation: When a solution of chelating ligand is added to solution containing toxic metal ligands chelates the metal ions by formation of stable complex.

- Q. 2. Assertion (A):** Linkage isomerism arises in coordination compounds containing ambidentate ligand.

Reason (R): Ambidentate ligand has two different donor atoms.

Ans. Option (A) is correct.

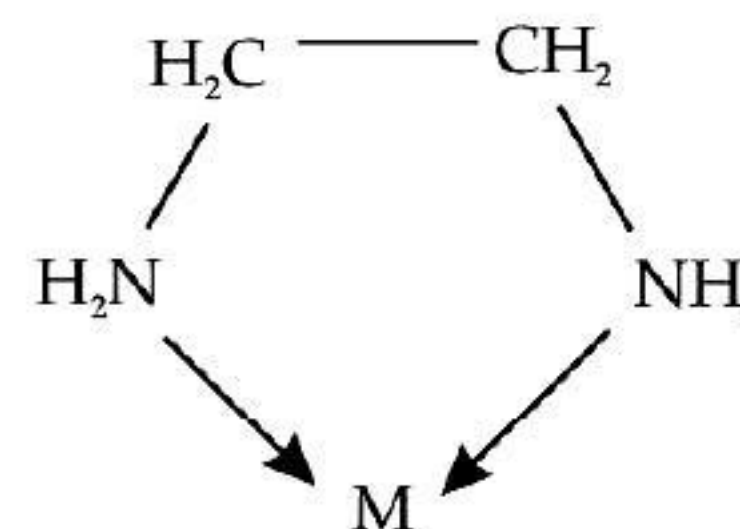
Explanation: Linkage isomerism arises due to two different donor atoms in ambidentate ligand.

- Q. 3. Assertion:** Among $[\text{Co}(\text{NH}_3)_6]^{3+}$ and $[\text{Co}(\text{en})_3]^{3+}$, coordination compound $[\text{Co}(\text{en})_3]^{3+}$ is a more stable complex.

Reason: Because (en) is a chelating ligand/bidentate ligand.

Ans. Option (A) is correct.

Explanation: Since (ethylene diamine-en) is a chelating ligand/bidentate ligand, $[\text{Co}(\text{en})_3]^{3+}$ is a more stable complex as compared to the other one.



- AI Q. 4. Assertion (A):** $[\text{Fe}(\text{CN})_6]^{3-}$ ion shows magnetic moment corresponding to two unpaired electrons.

Reason (R): Because it has d^2sp^3 type hybridisation.

Ans. Option (D) is correct.

Explanation: $[\text{Fe}(\text{CN})_6]^{3-}$ ion shows magnetic moment corresponding to two unpaired electrons.

- Q. 5. Assertion (A):** $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_2$ and $[\text{Fe}(\text{H}_2\text{O})_6]\text{Cl}_2$ are reducing in nature.

Reason (R): Unpaired electrons are present in their d-orbitals.

Ans. Option (B) is correct.

Explanation: In the complexes, Co exists as Co^{2+} and Fe as Fe^{2+} . Both of the complexes become stable by oxidation of metal ion to Co^{3+} and Fe^{3+} .

- Q. 6. Assertion (A):** Complexes of MX_6 and MX_5L type (X and L are unidentate) do not show geometrical isomerism.

Reason (R): Geometrical isomerism is not shown by complexes of coordination number 6.

Ans. Option (B) is correct.

Explanation: For complexes of MX_6 and MX_5L type, different geometric arrangements of the ligands are not possible due to presence of plane of symmetry.

Q. 7. Assertion (A): Low spin tetrahedral complexes are rarely observed.

Reason (R): Crystal field splitting is less than pairing energy for tetrahedral complexes.

[R] [CBSE Delhi Set-I 2020]

Ans. Option (A) is correct.

Explanation: In tetrahedral complexes, the splitting of the d orbitals is inverted and is smaller in comparison to octahedral complexes. The Crystal field splitting energy is not large enough to force pairing and hence, low spin complexes are rarely observed.



CASE-BASED MCQs

I. Read the passage given below and answer the following questions:

The crystal field theory (CFT) is an electrostatic model which considers the metal-ligand bond to be ionic arising purely from electrostatic interactions between the metal ion and the ligand. Ligands are treated as point charges in case of anions or dipoles in case of neutral molecules. The five d orbitals in an isolated gaseous metal atom/ion have same energy, i.e., they are degenerate. This degeneracy is maintained if a spherically symmetrical field of negative charges surrounds the metal atom/ion. However, when this negative field is due to ligands (either anions or the negative ends of dipolar molecules like NH_3 and H_2O) in a complex, it becomes asymmetrical and the degeneracy of the d orbitals is lifted. It results in splitting of the d orbitals.

The following questions are multiple choice questions. Choose the most appropriate answer:

- [AI] Q. 1.** The colour of the coordination compounds depends on the crystal field splitting. What will be the correct order of absorption of wavelength of light in the visible region, for the complexes, $[Co(NH_3)_6]^{3+}$, $[Co(CN)_6]^{3-}$, $[Co(H_2O)_6]^{3+}$
- (A) $[Co(CN)_6]^{3-} > [Co(NH_3)_6]^{3+} > [Co(H_2O)_6]^{3+}$
(B) $[Co(NH_3)_6]^{3+} > [Co(H_2O)_6]^{3+} > [Co(CN)_6]^{3-}$
(C) $[Co(H_2O)_6]^{3+} > [Co(NH_3)_6]^{3+} > [Co(CN)_6]^{3-}$
(D) $[Co(CN)_6]^{3-} > [Co(NH_3)_6]^{3+} > [Co(H_2O)_6]^{3+}$

Ans. Option (C) is correct.

Explanation: $[Co(H_2O)_6]^{3+} > [Co(NH_3)_6]^{3+} > [Co(CN)_6]^{3-}$

Q. 2. The CFSE for octahedral $[CoCl_6]^{4-}$ is $18,000\text{ cm}^{-1}$. The CFSE for tetrahedral $[CoCl_4]^{2-}$ will be

- (A) $18,000\text{ cm}^{-1}$ (B) $16,000\text{ cm}^{-1}$
(C) $8,000\text{ cm}^{-1}$ (D) $20,000\text{ cm}^{-1}$

Ans. Option (C) is correct.

Explanation: $8,000\text{ cm}^{-1}$

Q. 3. An aqueous pink solution of cobalt(II) chloride changes to deep blue on addition of excess of HCl. This is because _____.

- (A) $[Co(H_2O)_6]^{2+}$ is transformed into $[CoCl_6]^{4-}$
(B) $[Co(H_2O)_6]^{2+}$ is transformed into $[CoCl_4]^{2-}$
(C) tetrahedral complexes have larger crystal field splitting than octahedral complex.
(D) None of the above

Ans. Option (B) is correct.

Explanation:

$[Co(H_2O)_6]^{2+}$ is transformed into $[CoCl_4]^{2-}$.

Q. 4. A chelating agent has two or more than two donor atoms to bind to a single metal ion. Which of the following is not a chelating agent?

- (A) thiosulphato (B) oxalato
(C) glycinato (D) ethane-1,2-diamine

Ans. Option (A) is correct.

Explanation: Thiosulphato is a monodentate ligand whereas Oxalato, glycinato and ethylene diamine are bidentate ligands and can form rings with the central metal ion. So, they are also chelating ligands. Thiosulphato is a monodentate ligand and hence, cannot form chelate rings. Hence, it is not a chelating ligand

II. Read the passage given below and answer the following questions:

According to Valence Bond Theory, the metal atom or ion under the influence of ligands can use its $(n-1)d$, ns , np or ns , np , nd orbitals for hybridisation to yield a set of equivalent orbitals of definite geometry such as octahedral, tetrahedral, square planar and so on. These hybridised orbitals are allowed to overlap with ligand orbitals that can donate electron pairs for bonding.

In these questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

- (A) Assertion and reason both are correct statements and reason is correct explanation for assertion.
- (B) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
- (C) Assertion is correct statement but reason is wrong statement
- (D) Assertion is wrong statement but reason is correct statement.

AI Q. 1. Assertion (A): In the diamagnetic octahedral complex, $[\text{Co}(\text{NH}_3)_6]^{3+}$, the cobalt ion is in +3 oxidation state.

Reason (R): Six pairs of electrons, one from each NH_3 molecule, occupy the six hybrid orbitals.

Ans. Option (B) is correct.

Explanation: In the diamagnetic octahedral complex, $[\text{Co}(\text{NH}_3)_6]^{3+}$, the cobalt ion is in +3 oxidation state and has the electronic configuration $3d^6$.

Q. 2. Assertion (A): $[\text{NiCl}_4]^{2-}$ is an inner orbital complex.

Reason (R): An inner orbital or low spin or spin paired complex uses inner d orbitals of the metal ion for hybridisation.

Ans. Option (D) is correct.

Explanation: $[\text{NiCl}_4]^{2-}$ is high spin complex.

Q. 3. Assertion (A): In the square planar complexes, the hybridisation involved is dsp^2 .

Reason (R): In $[\text{Ni}(\text{CN})_4]^{2-}$. Here nickel is in +2 oxidation state and has the electronic configuration $3d^8$.

Ans. Option (B) is correct.

Q. 4. Assertion (A): The paramagnetic octahedral complex, $[\text{CoF}_6]^{3-}$ uses outer orbital (4d) in hybridisation (sp^3d^2).

Reason (R): It is a high spin complex.

Ans. Option (C) is correct.

Explanation: The paramagnetic octahedral complex, $[\text{CoF}_6]^{3-}$ uses outer orbital (4d) in hybridisation (sp^3d^2). It is a low spin complex.

III. Read the passage given below and answer the following questions:

The existence of coordination compounds with the same formula but different arrangements of the ligands was crucial in the development of

coordination chemistry. Two or more compounds with the same formula but different arrangements of the atoms are called isomers. Isomers are compounds with the same molecular formula but different structural formulas and do not necessarily share similar properties. There are many different classes of isomers, like stereoisomers, enantiomers, and geometrical isomers. There are two main forms of isomerism: structural isomerism and stereoisomerism. The different chemical formulas in structural isomers are caused either by a difference in what ligands are bonded to the central atoms or how the individual ligands are bonded to the central atoms.

The following questions are multiple choice questions. Choose the most appropriate answer:

AI Q. 1. What kind of isomerism exists between $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ (violet) and $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$ (greyish-green)?

- (A) linkage isomerism
(B) solvate isomerism
(C) ionisation isomerism
(D) coordination isomerism

Ans. Option (B) is correct.

Q. 2. Which of the following complexes show linkage isomerism?

- (A) $[\text{Co}(\text{H}_2\text{O})_5\text{CO}]^{3+}$ (B) $[\text{Cr}(\text{NH}_3)_5\text{SCN}]^{2+}$
(C) $[\text{Fe}(\text{en})_2\text{Cl}_2]^+$ (D) All of the above

Ans. Option (B) is correct.

Explanation: Linkage isomerism is the existence of coordination compounds that have the same composition differing with the connectivity of the metal to a ligand. Typical ligands that give rise to linkage isomers are: thiocyanate, SCN^- , isothiocyanate, NCS^-

AI Q. 3. Due to the presence of ambidentate ligands coordination compounds show isomerism. Palladium complexes of the type $[\text{Pd}(\text{C}_6\text{H}_5)_2(\text{SCN})_2]$ and $[\text{Pd}(\text{C}_6\text{H}_5)_2(\text{NCS})_2]$ are

- (A) linkage isomers
(B) coordination isomers
(C) ionisation isomers
(D) geometrical isomers

Ans. Option (A) is correct.

Explanation: Same as above