Chapter 11

d & f-Block Elements, and Coordination Compounds

Syllabus

Transition elements : General introduction, electronic configuration, occurrence and characteristics, general trends in properties of the first row transition elements - physical properties, ionization enthalpy, oxidation states, atomic radii, colour, catalytic behaviour, magnetic properties, complex formation, interstitial compounds, alloy formation; preparation, properties and uses of $K_2Cr_2O_7$ and $KMnO_4$.

Inner transition elements : Lanthanoids - Electronic configuration, oxidation states and lanthanoid contraction. **Actinoids** - Electronic configuration and oxidation states.

Coordination compounds : Introduction to co-ordination compounds, Werner's theory, Ligands, co-ordination number, denticity, Chelation: IUPAC nomenclature of mononuclear co-ordination compounds, isomerism, Bonding - valence bond approach and basic ideas of crystal field theory, colour and magnetic properties, importance of co-ordination compounds (In quantitative analysis, extraction of metals and in biological systems).

Topic-1

d and *f* Block Elements

LIST OF TOPICS :

Topic-1 : *d* and *f* Block Elements

Topic-2 : Co-ordination Compounds

JEE (Main) Previous Year Questions

Multiple Choice Questions

1. During the reaction of permanganate with thiosulphate, the change in oxidation of manganese occurs by value of 3. Identify which of the below medium will favour the reaction:

(1) aqueous neutral

(2) aqueous acidlic

(3) both aqueous acidic and neutral

(4) both aqueous acidic and faintly alkaline

[JEE (Main) – 6th April 2023 - Shift-2]

2. In chromyl chloride, the number of d-electrons present on chromium is same as in: (Given at no. of Ti: 22, V : 23, Cr : 24, Mn : 25, Fe : 26)

(1) Fe (III) **(2)** V (IV)

(3) Ti (III) **(4)** Mn (VII)

[JEE (Main) – 8th April 2023 - Shift-1]

3. Prolonged heating is avoided during the preparation of ferrous ammonium sulphate to:

(1) prevent hydrolysis **(2)** prevent reduction

(3) prevent breaking **(4)** prevent oxidation

[JEE (Main) – 10th April 2023 - Shift-1]

4. Given below are two statements:

Statement I: Aqueous solution of $K_2Cr_2O_7$ is preferred as a primary standard in volumetric analysis over $Na_2Cr_2O_7$ aqueous solution.

Statement II: $K_2Cr_2O_7$ has a higher solubility in water than $Na_2Cr_2O_7$.

In the light of the above statements, choose the correct answer from the options given below:

(1) Statement I is false but statement II is true.

(2) Statement I is true but statement II is false.

(3) Both statement I and statement II are true.

(4) Both statement I and statement II are false.

[JEE (Main) – 10th April 2023 - Shift-1]

5. When a solution of mixture having two inorganic salts was treated with freshly prepared ferrous sulphate in acidic medium, a dark brown ring was formed whereas on treatment with neutral $FeCl_3$ it gave deep red colour which disappeared on boiling and a brown red ppt was formed. The mixture contains:

(1) $C_2O_4^{2-}$ & NO_3^- **(2)** SO_3^{2-} & $C_2O_4^{2-}$
(3) CH_3COO^- & NO_3^- **(4)** SO_3^{2-} & $CH3COO^-$

[JEE (Main) – 11th April 2023 - Shift-1]

6. Given below are two statement :

Statement I: Methane and steam passed over a heated Ni catalyst produces hydrogen gas.

Statement II: Sodium nitrite reacts with NH_4Cl to give H_2O, N_2 and NaCl.

In the light of the above statements, choose the most appropriate answer from the options given below:

(1) Both the statement I and II are incorrect.
(2) Statement I is incorrect but statement II is correct.
(3) Statement I is correct but statement II is incorrect.
(4) Both the statements I and II are correct.

[JEE (Main) – 11th April 2023 - Shift-1]

7. The pair of lanthanides in which both elements have high third - ionization energy is:

(1) Dy, Gd **(2)** Eu,Gd **(3)** Lu,Yb **(4)** Eu,Yb

[JEE (Main) – 13th April 2023 - Shift-1]

8. $K_2Cr_2O_7$ paper acidified with dilute H_2SO_4 turns green when exposed to:

(1) Carbon dioxide **(2)** Sulphur trioxide
(3) Sulphur dioxide **(4)** Hydrogen sulphide

[JEE (Main) – 24th Jan 2023 - Shift-2]

9. Which one amongst the following are good oxidizing agents?

(A) Sm^{2+} **(B)** Ce^{2+} **(C)** Ce^{4+} **(D)** Tb^{4+}

Choose the most appropriate answer from the options given below:

(1) D only **(2)** C only
(3) C and D only **(4)** A and B only

[JEE (Main) – 24th Jan 2023 - Shift-2]

10. Match the List-I with List-II:

	List-I **Cations**		**List-II** **Group reagents**
A.	Pb^{2+}, Cu^{2+}	**(i)**	H_2 S gas in presence of dilute HCl
B.	Al^{3+}, Fe^{3+}	**(ii)**	$(NH_4)_2CO_3$ in presence of NH_4OH
C.	Co^{2+},Ni^{2+}	**(iii)**	NH_4OH in presence of NH_4Cl
D.	Ba^{2+}, Ca^{2+}	**(iv)**	H_2 S in presence of NH_4OH

Correct match is –

(1) A → (iii), B → (i), C → (iv), D → (ii)
(2) A → (i), B → (iii), C → (ii), D → (iv)
(3) A → (iv), B → (ii), C → (iii), D → (i)
(4) A → (i), B → (iii), C → (iv), D → (ii)

[JEE (Main) – 25th Jan 2023 - Shift-1

11. Potassium dichromate acts as a strong oxidizing agent in acidic solution. During this process, the oxidation state changes from:

(1) +2 to +1 **(2)** +3 to +1
(3) +6 to +2 **(4)** +6 to +3

[JEE (Main) – 25th Jan 2023 - Shift-2]

12. Match List I with List II

	LIST I		**LIST II**
A.	Cobalt catalyst	I.	$(H_2 + Cl_2)$ production
B.	Syngas	II.	Water gas production
C.	Nickel catalyst	III.	Coal gasification
D.	Brine solution	IV.	Methanol production

Choose the correct answer from the options given below:

(1) A-IV, B-I, C-II, D-III **(2)** A-IV, B-III, C-II, D-I
(3) A-II, B-III, C-IV, D-I **(4)** A-IV, B-III, C-I, D-II

[JEE (Main) – 25th Jan 2023 - Shift-2]

13. During the borax bead test with $CuSO_4$, a blue green colour of the bead was observed in oxidising flame due to the formation of:

(1) CuO **(2)** $Cu(BO_2)_2$ **(3)** Cu_3B_2 **(4)** Cu

[JEE (Main) – 29th Jan 2023 - Shift-1]

14. The reaction representing the Mond process for metal refining is__________

(1) $ZnO\ ZnO + C \xrightarrow{\Delta} Zn + CO$
(2) $Zr + 2I_2 \xrightarrow{\Delta} ZrI_4$
(3) $2K[Au(CN)_2] + Zn \xrightarrow{\Delta} K_2[Zn(CN)_4] + 2Au$
(4) $Ni + 4CO \xrightarrow{\Delta} Ni(CO)_4$

[JEE (Main) – 29th Jan 2023 - Shift-1]

15. A solution of CrO_5 in amyl alcohol has a _______ colour.

(1) Green **(2)** Orange–Red
(3) Yellow **(4)** Blue

[JEE (Main) – 29th Jan 2023 - Shift-2]

16. The set of correct statements is :

(i) Manganese exhibits +7 oxidation state in its oxide.
(ii) Ruthenium and Osmium exhibit +8 oxidation in their oxides.

(iii) Sc shows +4 oxidation state which is oxidizing in nature.

(iv) Cr shows oxidising nature in +6 oxidation state.

(1) (ii) and (iii) **(2)** (i), (ii) and (iv)
(3) (ii), (iii) and (iv) **(4)** (i) and (iii)

[JEE (Main) – 29th Jan 2023 - Shift-2]

17. During the qualitative analysis of SO_3^{2-} using dilute H_2SO_4, SO_2 gas is evolved which turns $K_2Cr_2O_7$ solution (acidified with dilute H_2SO_4):

(1) green **(2)** blue **(3)** red **(4)** black

[JEE (Main) – 30th Jan 2023 - Shift-1]

18. 1 L, 0.02M solution of $[Co(NH_3)_5SO_4]Br$ is mixed with 1 L, 0.02M solution of $[Co(NH_3)_5Br]SO_4$. The resulting solution is divided into two equal parts (X) and treated with excess of $AgNO_3$ solution and $BaCl_2$ solution respectively as shown below:

1 L solution (X) + $AgNO_3$ solution (excess) → Y

1 L Solution (X) + $BaCl_2$ solution (excess) → Z

The number of moles of Y and Z respectively are:

(1) 0.02, 0.01 **(2)** 0.01, 0.01
(3) 0.01, 0.02 **(4)** 0.02, 0.02

[JEE (Main) – 30th Jan 2023 - Shift-2]

19. Formulae for Nessler's reagent is:

(1) HgI_2 **(2)** K_2HgI_4 **(3)** $KHgI_3$ **(4)** KHg_2I_2

[JEE (Main) – 30th Jan 2023 - Shift-2]

20. When Cu^{2+} ion is treated with KI, a white precipitate, X appears in solution. The solution is titrated with sodium thiosulphate, the compound Y is formed. X and Y respectively are:

(1) $X=CuI_2$ $Y=Na_2S_4O_6$
(2) $X=CuI_2$ $Y=Na_2S_2O_3$
(3) $X=Cu_2I_2$ $Y=Na_2S_4O_5$
(4) $X=Cu_2I_2$ $Y=Na_2S_4O_6$

[JEE (Main) – 31th Jan 2023 - Shift-1]

21. $Nd^{2+}=$

(1) $4f^3$ **(2)** $4f^46s^2$ **(3)** $4f^4$ **(4)** $4f^26s^2$

[JEE (Main) – 31th Jan 2023 - Shift-1]

22. The correct order of basicity of oxides of vanadium is:

(1) $V_2O_5>V_2O_4>V_2O_3$ **(2)** $V_2O_4>V_2O_3>V_2O_5$
(3) $V_2O_3>V_2O_5>V_2O_4$ **(4)** $V_2O_3>V_2O_4>V_2O_5$

[JEE (Main) – 31th Jan 2023 - Shift-1]

23. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): The first ionization enthalpy of 3*d* series elements is more than that of group 2 metals

Reason (R): In 3*d* series of elements successive filling of *d*-orbitals takes place.

In the light of the above statements, choose the correct answer from the options given below:

(1) Both (A) and (R) are true but (R) is not the correct explanation of (A).
(2) Both (A) and (R) are true and (R) is the correct explanation of (A).
(3) (A) is true but (R) is false.
(4) (A) is false but (R) is true.

[JEE (Main) – 31th Jan 2023 - Shift-2]

24. Given below are two statements:

Statement I: Upon heating a borax bead dipped in cupric sulphate in a luminous flame, the colour of the bead becomes green.

Statement II: The green colour observerd is due to the formation of copper(I) metaborate.

In the light of the above statements, choose the most appropriate answer from the options given below:

(1) Both statement I and statement II are true.
(2) Statement I is true but statement II is false.
(3) Statement I is false but statement II is true.
(4) Both statement I and statement II are false.

[JEE (Main) – 31th Jan 2023 - Shift-2]

25. Which of the following elements have half–filled *f*–orbitals in their ground state?

(Given: atomic number Sm = 62; Eu = 63; Tb = 65; Gd = 64, Pm = 61)

A. Sm B. B.Eu C. Tb D. Gd
E. Pm

Choose the correct answer from the options given below:

(1) A and B only **(2)** A and E only
(3) C and D only **(4)** B and D only

[JEE (Main) – 31th Jan 2023 - Shift-2]

26. In the flame test of a mixture of salts, a green flame with blue centre was observed. Which one of the following cations may be present?

(1) Cu^{2+} **(2)** Sr^{2+} **(3)** Ba^{2+} **(4)** Ca^{2+}

[JEE (Main) – 24th June 2022 - Shift-2]

27. Cerium (IV) has a noble gas configuration. Which of the following is correct statement about it?

(1) It will not prefer to undergo redox reactions.
(2) It will prefer to gain electron and act as an oxidizing agent.
(3) It will prefer to give away an electron and behave as reducing agent.
(4) It acts as both, oxidizing and reducing agent.

[JEE (Main) – 25th June 2022 - Shift-1]

28. Among the following, which is the strongest oxidizing agent?

(1) Mn^{3+} **(2)** Fe^{3+} **(3)** Ti^{3+} **(4)** Cr^{3+}

[JEE (Main) – 25th June 2022 - Shift-1]

29. The most common oxidation state of Lanthanoid elements is +3. Which of the following is likely to deviate easily from +3 oxidation state?

(1) Ce (At. No. 58) **(2)** La (At. No. 57)
(3) Lu (At. No. 71) **(4)** Gd (At. No. 64)

[JEE (Main) – 26th June 2022 - Shift-2]

30. The '*f*' orbitals are half and completely filled respectively in lanthanide ions:

[Given : Atomic no. Eu = 63; Sm = 62; Tm = 69; Tb = 65; Yb = 70; Dy = 66]

(1) Eu^{2+} and Tm^{2+} **(2)** Sm^{2+} and Tm^{3+}
(3) Tb^{4+} and Yb^{2+} **(4)** Dy^{3+} and Yb^{3+}

[JEE (Main) – 27th June 2022 - Shift-2]

31. Which one of the lanthanoids given below is the most stable in divalent form?

(1) Ce (Atomic number 58)
(2) Sm (Atomic number 62)
(3) Eu (Atomic number 63)
(4) Yb (Atomic number 70)

[JEE (Main) – 28th June 2022 - Shift-1]

32. Match List – I with List-II

List – I (Reaction)	**List – II (Catalyst)**
(1) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	(I) Cu
(2) $CO(g) + 3H_2(g) \rightarrow CH_4(g) + H_2O(g)$	(II) $Cu/ZnO - Cr_2O_3$
(3) $CO(g) + H_2(g) \rightarrow HCHO(g)$	(III) $Fe_2O_3 + K_2O + Al_2O_3$
(4) $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$	(IV) Ni

Choose the correct answer from the options given below:

(1) (1)-(II), (2)-(IV), (3)-(I), (4)-(III)
(2) (1)-(II), (2)-(I), (3)-(IV), (4)-(III)
(3) (1)-(III), (2)-(IV), (3)-(I), (4)-(II)
(4) (1)-(III), (2)-(I), (3)-(IV), (4)-(II)

[JEE (Main) – 25th July 2022 - Shift-1]

33. The reaction of H_2O_2 with potassium permanganate in acidic medium leads to the formation of mainly:

(1) Mn^{2+} **(2)** Mn^{4+} **(3)** Mn^{3+} **(4)** Mn^{6+}

[JEE (Main) – 25th July 2022 - Shift-1]

34. Match List – I with List – II.

List – I (Reaction)	**List – II (Catalyst)**
(1) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$	(I) Fe(s)
(2) $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$	(II) Pt(s) – Rh(s)
(3) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	(III) V_2O_5
(4) Vegetable oil (*l*) + H_2 → Vegetable ghee(s)	(IV) Ni(s)

Choose the correct answer from the options given below :

(1) (1)–(III),(2)–(I),(3)–(II),(4)–(IV)
(2) (1)–(III),(2)–(II),(3)–(I),(4)–(IV)
(3) (1)–(IV),(2)–(III),(3)–(I),(4)–(II)
(4) (1)–(IV),(2)–(II),(3)–(II),(4)–(I)

[JEE (Main) – 26th July 2022 - Shift-1]

35. Given below are two statements.

Statement I : Iron (III) catalyst, acidified $K_2Cr_2O_7$ and neutral $KMnO_4$ have the ability to oxidise I^- to I_2 independently.

Statement II : Manganate ion is paramagnetic in nature and involves pπ-pπ bonding.

In the light of the above statements, choose the correct answer from the options given below.

(1) Both statement I and statement II are true.
(2) Both statement I and statement II are false.
(3) Statement I is true but statement II is false.
(4) Statement I is false but statement II is true.

[JEE (Main) – 27th July 2022 - Shift-1]

36. In neutral or alkaline solution, MnO_4^- oxidises thiosulphate to:

(1) $S_2O_7^{2-}$ **(2)** $S_2O_8^{2-}$ **(3)** SO_3^{2-} **(4)** SO_4^{2-}

[JEE (Main) – 27th July 2022 - Shift-2]

37. Given below are two statements : One is labelled as Assertion **(A)** and the other is labelled as Reason (R).

Assertion (A): Permanganate titrations are not performed in presence of hydrochloric acid.

Reason (R): Chlorine is formed as a consequence of oxidation of hydrochloric acid.

In the light of the above statements, choose the correct answer from the options given below.

(1) Both A and R are true and R is the correct explanation of A.
(2) Both A and R are true but R is NOT the correct explanation of A.
(3) A is true but R is false.
(4) A is false but R is true.

[JEE (Main) – 28th July 2022 - Shift-2]

38. The reaction of zinc with excess of aqueous alkali evolves hydrogen gas and gives :

(1) $Zn(OH)_2$ **(2)** ZnO
(3) $[Zn(OH)_4]^{2-}$ **(4)** $[ZnO_2]^{2-}$

[JEE (Main) – 29th July 2022 - Shift-1]

39. In following pairs, the one in which both transition metal ions are colourless is :

(1) Sc^{3+}, Zn^{2+} **(2)** Ti^{4+}, Cu^{2+}
(3) V^{2+}, Ti^{3+} **(4)** Zn^{2+}, Mn^{2+}

[JEE (Main) – 29th July 2022 - Shift-1]

40. Which of the following 3d-metal ion will give the lowest enthalpy of hydration ($\Delta_{hyd}H$) when dissolved in water ?

(1) Cr^{2+} **(2)** Mn^{2+} **(3)** Fe^{2+} **(4)** Co^{2+}

[JEE (Main) – 29th July 2022 - Shift-2]

41. What is the correct order of the following elements with respect to their density ?

(1) Cr < Fe < Co < Cu < Zn
(2) Cr < Zn < Co < Cu < Fe
(3) Zn < Cu < Co < Fe < Cr
(4) Zn < Cr < Fe < Co < Cu

[JEE (Main) – 24th Feb 2021 - Shift-2]

42. Given below are two statements

Statement I: CeO_2 can be used for oxidation of aldehydes and ketones.

Statement II: Aqueous solution of $EuSO_4$ is a strong reducing agent.

(1) Statement I is true, statement II is false.
(2) Statement I is false, statement II is true.
(3) Both statement I and statement II are false.
(4) Both statement I and statement II are true.

[JEE (Main) – 25th Feb 2021 - Shift-1]

43. In which of the following pairs, the outer most electronic configuration will be the same ?

(1) Fe^{2+} and Co^{+} **(2)** Cr^{+} and Mn^{2+}
(3) Ni^{2+} and Cu^{+} **(4)** V^{2+} and Cr^{+}

[JEE (Main) – 25th Feb 2021 - Shift-1]

44. Which one of the following lanthanoids does not form MO_2 ?
[M is lanthanoid metal]

(1) Nd **(2)** Yb **(3)** Dy **(4)** Pr

[JEE (Main) – 26th Feb 2021 - Shift-1]

45. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): In TI_3, isomorphous to CsI_3, the metal is present in +1 oxidation state.

Reason (R): Tl metals has fourteen *f* electrons in its electronic configuration.

In the light of the above statements, choose the most appropriate answer from the options given below:

(1) Both A and R are correct and R is the correct explanation of A.
(2) A is not correct but R is correct.
(3) Both A and R are correct R is NOT the correct explanation of A.
(4) A is correct but R is not correct.

[JEE (Main) – 26th Feb 2021 - Shift-2]

46. Given below are two statements : One is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): Size of Bk^{3+} ion is less than Np^{3+} ion.

Reason (R): The above is a consequence of the lanthanoid contraction.

In the light of the above statements, choose the correct answer from the options given below:

(1) A is false but R is true.
(2) Both A and R are true but R is not the correct explanation of A.
(3) A is true but R is false.
(4) Both A and R are true and R is the correct explanation of A.

[JEE (Main) – 16th March 2021 - Shift-1]

47. Given below are two statements :

Statement **I:** Potassium permanganate on heating at 573 K forms potassium manganate.

Statement II: Both potassium permanganate and potassium manganate are tetrahedral and paramagnetic in nature.

In the light of the above statements, choose the most appropriate answer from the options given below :

(1) Both statement I and statement II are true.
(2) Both statement I and statement II are false.
(3) Statement I is true but and statement II is false.
(4) Statement I is false but statement II is true.

[JEE (Main) – 17th March 2021 - Shift-1]

48. Which one of the following species doesn't have a magnetic moment of 1.73 BM. (spin only value)?

(1) CuI **(2)** $[Cu(NH_3)_4]Cl_2$
(3) O_2^+ **(4)** O_2^-

[JEE (Main) – 20th July 2021 - Shift-2]

49. Spin only magnetic moment of an octahedral complex of Fe^{2+} in the presence of a strong field ligand in B.M. is:

(1) 4.89 **(2)** 0 **(3)** 2.82 **(4)** 3.46

[JEE (Main) – 20th July 2021 - Shift-2]

50. The set having ions which are coloured and paramagnetic both is :

(1) Sc^{3+}, V^{5+}, Ti^{4+} **(2)** Cu^{2+}, Cr^{3+}, Sc^{+}
(3) Ni^{2+}, Mn^{7+}, Hg^{2+} **(4)** Cu^{+}, Zn^{2+}, Mn^{4+}

[JEE (Main) – 22nd July 2021 - Shift-2]

51. The correct order of following 3d metal oxides, according to their oxidation numbers is :

(i) CrO_3 **(ii)** Fe_2O_3 **(iii)** MnO_2 **(iv)** V_2O_5
(v) Cu_2O

(1) (i) > (iii) > (iv) > (ii) > (v)
(2) (iv) > (i) > (ii) > (iii) > (v)
(3) (i) > (iv) > (iii) > (ii) > (v)
(4) (iii) > (i) > (iv) > (v) > (iv)

[JEE (Main) – 25th July 2021 - Shift-1]

52. The spin only magnetic moments (in BM) for free Ti^{3+}, V^{2+} and Sc^{3+} ions respectively are: (At.No. Sc : 21; Ti : 22; V : 23)

(1) 1.73, 3.87, 0 **(2)** 0, 3.87, 1.73
(3) 3.87, 1.73, 0 **(4)** 1.73, 0, 3.87

[JEE (Main) – 25th July 2021 - Shift-2]

53. Which one of the following metals forms interstitial hydride easily ?

(1) Fe **(2)** Mn **(3)** Cr **(4)** Co

[JEE (Main) – 25th July 2021 - Shift-2]

54. Identify the process in which change in the oxidation state is five :

(1) $C_2O_4^{2-} \rightarrow 2CO_2$ **(2)** $CrO_4^{4-} \rightarrow Cr^{3+}$
(3) $Cr_2O_7^{2-} \rightarrow 2Cr^{3+}$ **(4)** $MnO_4^{-} \rightarrow Mn^{2+}$

[JEE (Main) – 25th July 2021 - Shift-2]

55. Which one of the following when dissolved in water gives coloured solution in nitrogen atmosphere ?

(1) AgCl **(2)** $CuCl_2$ **(3)** Cu_2Cl_2 **(4)** $ZnCl_2$

[JEE (Main) – 26th Aug 2021 - Shift-2]

56. The nature of oxides V_2O_3 and CrO is indexed as 'X' and 'Y' type respectively. The correct set of X and Y is :

(1) X = Amphoteric Y = Basic
(2) X = Basic Y = Basic
(3) X = Acidic Y = Acidic
(4) X = Basic Y= Amphoteric

[JEE (Main) – 27th Aug 2021 - Shift-1]

57. Potassium permanganate on heating at 513K gives a product which is:

(1) paramagnetic and green
(2) diamagnetic and colourless
(3) paramagnetic and colourless
(4) diamagnetic and green

[JEE (Main) – 27th Aug 2021 - Shift-2]

58. The addition of dilute NaOH to Cr^{3+} salt solution will give :

(1) precipitate of $[Cr(OH)_6]^{3-}$
(2) precipitate of $Cr_2O_3(H_2O)_n$
(3) a solution of $[Cr(OH)_4]^{-}$
(4) precipitate of $Cr(OH)_3$

[JEE (Main) – 27th Aug 2021 - Shift-2]

59. In the structure of the dichromate ion, there is a :

(1) Non – linear unsymmetrical Cr – O – Cr bond.
(2) Linear symmetrical Cr – O – Cr bond.
(3) Linear unsymmetrical Cr – O – Cr bond.
(4) Non – linear symmetrical Cr – O – Cr bond.

[JEE (Main) – 31st Aug 2021 - Shift-1]

60. Which one of the following lanthanides exhibits +2 oxidation state with diamagnetic nature ? (Given Z for Nd = 60, Y*b* = 70, L*a* = 57, C*e* = 58)

(1) La **(2)** Ce **(3)** Nd **(4)** Yb

[JEE (Main) – 31st Aug 2021 - Shift-1]

61. The Eu^{2+} ion is a strong reducing agent in spite of its ground state electronic configuration (outermost): [Atomic number of Eu = 63]

(1) $4f^6$ **(2)** $4f^6 6s^2$ **(3)** $4f^7$ **(4)** $4f^7 6s^2$

[JEE (Main) – 31st Aug 2021 - Shift-2]

62. Identify the element for which electronic configuration in +3 oxidation state is $[Ar]3d^5$:

(1) Co **(2)** Mn **(3)** Fe **(4)** Ru

[JEE (Main) – 1st Sep 2021 - Shift-2]

63. The correct electronic configuration and spin only magnetic moment (BM) of Gd^{3+} (Z = 64) respectively are:

(1) [Xe] $5f^7$ and 7·9 **(2)** [Xe] $5f^7$ and 8·9
(3) [Xe] $4f^7$ and 7·9 **(4)** [Xe] $4f^7$ and 8·9

[JEE (Main) – 5th Sept 2020 - Shift-1]

64. The Lanthanide ion that would show colour is:

(1) Gd^{3+} **(2)** Sm^{3+} **(3)** La^{3+} **(4)** Lu^{3+}

[JEE (Main) – 8th April 2019 - Shift-1]

ANSWER – KEY

1. (1)	**2. (4)**	**3. (4)**	**4. (2)**
5. (3)	**6. (4)**	**7. (4)**	**8. (3)**
9. (3)	**10. (4)**	**11. (4)**	**12. (2)**
13. (2)	**14. (4)**	**15. (4)**	**16. (2)**
17. (1)	**18. (2)**	**19. (2)**	**20. (4)**
21. (3)	**22. (4)**	**23. (1)**	**24. (4)**
25. (4)	**26. (1)**	**27. (2)**	**28. (1)**
29. (1)	**30. (3)**	**31. (3)**	**32. (3)**
33. (1)	**34. (2)**	**35. (2)**	**36. (4)**
37. (1)	**38. (3)**	**39. (1)**	**40. (2)**
41. (4)	**42. (4)**	**43. (2)**	**44. (2)**
45. (1)	**46. (4)**	**47. (3)**	**48. (1)**
49. (2)	**50. (2)**	**51. (3)**	**52. (1)**
53. (3)	**54. (4)**	**55. (2)**	**56. (2)**
57. (1)	**58. (2)**	**59. (4)**	**60. (4)**
61. (3)	**62. (3)**	**63. (3)**	**64. (2)**

ANSWERS WITH EXPLANATIONS

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

   The reaction of permanganate with thiosulphate is as follows

   $$\overset{+7}{KMnO_4} + \overset{+2}{S_2O_3^{2-}} \rightarrow \overset{+6}{SO_4^{2-}} + \overset{+4}{MnO_2}$$

   This reaction takes place in neutral or faintly alkaline medium.

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

   When a mixture containing chloride ion is heated with $K_2Cr_2O_7$ and concentrated H_2SO_4, deep orange-red fumes of chromyl chloride (CrO_2Cl_2) are formed

   $K_2Cr_2O_7 + 4NaCl + 6H_2SO_4 \rightarrow 2KHSO_4 + 4NaHSO_4 + 2CrO_2Cl_2\uparrow + 3H_2O$

   Orange-red fumes

   So in this case, X in CrO_2Cl_2.

   Oxidation state of Cl = –1, O = –2, Cr = x

   $x + 2 \times (-2) + 2 \times (-1) = 0 \Rightarrow x = +6$

   $$CrO_2Cl_2 \rightarrow \text{ Chromyl chloride}$$
   $$\Downarrow$$
   $$\left.\begin{array}{l} Cr^{+6} \rightarrow 4s^0\,3d^0 \\ Mn(vii) \rightarrow Mn^{+7} \\ \qquad\quad \Downarrow \\ \qquad\quad 4s^0\,3d^0 \end{array}\right] \text{Same}$$

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

   Prolonged heating of ferrous ammonium sulfate is avoided to prevent oxidation. Ferrous ammonium sulfate is a green crystalline solid that is used as a reducing agent in various chemical reactions. When heated, it can undergo oxidation to form ferric ammonium sulfate. This is because heating provides energy that can be used to overcome the activation energy required for the oxidation reaction to occur. The oxidation of ferrous ammonium sulfate can be represented by the following chemical equation:

   $NH_4FeSO_4(NH_4)2SO_4.6H_2O + O_2$

   $\rightarrow 2Fe_2(SO_4)_3.(NH_4)_2SO_4 + 12H_2O$

   This reaction is exothermic and releases a large amount of heat. Therefore, prolonged heating can provide the energy required to drive the reaction forward, leading to the formation of ferric ammonium sulfate. To prevent this oxidation reaction from occurring, prolonged heating of ferrous ammonium sulfate is avoided.

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

   $K_2\ Cr_2\ O_7$ is generally preferred than $Na_2\ Cr_2\ O_7$ in volumetric analysis as $Na_2\ Cr_2\ O_7$ is hygroscopic in nature, therefore it is difficult to prepare its standard solution for volumetric analysis as accurate weighing is not possible in normal atmospheric conditions. A hygroscopic substance can absorb moisture from the atmosphere due to which there will be inaccuracy in weight.

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

   Here the reaction of $FeCl_3$ with CH_3COO^- takes place to give blood red colour.

   $CH_3COO^- + FeCl_3 \rightarrow Fe(CH_3COO)_3$

   or $[Fe_3(OH)_2(CH_3COO)_6]+$

   Blood red colour

   $\downarrow\Delta$

   $[Fe_3(OH)_2(CH_3COO)]\downarrow$

   Red brown precipitate

   Similarly Fe^{2+} on reaction with NO_3^- ion in presence of acidic medium to give brown red ppt.

   $$2NO_3^- + 4H_2SO_4 + 6Fe^{2+} \rightarrow 6Fe^{3+} + 2NO\uparrow + 4SO_4^{2-} + 4H_2O$$

   $$[Fe(H_2O)_6]^{2+} + NO \rightarrow \underset{\text{brown colour complex}}{[Fe(H_2O)_5NO]^{2+}} + H_2O$$

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

   Statement I is correct.

   Methane and steam passed over a heated Ni catalyst produces H_2 gas.

   $$CH_4(g) + \underset{\text{Steam}}{H_2O(g)} \xrightarrow[1270\,K]{Ni} CO(g) + 3H_2(g)$$

   Statement (II) is correct.

   Sodium nitrile reacts with NH_4Cl to give H_2O, N_2 and NaCl.

   $$NaNO_2(aq) + NH_4Cl(aq) \rightarrow N_2(g) + NaCl(aq) + 2H_2O(l)$$

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

   Eu : $4f^7 6s^2$
   (z = 63)
   Eu^{2+} : $4f^7$ (half filled configuration)
   Yb : $4f^{14} 6s^2$
   (z = 70)
   Yb^{2+} : $4f^{14}$ (full filled configuration)

   The pair of lanthanide in which both elements have high 3rd ionization energy is Yb^{2+} & Eu^{2+} and the reasons of high ionization is half filled and full filled configuration of the ions.

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

   The reaction of potassium dichromate ($K_2Cr_2O_7$) with sulphur dioxide (SO_2) in the presence of dilute acid gives green colour of chromic sulphate and sulphate ion.

   In this reaction, potassium dichromate act as an oxidizing agent which oxidises sulphur dioxide

into sulphate ion and itself get reduced to chromic sulphate, which has green colour.
The reaction between potassium dichromate and sulphur dioxide is shown as follows

$$Cr_2O_7^{2-} + 2H^+ + 3SO_2 \rightarrow \underset{\text{(Green)}}{2Cr^3} + 3SO_4^{2-} + H_2O$$

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

The electronic configuration of the ions are as follows:

A. Sm^{2+}: [Xe] $4f^6$
B. Ce^{2+}: [Xe] $4f^2$
C. Ce^{4+}: [Xe] $4f^0$
D. Tb^{4+}: [Xe] $4f^7$

Out of the following ions Ce^{4+} and Tb^{4+} act as good oxidizing agent. Because they can be readily converted to their +3 oxidation states.

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

	Cation	**Group No**		**Group Reagent**
A	Pb^{2+}, Cu^{2+}	II	(i)	H_2S gas in presence of deil HCl
B.	Al^{3+}, Fe^{3+}	III	(ii)	NH_4OH in present of NH_4Cl
C.	Co^{2+}, Ni^{2+}	IV	(iii)	H_2S in presence of NH_4OH
D.	Ba^{2+}, Ca^{2+}	V	(iv)	$(NH_4)_2$ CO_3 in presence of NH_4OH

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

The balanced chemical reaction of dichromate ion in an acidic solution is shown as follows:-

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

From above it is clear that, the change in oxidation state of chromium atom takes place from +6 to +3.

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

LIST I		**LIST II**	
A.	Cobalt catalyst	IV.	Methanol production
B.	Syngas	III.	Coal gasification
C.	Nickel catalyst	II.	Water gas production
D.	Brine solution	I.	$(H_2 + Cl_2)$ production

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

Borax bead test is an example of dry test in which metal ion reacts with a sample of borax ($Na_2B_4O_7$. $10H_2O$) which gives characteristics colour beads.

$$Na_2B_4O_7 \xrightarrow{\Delta} 2NaBO_2 + B_2O_3$$

$$CuSO_4 \xrightarrow{\Delta} CuO + SO_3$$

$$CuO + B_2O_3 \rightarrow \underset{\substack{\text{Copper (II) metaborate} \\ \text{(blue–green color)}}}{Cu(BO_2)_2}$$

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

Mond process is an example of vapour phase refining in which metal is converted into its volatile compound & collected elsewhere when then decomposed to give pure metal,
Here, nickel is heated in a stream of carbon monoxide (CO) to form volatile complex, nickel tetracarbonyl

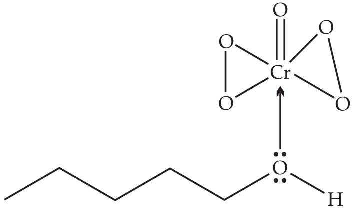
$$Ni + 4CO \xrightarrow{330\text{-}350K} Ni(CO)_4$$

The carbonyl is subjected to higher temperature so it is decomposed to give pure metal.

$$Ni(CO)_4 \xrightarrow{450\text{-}470K} Ni + 4CO$$

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

The amyl alcohol forms a complex with the CrO_5 that results in the blue colour.



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

(i) In Mn_2O_7, Mn is in +7 oxidation state.

(ii) Ru and Os exhibits highest oxidation state of +8. [OsO_4 and RuO_4]

(iii) Sc exists in maximum oxidation state of +3.

(iv) Cr show maximum oxidation state of +6. It act as an oxidizing agent in +6 state.

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

On treating sulphite with warm dil. H_2SO_4, SO_2 gas is evolved which is suffocating with the smell of burning sulphur.

$$Na_2SO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + SO_2$$

The gas turns potassium dichromate paper green when acidified with dil. H_2SO_4, -

$$K_2Cr_2O_7 + H_2SO_4 + 3SO_2 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + H_2O$$

Chromium sulphate (green)

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

Mixture X contains 0.02 moles of $[Co\ (NH_3)_5\ Br]SO_4$ and 0.02 moles of $[Co(NH_3)_5\ Br]SO_4$ was prepared in two litres of solution. So, the concentration of $[Co(NH_3)_5\ SO_4]Br$

and $[Co(NH_3)_5\ Br]\ SO_4$ in solution are 0.01 mol L and 0.01 mol L respectively. During the reaction with $AgNO_3$ (excess), AgBr is precipitated as follows:

$$\underset{0.01\ mol/L}{[Co(NH_3)_5\ SO_4]Br} + \underset{(excess)}{AgNO_3} \rightarrow \underset{Soluble}{[Co(NH_3)_5\ SO_4]NO_3} + \underset{\substack{Y \\ 0.01\ mol/L\ (\gamma)}}{AgBr\downarrow}$$

Hence, number of moles of Y = 0.01

On addition of excess $BaCl_2$, SO_4^{2-} ions of $[Co(NH_3)_5\ Br]SO_4$ is precipitated in form of Z.

$$\underset{0.01\ mol/L}{[Co(NH_3)_5\ SO_4]} + \underset{(excess)}{BaCl_2} \rightarrow \underset{\substack{0.01 mol/L \\ 'Z'}}{BaSO_4\downarrow} + \underset{Soluble}{[Co(NH_3)_5Br]\underset{Z}{Cl_2}}$$

Hence, number of moles of Z = 0.01

Thus, the number of moles of Y and Z are 0.01 and 0.01 respectively.

19. Option (2) is correct.

Nessler's reagent is an aqueous solution of potassium iodide, mercuric chloride hydroxide (KOH). It's molecular formula is K_2HgI_4.

Nessler's reagent is used as confirmatory test for ammonium ion NH_4^+.

Confirmatory test for ammonium ion: Take aqueous solution of salt in test tube and add Nessler's reagent mixture. Appearance of brown or yellow precipitate confirms the presence of NH_4^+ ion.

$$2K_2HgI_4 + NH_4Cl + 4KOH \rightarrow \underset{\text{brown ppt.}}{NH_2HgOHgI\downarrow} + 7KI + KCl + 3H_2O$$

20. Option (4) is correct.

$X = Cu_2I_2$, $Y = Na_2S_4O_6$

$2CuSO_4 + 4KI \rightarrow Cu_2I_2\ (X) + 2K_2SO_4 + I_2$

$2I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6(Y)$

21. Option (3) is correct.

The electronic configuration of Nd (Z=60): $[Xe]4f^4\,6s^2$. In the (+2) state, the configuration is $[Xe]\ 4f^4$.

22. Option (4) is correct.

As positive oxidation state increases, acidic nature increases and basic nature decreases. $V_2O_3 > V_2O_4 > V_2O_5$.

23. Option (1) is correct.

The first ionization enthalpy of 3*d*–block elements is higher than the Group–II elements due to the poor shielding effect of d–orbitals.

24. Option (4) is correct.

On treatment with metal salt, boric anhydride forms metaborate of the metal which gives different colours in oxidising and reducing flame.

Upon heating a borax bead dipped in cupric sulphate in a luminous flame, the colour of the bead becomes blue due to the formation of cupric metaborate $Cu(BO_2)_2$. In reducing flame The blue-green of is reduced to colourless cuprous metaborate. Also Cupric metaborate may be reduced to metallic copper and bead appears red opaque. Thus, both the statements are incorrect.

25. Option (4) is correct.

61	Pm	$4f^6 6s^2$
62	Sm	$4f^6 6s^2$
63	Eu	$4f^7 6s^2$
64	Gd	$4f^7 5d' \ 6s^2$
65	Tb	$4f^9\ 6s^2$

Eu & Gd has half filled.

26. Option (1) is correct.

In the flame test of a mixture of salts, a green flame with blue centre was observed. The cation which may be present in it is Cu^{2+}.

The colour of other salts:

Sr^{2+} Crimson red

Ca^{2+} Brick red

Ba^{2+} Green

27. Option (2) is correct.

Cerium exists in two different oxidation state +3, +4.

It shows Ce^{+4} and acts as strong oxidising agent & accepts electron. Most stable and common oxidation state of lanthanoids is +3. Because half filled *d* subshell.

28. Option (1) is correct.

Mn^{3+} gains one more electron to acquire stable electronic configuration. If it gains one electron, its configuration will be $3d^5$, which is stable. Because half filled $3d^5$ subshell show extra stability.

29. Option (1) is correct.

The most common and stable oxidation state of Lanthanides is + 3. It is attained by removing valence shell of 2 electrons of 6*s* electrons and 1 electron from 4*f* electrons. It is due to high energy difference in 4*f* and 6*s* it is difficult to remove more electrons from 4*f* sub-shell.

$Ce = [Xe]\ 4f^1 5d^1 6s^2$

$Ce^{3+} = [Xe]\ 4f^1 5d^0$

$Ce^{4+} = [Xe]\ 4f^0 5d^0$ (Noble gas configuration)

30. Option (3) is correct.

Lanthanides are the rare earth elements of the periodic table i.e. the elements with atomic number from 58 to 71 following the element

Lanthanum. Electronic configurations achieve extra stability due to empty, half-filled and completely filled *f* orbitals .

$Tb^{4+}: 4f^7 5d^0 6s^0$

$Yb^{2+}: 4f^{14} 5d^0 6s^0$

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

The electronic configuration of Europium = $[Xe]4f^7 6s^2$, on losing two electrons it form stable half filled configuration of $4f^7$ which makes +2 oxidation state more stable.

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

Use of catalyst such as iron oxide with small amounts of K_2O and Al_2O_3 (these act as promoters) increases the rate of attainment of equilibrium in Haber's Process.

$$N_2(g) + 3H_2(g) \xrightarrow{Fe_2O_3 + K_2O + Al_2O_3} 2NH_3(g)$$

A mixture of CO and H_2 is called "syngas".

One of the important features of catalyst is the selectivity. It is the ability of a catalyst to direct a reaction to yield a particular product selectively. Under same reaction conditions, different products are possible for different catalyst.

Here, on reaction of CO and H_2 in presence of nickel bed, it forms CH_4 and H_2O products selectively.

Different products are obtained from the same reactant by changing the metal bed (catalyst).

For the same reactants, copper (Cu) metal bed forms formaldehyde and ZnO metal bed forms CH_3OH.

$$CO_{(g)} + 3H_{2(g)} \xrightarrow{Ni} CH_{4(g)} + H_2O_{(l)}$$

$$CO_{(g)} + H_{2(g)} \xrightarrow{Cu} HCHO$$

$$CO_{(g)} + 2H_{2(g)} \xrightarrow{Cu/ZnO-Cr_2O_3} CH_3OH_{(g)}$$

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

The reaction of aqueous $KMnO_4$ with H_2O_2 in acidic conditions gives:

$$3H_2SO_4 + 2KMnO_4 + 5H_2O_2 \rightarrow 5O_2 + 2MnSO_4 + 8H_2O + K_2SO_4$$

The oxidation number of Mn in $MnSO_4$ is +2.

$$H_2O_2 + MnO_4^- \rightarrow Mn^{2+} + O_2$$

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

List – I	List – II	Process Name
(A) $2SO_{2(g)} + O_2 \xrightarrow{V_2O_5} 2SO_{3(g)}$	(III) V_2O_5	Contact Process
(B) $4NH_{3(g)} + 5O_{2(g)} \xrightarrow{Pt_{(s)}-Rh_{(s)}} 4NO_{(g)} + 6H_2O_{(g)}$	(II) $Pt_{(s)} - Rh_{(s)}$	Ostwald process
(C) $N_{2(g)} + 3H_{2(g)} \xrightarrow{Fe_{(s)}} 2NH_{3(g)}$	(I) $Fe_{(s)}$	Haber ammonia process
(D) Vegetable $oil_{(l)} + H_{2(g)} \xrightarrow{Ni_{(s)}}$ Vegetable ghee(s)	(IV) $Ni_{(s)}$	Hydrogenation of oil

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

Statement I is false: Being oxidizing agent, $KMnO_4$ and $K_2Cr_2O_7$ both oxidizes I^- to I_2 but Fe^{3+} cannot oxidize I^- to I_2 because the reduction potential of Fe^{3+} ion is lower than that of I^- .

Statement II is false: Magnate ion (MnO_4^{2-}) is paramagnetic in nature and it contains $d\pi - p\pi$ bonding.

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

$KMnO_4$ is a strong oxidizing agent which oxidizes other species and reduces itself. In neutral or alkaline solution, MnO_4^- oxidizes thiosulphate into sulphate ion.

$$8KMnO_4 + 3S_2O_8^{2-} + H_2O \rightarrow 8MnO_2 + 6SO_4^{2-} + 2OH^-$$

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

$$2KMnO_4 + 16HCl \rightarrow 2MnCl_2 + 2KCl + 8H_2O + 5Cl_2 \text{ (gas)}$$

$KMnO_4$ oxidize HCl to Cl_2 that's why for acidic medium HCl is not used in permanganate titration.

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

Zinc dissolves in excess of aqueous alkali

$$Zn + 2OH^- + 2H_2O \rightarrow \underset{\text{Tetrahydroxozincate(II) ion}}{[Zn(OH)_4]^{2-}} + H_2\uparrow$$

However, this reaction in NCERT is given as:

$$Zn + 2NaOH \rightarrow Na_2ZnO_2 + H_2\uparrow$$

ZnO_2^{2-} is anhydrous form of $[Zn(OH)_4]^{2-}$

So, in aqueous medium best answer of this question is $[Zn(OH)_4]^{2-}$.

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

The transition metal which has either completely filled *d*-orbital or vacant *d*-orbital are colourless because no *d*-*d* transition will occur.

Or in other words, A transition metal ion is coloured if it has one or more unpaired electron in $(n-1)d$ orbitals i.e. $3d$ orbitals.

$_{21}Sc \rightarrow [Ar]3d^1 4s^2;\quad Sc^{3+} \rightarrow [Ar]3d^0 4s^0$

$_{30}Zn \rightarrow [Ar]3d^{10} 4s^2;\quad Zn^{2+} \rightarrow [Ar]3d^{10} 4s^0$

$_{22}Ti \rightarrow [Ar]3d^2 4s^2;\quad Ti^{4+} \rightarrow [Ar]3d^0 4s^0$

$_{23}V \rightarrow [Ar]3d^3 4s^2;\quad V^{2+} \rightarrow [Ar]3d^3$

$_{29}Cu \rightarrow [Ar]3d^{10} 4s^1;\quad Cu^{2+} \rightarrow [Ar]3d^9 4s^0$

$_{25}Mn \rightarrow [Ar]3d^5 4s^2;\quad Mn^{2+} \rightarrow [Ar]3d^5 4s^0$

The colourless ions are: Sc^{3+}, Zn^{2+}

40. Option (2) is correct.

Generally hydration energy increases with increase in charge and decreases with increase in radius.

d-block elements also follow similar trend with some exceptions

Ions	**Hydration enthalpy**
Cr^{2+} =	–1925 kJ/mol
Mn^{2+} =	–1862 kJ/mol
Fe^{2+} =	–1998 kJ/mol
Co^{2+} =	–2079 kJ/mol

Mn^{2+} has lowest $\Delta_{hyd}H$.

41. Option (4) is correct.

As we move along a transition series from left to right atomic radii decreases due to increase in nuclear charge and also increase in atomic mass but decrease in atomic volume. Hence the density increase. But 'Zn' possesses large atomic volume and have low density.

Element	Cr	Fe	Co	Cu	Zn
Density g/cm^3	7.19	7.8	8.7	8.9	7.1

42. Option (4) is correct.

The function of CeO_2 is very similar of SeO_2. SeO_2 oxidises methyl or methylene CeO_2 also to the carbonyl group, oxidises to carbonyl group.

Aqueous solution of $EuSO_4$ acts as reducing agent which is very similar with $BaSO_4$.

43. Option (2) is correct.

$Cr^{2+} = [Ar]\ 3d^5$

$Mn^{2+} = [Ar]\ 3d^{5.}$

44. Option (2) is correct.

Symbol (Lin)	Atomic No.	Electronic configuration	Oxidation state
Nd	60	$[Xe]4f^4 5d^{\circ} 6s^2$	+ 2, + 3, + 4
Yb	70	$[Xe]4f^{14} 5d^{\circ} 6s^2$	+ 2, + 3
Dy	66	$[Xe]4f^{10} 5d^{\circ} 6s^2$	+ 3, + 4
Pr	59	$[Xe]4f^{13} 5d^{\circ} 6s^2$	+ 3, + 4

Hence, Yb does not form MO_2 type oxide.

45. Option (1) is correct.

$TlI_3 \rightleftharpoons Tl^+ + I_3$

$CsI_3 \rightleftharpoons Cs^+ + I_3$

[Both have same crystalline structure so called isomorphous] Hence, both Tl^+ and Cs have +1 oxidation state.

$Tl^+{}_{(81)} = [Xe_{54}]\ 4f^{14}, 5d^{10}\ 6s^2$

Tl shows +1 oxidation state due to inert pair effect and it is correct due to present f^{14} electrons in Tl^+(ion).

46. Option (4) is correct.

$_{93}Np^{3+}$, $_{97}Bk^{3+}$ as atomic number increases, ionic size decreases due to Lanthanoid/Actinide contraction.

47. Option (3) is correct.

$$KMnO_4 \xrightarrow{573K} K_2MnO_4 + MnO_2 + O_2$$

(Diamagnetic nature) Potassium manganate with one unpaired electron (Paramagnetic nature)

$KMnO_4$ and K_2MnO_4 both are tetrahedral in shape.

48. Option (1) is correct.

The magnetic moment of a species is given by,

$$\mu = \sqrt{n(n+2)}$$

Here, μ denoted the magnetic moment in BM and n represents the number of unpaired electrons in a species.

When $n = 1$, the magnetic moment is 1.73 BM.

$$\mu = \sqrt{1(1+2)}$$
$$= \sqrt{3}$$
$$= 1.73 BM$$

To find out the number of unpaired electron in each given species, we have to write their electronic configuration.

(1) In CuI, Cu is in +1 oxidation state and the electronic configuration is as shown below.

$Cu^{+1} : [Ar]3d^{10}$

The $3d$ orbital is completely filled and there is no unpaired electron present. Hence, $n = 0$.

The species CuI will not have magnetic moment of 1.73 BM.

(2) In $[Cu(NH_3)_4]Cl_2$, copper is in +2 oxidation state.

$Cu^{+2} : [Ar]3d^9$

There are 9 electrons in $3d$ subshell and hence, $n = 1$ in this case.

Hence, $[Cu(NH_3)_4]Cl_2$ will show magnetic moment of 1.73 BM.

(3) The electronic configuration of O_2^+ is shown below.

$$O_2^+ \rightarrow \sigma_{1s}^2 < \sigma_{1s}^{*2} < \sigma_{2s}^2 < \sigma_{2s}^{*2} < \sigma_{2pz}^2 < \pi_{2px}^2$$

$$= \pi_{2py}^2 < \pi_{2px}^{*1}$$

$$= \pi_{2py}^{*}$$

Here, $n = 1$

Therefore, O_2^+ will show magnetic moment of 1.73 BM.

(4) The electronic configuration of O_2^- is shown below.

$$\sigma_{1s}^2 < \sigma_{1s}^{*2} < \sigma_{2s}^2 < \sigma_{2s}^{*2} < \sigma_{2px}^2 < \pi_{2px}^2$$

$$= \pi_{2py}^2 < \pi_{2px}^{*1}$$

$$= \pi_{2py}^{*}$$

There are 11 electrons and hence, O_2^- will contain a single unpaired electron making $n = 1$.

Therefore, O_2^- will show magnetic moment of 1.73 BM.

49. Option (2) is correct.

To calculate the spin only magnetic moment, the formula used is:

$$\mu = \sqrt{n(n+2)} \qquad ...(1)$$

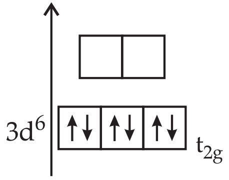
Here, μ denoted the spin only magnetic moment and n represents the number of unpaired electrons in the central metal atom.

As Fe^{2+} forming octahedral complex in presence of strong field ligand, the pairing of electrons will occur.

The electronic configuration of Fe^{2+} is,

$Fe^{+2}[Ar]3d^6$

The splitting of orbitals will be,



From the above diagram, it is clear that there is no unpaired electron in Fe^{2+} in presence of strong field ligand.

$\therefore \qquad n = 0$

Substituting respective values in equation 1, we get,

$$\mu = \sqrt{0(0+2)} = 0$$

Hence, spin only magnetic moment of an octahedral complex of Fe^{2+} in the presence of a strong field ligand in B.M. is 0.

50. Option (2) is correct.

Hint : The coloured ions will have partially filled or completely half-filled d orbital. The paramagnetic ions will have unpaired electrons. The colour of ions is due to d-d transition so we have to check whether the given ions have electrons in their d-orbitals. The paramagnetic nature of an ion is due to presence of unpaired electrons.

We will check the electronic configuration of set of ions given in each option to check which ions are both coloured and paramagnetic.

(1) The electronic configuration of each ion is shown below :

Sc^{3+} : [Ar]
V^{5+} : [Ar]
Ti^{4+} : [Ar]

All three ions are not coloured due to absence of electrons in d-orbitals. All three ions have paired electrons and thus, diamagnetic in nature.

(2) The electronic configuration of each ion is shown below :

Cu^{2+} : $[Ar]3d^9\,4s^0$
Cr^{3+} : $[Ar]3d^3\,4s^0$
Sc^+ : $[Ar]3d^1\,4s^1$

All three ions are coloured due to presence of electrons in d-orbitals. All three ions have unpaired electrons and thus, are paramagnetic in nature.

(3) The electronic configuration of each ion is shown below :

Ni^{2+}: $[Ar]\,3d^8$
Mn^{7+} : [Ar]
Hg^{2+} : $[Xe]\,4f^{14}\,5d^{10}$

The Ni^{2+} ion will be coloured as well as paramagnetic in nature. The Mn^{+7} ion will not be coloured and is diamagnetic in nature. The Hg^{2+} will be coloured but diamagnetic in nature due to absence of unpaired electrons.

(4) The electronic configuration of each ion is shown below :

Cu^+ : $[Ar]\,3d^{10}$
Zn^{2+} : $[Ar]\,3d^{10}$
Mn^{4+} : $[Ar]\,3d^3$

Both Cu^+ and $Zn^{2+}$are colourless and are diamagnetic in nature. The Mn^{4+} is coloured as well as paramagnetic in nature.

Hence, the set having ions which are coloured and paramagnetic both is Cu^{2+}, Cr^{3+}, Sc^+.

51. Option (3) is correct.

Metal oxide	Oxidation State of metal
(a) CrO_3	+6
(b) Fe_2O_3	+3
(c) MnO_2	+4
(d) V_2O_5	+ 5
(e) Cu_2O	+1

The oxidation state of O atom = – 2

On the basis of oxidation state, the correct order is $a > d > c > b > e$

52. Option (1) is correct.

Element	Ion e⁻	Configuration	No. of unpaired e⁻	$\mu = \sqrt{n(n+2)}$
Sc	Sc^{3+}	$[Ar]3d^0$	0	0 = B.M.
V	V^{2+}	$[Ar]3d^3$	3	$\sqrt{15}$ = 3.87 M.
Ti	Ti^{3+}	$[Ar]3d^1$	1	$\sqrt{3}$ = 1.73 B.M

53. Option (3) is correct.

Element of group 7, 8, 9, do not form hydrides and Cr belong to group 6, hence it form interstitial hydrides easily.

54. Option (4) is correct.

Process	Oxidation state change
(1) $C_2O_4^{2-} \longrightarrow 2CO_2$	2
(2) $CrO_4^{2-} \longrightarrow Cr^{3+}$	3
(3) $Cr_2O_7^{2-} \longrightarrow 2Cr^{3+}$	6
(4) $MnO_4^{-} \longrightarrow Mn^{2+}$	5

55. Option (2) is correct.

$CuCl_2 + nH_2O \longrightarrow Cu^{2+}(aq)$ blue in colour

Rest of the chloride do not get dissolved in water to give coloured solution.

56. Option (2) is correct.

Generally metals form two types of oxides *i.e.*, basic oxide and amphoteric. Here, V_2O_3 and CrO both are basic in nature.

57. Option (1) is correct.

$KMnO_4$ molecule on dissociation produces K_2MnO_4 and MnO_2.

In K_2MnO_4, the oxidation state of Mn is +6 and it contains one unpaired e^- due to which it is green in colour.

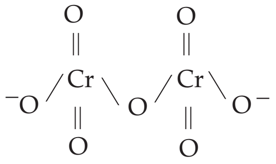
$$2KMnO_4 \xrightarrow[200°C]{\Delta} \underset{\text{Green colour and paramagnetic}}{K_2MnO_4} + MnO_2 + O_2$$

58. Option (2) is correct.

The addition of NaOH in a solution containing Cr^{3+} forms a precipitate of $Cr_2O_3(H_2O)_{12}$.

59. Option (4) is correct.

$Cr_2O_7^{2-}$ is a symmetrical structure and in this Cr atom is tetrahedrally attached with O-atom.



Non-linear symmetrical structure

60. Option (4) is correct.

The electronic configuration of Y*b* (Z = 70) [X*e*] $4f^{14}\,6s^2$

Electronic configuration of Yb^{2+} = [X*e*]$4f^{14}$

here *f*-orbital is completely filled so it does not contain any unpaired electrons. Hence, it is diamagnetic in nature.

61. Option (3) is correct.

E*u*(Z = 63) [X*e*]$4f^7\,6s^2$

Eu^{2+} [X*e*]$4f^7$

62. Option (3) is correct.

Element	E.C fo metal	E.C of ion (M^{3+})
Co(Z = 27)	[Ar] $3d^7 4s^2$	[Ar] $3d^6$
Mn(Z = 25)	[Ar] $3d^5\,4s^2$	[Ar]$3d^4$
Fe (Z = 26)	[Ar] $3d^6\,4s^2$	[Ar]$3d^5$
Ru(Z = 44)	[Kr] $4d^6\,5s^2$	[Kr]$4d^5$

63. Option (3) is correct.

Electronic configuration of $_{64}Gd$ is [Xe] $4f^7 5d^1\,6s^2$

Gd^{3+} = [Xe]$4f^7$

Therefore no. of unpaired electrons = 7

$$\therefore \mu = \sqrt{n(n+2)}\ BM = \sqrt{7(7+2)}\ BM = \sqrt{63}\ BM$$

$$= 7.93\ BM$$

64. Option (2) is correct.

The color of lanthanide depends on the number of unpaired electrons in 4*f*-orbitals. The tripositive lanthanide with $4f^n$ configuration shows same color as tripositive lanthanide with $4f^{14-n}$ configuration.

$Gd^{3+} = 4f^7$

$Sm^{3+} = 4f^5$

$La^{3+} = 4f^0$

$Lu^{3+} = 4f^{14}$

The tripositive lanthanide with f^0, f^7 and f^{14} configuration will not show any color because of vacant *f*-orbital, half-filled stability and fully occupied state respectively.

Topic-2

Co-ordination Compounds

JEE (Main) Previous Year Questions

Multiple Choice Questions

1. Given below are two statements, one labeled as Assertion (A) and the other is labeled as Reason (R).

Assertion (A): The spin only magnetic moment value for $[Fe(CN)_6]^{3-}$ is 1.74 BM, Whereas for $[Fe(H_2O)_6]^{3+}$ is 5.92 BM.

Reason (R): In both complexes, Fe is present in +3 oxidation state.

In the light of the above statements, choose the correct answer from the options given below:

(1) (A) is false but (R) is true.
(2) (A) is true but (R) is false.
(3) Both (A) and (R) are true but (R) is not the correct explanation of (A).
(4) Both (A) and (R) are true but (R) is the correct explanation of (A).

[JEE (Main) – 6th April 2023 - Shift-1]

2. The IUPAC name of $K_3[Co(C_2O_4)_3]$ is-

(1) Potassium tris (oxalate) cobaltate (III)
(2) Potassium trioxalatocobalt (III)
(3) Potassium trioxalatocobaltate (III)
(4) Potassium tris (oxalate) cobalt (III)

[JEE (Main) – 6th April 2023 - Shift-2]

3. Given below are two statements: one is labelled as "Assertion A" and the other is labelled as "Reason R".

Assertion (A): In the complex $Ni(CO)_4$ and $Fe(CO)_5$, the metals have zero oxidation state.

Reason (R): Low oxidation states are found when a complex has ligands capable of π–donor character in addition to the σ–bonding.

In the light of the above statement, choose the most appropriate answer from the options given below:

(1) (A) is not correct but (R) is correct.
(2) (A) is correct but (R) is not correct.
(3) Both (A) and (R) are correct and (R) is the correct explanation of (A).
(4) Both (A) and (R) are correct but (R) is NOT the correct explanation of (A).

[JEE (Main) – 6th April 2023 - Shift-2]

4. Which of the following complex is octahedral, diamagnetic and the most stable?

(1) $K_3[Co(CN)_6]$ **(2)** $[Ni(NH_3)_6]Cl_2$
(3) $[Co(H_2O)_6]Cl_2$ **(4)** $Na_3[CoCl_6]$

[JEE (Main) – 8th April 2023 - Shift-1]

5. The correct order of spin only magnetic moments for the following complex ions is

(1) $[CoF_6]^{3-} < [MnBr_4]^{2-} < [Fe(CN)_6]^{3-} < [Mn(CN)_6]^{3-}$
(2) $[Fe(CN)_6]^{3-} < [CoF_6]^{3-} < [MnBr_4]^{2-} < [Mn(CN)_6]^{3-}$
(3) $[MnBr_4]^{2-} < [CoF_6]^{3-} < [Fe(CN)_6]^{2-} < [Mn(CN)_6]^{3-}$
(4) $[Fe(CN)_6]^{3-} < [Mn(CN)_6]^{3} < [CoF_6]^{3-} < [MnBr_4]^{2-}$

[JEE (Main) – 8th April 2023 - Shift-1]

6. $2IO_3^- + xI^- + 12H^+ \rightarrow 6I_2 + 6H_2O$

What is the value of x?

(1) 12 **(2)** 10 **(3)** 2 **(4)** 6

[JEE (Main) – 8th April 2023 - Shift-1]

7. Match list I with list II.

List I Coordination complex	List II Number of unpaired electrons
A. $[Cr(CN)_6]^{3-}$	I. 0
B. $[Fe(H_2O)_6]^{2+}$	II. 3
C. $[Co(NH_3)_6]^{3+}$	III. 2
D. $[Ni(NH_3)_6]^{2+}$	IV. 4

Choose the correct answer from the options given below:

(1) A-II, B-IV, C-I, D-III **(2)** A-IV, B-III, C-II, D-I
(3) A-II, B-I, C-IV, D-III **(4)** A-III, B-IV, C-I, D-II

[JEE (Main) – 8th April 2023 - Shift-2]

8. The octahedral diamagnetic low spin complex among the following is:

(1) $[CoF_6]^{3-}$ **(2)** $[CoCl_6]^{3-}$
(3) $[Co(NH_3)_6]^{3+}$ **(4)** $[NiCl_4]^{2-}$

[JEE (Main) – 10th April 2023 - Shift-1]

9. Match List I with List II.

List I Complex	List II Crystal Field splitting energy (Δ_0)
(A). $[Ti(H_2O)_6]^{2+}$	I. –1.2
(B). $[V(H_2O)_6]^{2+}$	II. –0.6
(C). $[Mn(H_2O)_6]^{3+}$	III. 0
(D). $[Fe(H_2O)_6]^{3+}$	IV. –0.8

Choose the correct answer from the options given below:

(1) A-IV, B-I, C-II, D-III **(2)** A-IV, B-I, C-III, D-II

(3) A-II, B-IV, C-III, D-I **(4)** A-II, B-IV, C-I, D-III

[JEE (Main) – 10th April 2023 - Shift-2]

10. The correct order of the number of unpaired electrons in the given complexes is:

(A) $[Fe(CN)_6]^{3-}$ (B) $[FeF_6]^{3-}$

(C) $[CoF_6]^{3-}$ (D) $[Cr(oxalate)_3]^{3-}$

(E) $[Ni(CO)_4]$

Choose the correct answer from the options given below:

(1) E < A < D < C < B **(2)** A < E < C < B < D

(3) A < E < D < C < B **(4)** E < A < B < D < C

[JEE (Main) – 10th April 2023 - Shift-2]

11. Which of the following complex has a possibility to exist as meridional isomer?

(1) $[Co(en)_2Cl_2]$ **(2)** $[Pt(NH_3)_2Cl_2]$

(3) $[Co(en)_3]$ **(4)** $[Co(NH_3)_3(NO_2)_3]$

[JEE (Main) – 11th April 2023 - Shift-1]

12. The set which does not have ambidentate ligand (s) is:

(1) $C_2O_4^{2-}$, NO_2^-, NCS^-

(2) $EDTA^{4-}$, NCS^-. $C_2O_4^{2-}$

(3) NO_2^-, $C_2O_4^{2-}$, $EDTA^{4-}$

(4) $C_2O_4^{2-}$, ethylene diamine, H_2O

[JEE (Main) – 11th April 2023 - Shift-1]

13. 25 mL of silver nitrate solution (1M) is added dropwise to 25 mL of potassium iodide (1.05 M) solution. The ion(s) present in very small quantity in the solution is/are:

(1) NO_3^- only **(2)** Ag^+ and I^- both

(3) K^+ only **(4)** I^- only

[JEE (Main) – 11th April 2023 - Shift-1]

14. The complex that dissolves in water is:

(1) $[Fe_3(OH)_2(OAc)_6]Cl$

(2) $Fe_4[Fe(CN)_6]_3$

(3) $K_3[Co(NO_2)_6]$

(4) $(NH_4)_3[As(Mo_3O_{10})_4]$

[JEE (Main) – 11th April 2023 - Shift-1]

15. The magnetic moment is measured in Bohr Magneton (BM). Spin only magnetic moment of Fe in $[Fe(H_2O)_6]^{3+}$ and $[Fe(CN)_6]^{3-}$ complexes respectively is:

(1) 3.87 B. M. and 1.732 B.M.

(2) 6.92 B.M. in both

(3) 5.92 B.M. and 1.732 B.M.

(4) 4.89 B.M. and 6.92 B.M.

[JEE (Main) – 11th April 2023 - Shift-2

16. Match List I with List II.

List I Complex	List II Colour
(A) $Mg(NH_4)PO_4$	I. Brown
(B) $K_3[Co(NO_2)_6]$	II. White
(C) $MnO(OH)_2$	III. Yellow
(D) $Fe_4[Fe(CN)_6]_3$	IV. blue

Choose the correct answer from the options given below:

(1) A–II, B–III, C–IV, D–I

(2) A–II, B–IV, C–I, D–III

(3) A–III, B–IV, C–II, D–I

(4) A–II, B–III, C–I, D–IV

[JEE (Main) – 11th April 2023 - Shift-2]

17. If Ni^{2+} is replaced by Pt^{2+} in the complex $[NiCl_2Br_2]^{2-}$, which of the following properties are expected to get changed?

A Geometry

B Geometrical isomerism

C Optical isomerism

D Magnetic properties

(1) A, B and C **(2)** A and D

(3) B and C **(4)** A, B and D

[JEE (Main) – 11th April 2023 - Shift-2]

18. Given below are two statements, one is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A): $[CoCl(NH_3)_5]^{2+}$ absorbs at lower wavelength of light with respect to $[CoCl(NH_3)_5(H_2O)]^{3+}$

Reason (R): It is because the wavelength of the light absorbed depends on the oxidation state of the metal ion.

In the light of the above statements, choose the correct answer from the options given below:

(1) Both (A) and (R) are true but (R) is NOT the correct explanation of (A).

(2) (A) is true but (R) is false.

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

(4) (A) is false but (R) is true.

[JEE (Main) – 11th April 2023 - Shift-2]

19. Match List I with List II.

Lisr I **Complex**	**List II** **CFSE (Δ_0)**
(A) $[Cu(NH_3)_6]^{2+}$	I. –0.6
(B) $[Ti(H_2O)_6]^{3+}$	II. –2.0
(C) $[Fe(CN)_6]^{3-}$	III. –1.2
(D) $[NiF_6]^{4-}$	IV. –0.4

Choose the correct answer from the options given below:

(1) A–III, B–IV, C–I, D–II
(2) A–II, B–III, C–I, D–IV
(3) A–I, B–IV, C–II, D–III
(4) A–I, B–II, C–IV, D–III

[JEE (Main) – 12th April 2023 - Shift-1]

20. The mismatched combinations are

(A) Chlorophyll - Co
(B) Water hardness - EDTA
(C) Photography – $[Ag(CN)_2]^-$
(D) Wilkinson catalyst - $[(Ph_3P)_3 RhCl]$
(E) Chelating ligand - D-Penicillamine

Choose the correct answer from the options given below :

(1) A and C Only **(2)** D and E Only
(3) A and E Only **(4)** A, C, and E Only

[JEE (Main) – 13th April 2023 - Shift-1]

21. The hybridization and magnetic behaviour of cobalt ion in $[Co(NH_3)_6]^{3+}$ complex, respectively is

(1) $d^2 sp^3$ and paramagnetic
(2) $sp^3 d^2$ and diamagnetic
(3) $d^2 sp^3$ and diamagnetic
(4) $sp^3 d^2$ and paramagnetic

[JEE (Main) – 24th Jan 2023 - Shift-2]

22. Which of the following cannot be explained by crystal field theory?

(1) The order of spectrochemical series.
(2) Stability of metal complexes.
(3) Magnetic properties of transition metal complexes.
(4) Colour of metal complexes.

[JEE (Main) – 24th Jan 2023 - Shift-2]

23. Match list I with List II.

List I **Coordination entity**		**List II** **Wavelength of light absorbed in nm**	
A.	$[CoCl(NH_3)_5]^{2+}$	I.	310
B.	$[Co(NH_3)_6]^{3+}$	II.	475
C.	$[Co(CN)_6]^{3-}$	III.	535
D.	$[Cu(H_2O)_4]^{2+}$	IV.	600

Choose the correct answer from the options given below:

(1) A-III, B-I, C-II, D-IV
(2) A-IV, B-I, C-III, D-II
(3) A-III, B-II, C-I, D-IV
(4) A-II, B-III, C-IV, D-I

[JEE (Main) – 25th Jan 2023 - Shift-2]

24. A chloride salt solution acidified with dil. HNO_3 gives a curdy white precipitate, [A], on addition of $AgNO_3$. [A] on treatment with NH_4OH gives a clear solution, B. A and B are respectively

(1) AgCl & $(NH_4)[Ag(OH)_2]$
(2) AgCl & $[Ag(NH_3)_2]Cl$
(3) $H[AgCl_3]$ & $(NH_4)[Ag(OH)_2]$
(4) $H[AgCl_3]$ & $[Ag(NH_3)_2]Cl$

[JEE (Main) – 25th Jan 2023 - Shift-2]

25. Chiral complex from the following is:
Here en = ethylene diamine

(1) cis $^-[PtCl_2(en)_2]^{2+}$
(2) trans – $[PtCl_2(en)_2]^{2+}$
(3) cis – $[PtCl_2(NH_3)_2]$
(4) trans – $[Co(NH_3)_4Cl_2]^+$

[JEE (Main) – 29th Jan 2023 - Shift-1]

26. Correct order of spin only magnetic moment of the following complex ions is:
(Given At.no. Fe: 26, Co:27)

(1) $[FeF_6]^{3-} > [Co(C_2O_4)_3]^{3-} > [CoF_6]^{3-}$
(2) $[FeF_6]^{3-} > [CoF_6]^{3-} > [Co(C_2O_4)_3]^{3-}$
(3) $[Co(C_2O_4)_3]^{3-} > [CoF_6]^{3-} > [FeF_6]^{3-}$
(4) $[CoF_6]^{3-} > [FeF_6]^{3-} > [Co(C_2O_4)_3]^{3-}$

[JEE (Main) – 29th Jan 2023 - Shift-2]

27. To inhibit the growth of tumours, identify the compounds used from the following:

A. EDTA
B. Coordination Compounds of Pt
C. D – Penicillamine
D. Cis – Platin

Choose the correct answer from the option given below:

(1) B and D Only **(2)** C and D Only
(3) A and C Only **(4)** A and B Only

[JEE (Main) – 30th Jan 2023 - Shift-1]

28. Which of the following is correct order of ligand field strength ?

(1) $CO<en<NH_3<C_2O_4^{2-}<S^{2-}$
(2) $NH_3<en<CO<S^{2-}<C_2O_4^{2-}$

(3) $S^{2-} < C_2O_4^{2-} < NH_3 < en < CO$

(4) $S^{2-} < NH_3 < en < CO < C_2O_4^{2}$

[JEE (Main) – 30th Jan 2023 - Shift-1]

29. The Cl−Co−Cl bond angle values in a fac – $[Co(NH_3)_3Cl_3]$ complex is/are:

(1) 90° **(2)** 90° &120°
(3) 180° **(4)** 90° &180°

[JEE (Main) – 30th Jan 2023 - Shift-2]

30. Match List I with List II:

List I (Complexes)	List II (Hybridisation)
A. $[Ni(CO)_4]$	I. sp^3
B. $[Cu(NH_3)_4]^{2+}$	II. dsp^2
C. $[Fe(NH_3)_6]^{2+}$	III. sp^3d^2
D. $[Fe(H_2O)_6]^{2+}$	IV. d^2sp^3

(1) A–I, B–II, C–IV, D–III
(2) A–II, B–I, C–III, D–IV
(3) A–II, B–I, C–IV, D–III
(4) A–I, B–II, C–III, D–IV

[JEE (Main) – 30th Jan 2023 - Shift-2]

31. Cobalt chloride when dissolved in water forms pink colored complex <u>X</u> which has octahedral geometry. This solution on treating with conc. HCl forms deep blue complex, <u>Y</u> which has a <u>Z</u> geometry. X, Y and Z, respectively, are

(1) X= $[Co(H_2O)_6]^{2+}$, Y=$[CoCl_4]^{2-}$,
Z= Tetrahedral
(2) X= $[Co(H_2O)_6]^{2+}$, Y=$[CoCl_6]^{3-}$,
Z= Octahedral
(3) X= $[Co(H_2O)_4Cl_2]^{+}$, Y=$[CoCl_4]^{2-}$,
Z= Tetrahedral
(4) X= $[Co(H_2O)_6]^{3+}$, Y=$[CoCl_6]^{3-}$,
Z= Octahedral

[JEE (Main) – 31th Jan 2023 - Shift-1]

32. Which of the following will have maximum stabilization due to crystal field?

(1) $[Ti(H_2O)_6]^{3+}$ **(2)** $[Co(H_2O)_6]^{2+}$
(3) $[Co(CN)_6]^{3-}$ **(4)** $[Cu(NH_3)_4]^{2+}$

[JEE (Main) – 27th June 2022 - Shift-1]

33. Arrange the following coordination compounds in the increasing order of magnetic moments. (Atomic number: Mn = 25; Fe = 26)

(1) $[FeF_6]^{3-}$ **(2)** $[Fe(CN)_6]^{3-}$
(3) $[MnCl_6]^{3-}$ **(4)** $[Mn(CN)_6]^{3-}$

Choose the correct answer from the options given below:

(1) 1 < 2 < 4 < 3 **(2)** 2 < 4 < 3 < 1
(3) 1 < 3 < 4 < 2 **(4)** 2 < 4 < 1 < 3

[JEE (Main) – 27th June 2022 - Shift-2]

34. Given below are two statements :

Statement I: $[Ni(CN)_4]^{2-}$ is square planar and diamagnetic complex, with dsp^2 hybridization for Ni but $[Ni(CO)_4]$ is tetrahedral, parama-gnetic and with sp^3 hybridisation for Ni.

Statement II : $[NiCl_4]^{2-}$ and $[Ni(CO)_4]$ both have same *d*-electron configuration, have same geometry and are paramagnetic.

In light the above statements, choose the **correct** answer form the options given below:

(1) Both statement I and statement II are true.
(2) Both statement I and statement II are false.
(3) Statement I is correct but statement II is false.
(4) Statement I is incorrect but statement II is true.

[JEE (Main) – 28th June 2022 - Shift-1]

35. The correct order of energy of absorption for the following metal complexes is:

1. $[Ni(en)_3]^{2+}$, 2. $[Ni(NH_3)_6]^{2+}$,
3. $[Ni(H_2O)_6]^{2+}$

(1) 3 < 2 < 1 **(2)** 2 < 3 < 1
(3) 3 < 1 < 2 **(4)** 1 < 3 < 2

[JEE (Main) – 25th July 2022 - Shift-2]

36. The metal complex that is diamagnetic is: (Atomic number: Fe, 26; Cu, 29)

(1) $K_3[Cu(CN)_4]$ **(2)** $K_2[Cu(CN)_4]$
(3) $K_3[Fe(CN)_4]$ **(4)** $K_4[FeCl_6]$

[JEE (Main) – 26th July 2022 - Shift-2]

37. The total number of Mn = O bonds in Mn_2O_7 is _______ .

(1) 4 **(2)** 5 **(3)** 6 **(4)** 3

[JEE (Main) – 27th July 2022 - Shift-1]

38. Low oxidation state of metals in their complexes are common when ligands:

(1) have good π-accepting character.
(2) have good σ -donor character.
(3) are having good π -donating ability.
(4) are having poor σ - donating ability.

[JEE (Main) – 27th July 2022 - Shift-2]

39. Match List I with List II:

List I (Complex)	List II (Hydridization)
1. $Ni(CO)_4$	I. sp^3
2. $[Ni(CN)_4]^{2-}$	II. sp^3d^2
3. $[Co(CN)_6]^{3-}$	III. d^2sp^3
4. $[CoF_6]^{3-}$	IV. dsp^2

Choose the correct answer from the options given below:

(1) 1–IV, 2–I, 3–III, 4–II **(2)** 1–I, 3–IV, 3–III, 4–II
(3) 1–I, 3–IV, 3–II, 4–III **(4)** 1–IV, 3–I, 3–II, 4–III

[JEE (Main) – 28th July 2022 - Shift-2]

40. Octahedral complexes of copper (II) undergo structural distortion (John-Teller).

Which one of the given copper (II) complexes will show the maximum structural distortion?

(en-ethylenediamine; $H_2N-CH_2-CH_2-NH_2$)

(1) $[Cu(H_2O)_6]SO_4$ **(2)** $[Cu(en)(H_2O)_4]SO_4$

(3) cis$-[Cu(en)_2Cl_2]$ **(4)** trans$-[Cu(en)_2Cl_2]$

[JEE (Main) – 29th July 2022 - Shift-2]

41. Which of the following are isostructural pairs?

(1) SO_4^{2-} and CrO_4^{2-} **(2)** $SiCl_4$ and $TiCl_4$

(3) NH_3 and NO_3^- **(4)** BCl_3 and $BrCl_3$

(1) 1 and 3 only **(2)** 1 and 2 only

(3) 2 and 3 only **(4)** 3 and 4 only

[JEE (Main) – 24th Feb 2021 - Shift-1]

42. The incorrect statement among the following is :

(1) $VOSO_4$ is a reducing agent.

(2) Red colour of ruby is due to the presence of CO^{3+}.

(3) Cr_2O_3 is an amphoteric oxide.

(4) RuO_4 is an oxidizing agent.

[JEE (Main) – 24th Feb 2021 - Shift-2]

43. The hybridization and magnetic nature of $[Mn(CN)_6]^{4-}$ and $[Fe(CN)_6]^{3-}$, respectively are:

(1) d^2sp^3 and paramagnetic

(2) sp^3d^2 and paramagnetic

(3) d^2sp^3 and diamagnetic

(4) sp^3d^2 and diamagnetic

[JEE (Main) – 25th Feb 2021 - Shift-1]

44. If which of the following order the given complex ions are arranged correctly with respect to their decreasing spin only magnetic moment?

(i) $[FeF_6]^{3-}$ (ii) $[Co(NH_3)_6]^{3+}$

(iii) $[NiCl_4]^{2-}$ (iv) $[Cu(NH_3)_4]^{2+}$

(1) (ii) > (i) > (iii) > (iv)

(2) (iii) > (iv) > (ii) > (i)

(3) (ii) > (iii) > (i) > (iv)

(4) (i) > (iii) > (iv) > (ii)

[JEE (Main) – 25th Feb. 2021 - Shift-2]

45. Given below the two statements :

Statement I : The identification of Ni^{2+} is carried out by dimethyl glyoxime in the presence of NH_4OH.

Statement II : The dimethyl glyoxime is a bidentate neutral ligand.

In the light of the above statements, choose the correct answer from the options given below :

(1) Both statement I and statement II are true.

(2) Both statement I and statement II are false.

(3) Statement I is false but statement II is true.

(4) Statement I is true but statement II is false.

[JEE (Main) – 25th Feb 2021 - Shift-2]

46. The correct pair(*s*) of the ambident nucleophiles is (are) :

(a) AgCN/KCN

(b) RCOOAg/RCOOK

(c) $AgNO_2/KNO_2$

(d) AgI/KI

(1) (a) and **(c)** only **(2)** (b) only

(3) (b) and **(c)** only **(4)** (a) only

[JEE (Main) – 17th March 2021 - Shift-2]

47. Match List – I with List – II :

List – I	List – II
(a) $[Co(NH_3)_6]$ $[Cr(CN)_6]$	(i) Linkage isomerism
(b) $[Co(NH_3)_3(NO_2)_3]$	(ii) Solvate isomerism
(c) $[Cr(H_2O)_6]Cl_3$	(iii) Co – ordination isomerism
(d) cis – $[CrCl(ox)_2]^{3-}$	(iv) Optical isomerism

Choose the correct answer from the options given below:

(1) (a) – (iii), (b) – (i), (c) – (ii), (d) – (iv)

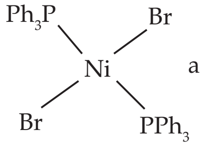
(2) (a) – (i), (b) – (ii), (c) – (iii), (d) – (iv)

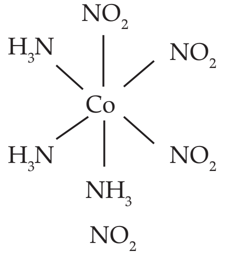
(3) (a) – (ii), (b) – (i), (c) – (iii), (d) – (iv)

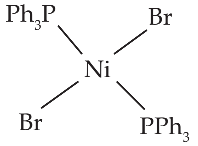
(4) (a) – (iv), (b) – (ii), (c) – (iii), (d) – (i)

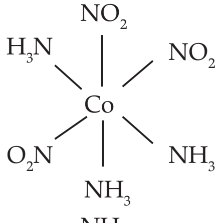
[JEE (Main) – 17th March 2021 - Shift-2]

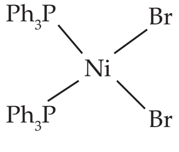
48. The correct structures of trans – $[NiBr_2 (PPh_3)_2]$ and meridonial – $[Co(NH_3)_3 (NO_2)_3]$ respectively are :

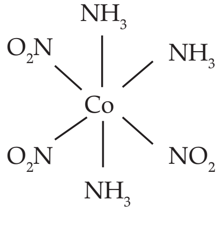
(1) 

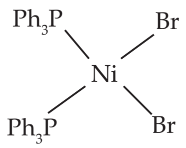
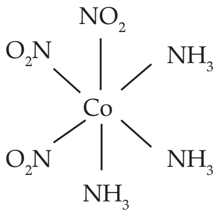
and 

(2) 

and 

(3) 

and 

(4)  and 

[JEE (Main) – 18th March 2021 - Shift-1]

49. The secondary valency and the number of hydrogen bonded water molecule(s) in $CuSO_4.5H_2O$, respectively, are :

(1) 6 and 4 **(2)** 4 and 1 **(3)** 5 and 1 **(4)** 6 and 5

[JEE (Main) – 18th March 2021 - Shift-2]

50. According to the valence bond theory, the hybridization of central metal atom is dsp^2 for which one of the following compounds ?

(1) $Na_2[NiCl_4]$ **(2)** $NiCl_2.6H_2O$
(3) $K_2[Ni(CN)_4]$ **(4)** $[Ni(CO)_4]$

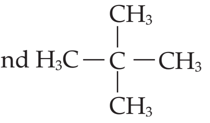
[JEE (Main) – 20th July 2021 - Shift-1]

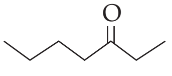
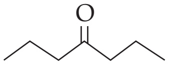
51. The correct order of intensity of colors of the compounds is :

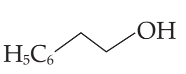
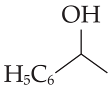
(1) $[Ni(CN)_4]^{2-} > [NiCl_4]^{2-} > [Ni(H_2O)_6]^{2+}$
(2) $[NiCl_4]^{2-} > [Ni(CN)_4]^{2-} > [Ni(H_2O)_6]^{2+}$
(3) $[NiCl_4]^{2-} > [Ni(H_2O)_6]^{2+} > [Ni(CN)_4]^{2-}$
(4) $[Ni(H_2O)_6]^{2+} > [NiCl_4]^{2-} > [Ni(CN)_4]^{2-}$

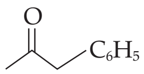
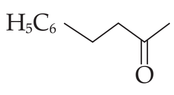
[JEE (Main) – 20th July 2021 - Shift-1]

52. Which one of the following pairs of isomers is an example of metamerism ?

(1) $CH_3CH_2CH_2CH_2CH_3$ and 
$H_3C-\underset{CH_3}{\overset{CH_3}{C}}-CH_3$

(2)  and 

(3)  and 

(4)  and 

[JEE (Main) – 20th July 2021 - Shift-2]

53. Which one of the following species responds to an external magnetic field?

(1) $[Fe(H_2O)_6]^{3+}$ **(2)** $[Ni(CO)_4]$
(3) $[Co(CN)_6]^{3-}$ **(4)** $[Ni(CN)_4]^{2-}$

[JEE (Main) – 25th July 2021 - Shift-1]

54. Which one of the following metal complexes is most stable?

(1) $[Co(en)(NH_3)_4]Cl_2$ **(2)** $Co(en)_3]Cl_2$
(3) $[Co(NH_3)_6]Cl_2$ **(4)** $[Co(en)_2(NH_3)_2]Cl_2$

[JEE (Main) – 25th July 2021 - Shift-2]

55. The number of geometrical isomers found in the metal complexes$[PtCl_2(NH_3)_2]$, $[Ni(CO)_4]$, $[Ru(H_2O)_3Cl_3]$ and $[CoCl_2(NH_3)_4]^+$ respectively, are :

(1) 1, 1, 1, 1 **(2)** 2, 1, 2, 2 **(3)** 2, 1, 2, 1 **(4)** 2, 0, 2, 2

[JEE (Main) – 27th July 2021 - Shift-1]

56. The type of hybridisation and magnetic property of the complex $[MnCl_6]^{3-}$, respectively, are :
(1) d^2sp^3 and paramagnetic
(2) d^2sp^3 and diamagnetic
(3) sp^3d^2 and paramagnetic
(4) sp^3d^2 and diamagnetic

[JEE (Main) – 27th July 2021 - Shift-1]

57. Given below are two statements:
Statement I: $[Mn(CN)_6]^{3-}$, $[Fe(CN)_6]^{3-}$ and $[Co(C_2O_4)_3]^{3-}$ are d^2sp^3 hybridised.
Statement II: $[MnCl_6]^{3-}$ and $[FeF_6]^{3-}$ are para magnetic and have 4 and 5 unpaired electrons, respectively.
In the light of the above statements, choose the correct answer from the options given below :
(1) Both statement I and statement II are false.
(2) Statement I is incorrect but statement II is true.
(3) Statement I is correct but statement II is false.
(4) Both statement I and statement II are true.

[JEE (Main) – 27th July 2021 - Shift-2]

58. Arrange the following Cobalt complexes in the order of increasing Crystal Field Stabilization Energy (CFSE) value.

Complexes :

$$\underset{A}{\left[CoF_6\right]^{3-}},\underset{B}{\left[Co\left(H_2O\right)_6\right]^{2+}},\underset{C}{\left[Co\left(NH_3\right)_6\right]^{3+}}$$

and $\underset{D}{[Co(en)_3]^{3+}}$.

Choose the correct option.
(1) A<B<C<D **(2)** B<C<D<A
(3) B<A<C<D **(4)** C<D<B<A

[JEE (Main) – 26th Aug 2021 - Shift-2]

59. The denticity of an organic ligand, biuret is :
(1) 6 **(2)** 3 **(3)** 2 **(4)** 4

[JEE (Main) – 31st Aug 2021 - Shift-1]

60. The Crystal Field Stabilization Energy (CFSE) and magnetic moment (spin – only) of an octahedral aqua complex of a metal ion (M^{z+}) are $-0.8\ \Delta_0$ and 3.87 BM, respectively. Identify (M^{z+}):

(1) Mn^{4+} **(2)** Co^{2+} **(3)** Cr^{3+} **(4)** V^{3+}

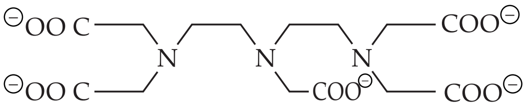
[JEE (Main) – 1st Sep 2021 - Shift-2]

61. Which of the following can't show isomerism?

(1) $[Ni(NH_3)_4(H_2O)_2]^{2+}$ **(2)** $[Ni(en)_3]^{2+}$
(3) $[Pt(NH_3)_2Cl_2]$ **(4)** $[NiCl_2(NH_3)_2]$

[JEE (Main) – 2nd Sept 2020 - Shift-2]

62. The maximum possible denticities of a ligand given below towards a common transition and inner transition metal ion respectively are:



(1) 8 and 8 **(2)** 8 and 6 **(3)** 6 and 6 **(4)** 6 and 8

[JEE (Main) – 9th April 2019 - Shift-2]

63. The correct statement among I to III are:

I. Valence bond theory can not explain the colour exhibited by transition metal complexes.

II. Valence bond theory can predict qualitatively the magnetic properties of transition metal complexes.

III. Valence bond theory cannot distinguish ligands as weak and strong field ones.

(1) II and III only **(2)** I, II and III
(3) I and II only **(4)** I and III only.

[JEE (Main) – 9th April 2019 - Shift-2]

ANSWER – KEY

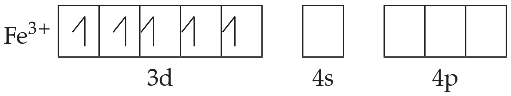
1. (3)	**2.** (2)	**3.** (4)	**4.** (1)
5. (4)	**6.** (2)	**7.** (1)	**8.** (3)
9. (1)	**10.** (1)	**11.** (4)	**12.** (4)
13. (2)	**14.** (1)	**15.** (3)	**16.** (4)
17. (4)	**18.** (2)	**19.** (3)	**20.** (1)
21. (3)	**22.** (1)	**23.** (3)	**24.** (2)
25. (1)	**26.** (2)	**27.** (1)	**28.** (1)
29. (1)	**30.** (1)	**31.** (1)	**32.** (3)
33. (2)	**34.** (2)	**35.** (1)	**36.** (1)
37. (3)	**38.** (1)	**39.** (2)	**40.** (1)
41. (2)	**42.** (2)	**43.** (1)	**44.** (4)
45. (4)	**46.** (1)	**47.** (1)	**48.** (2)
49. (2)	**50.** (3)	**51.** (3)	**52.** (2)
53. (1)	**54.** (2)	**55.** (4)	**56.** (3)
57. (4)	**58.** (3)	**59.** (3)	**60.** (2)
61. (1)	**62.** (4)	**63.** (4)	

ANSWERS WITH EXPLANATIONS

1. Option (3) is correct.

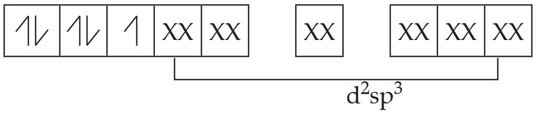
The oxidation state of Fe on both the complexes would be +3

In $[Fe(CN)_6]^{3-}$ The electronic configuration of Fe is $3d^6 4s^2$



CN^- is a strong ligands will pair up the electrons

$[Fe(CN)_6]^{3-}$



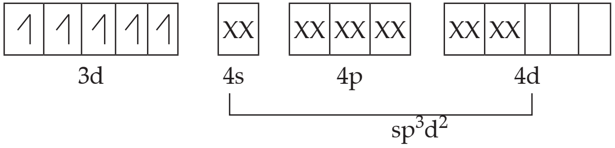
No. of unpaired electrons =1

$\sqrt{n\ n+2)}\quad \sqrt{\qquad +2)}\quad \sqrt{3}\quad 1.74$

In $[Fe(H_2O)_6]^{3+}$

As H_2O is a weak ligand it will not pair up e^-s.

$[Fe(H_2O)]^{3+}$



No. of unpaired electron = 5

$\sqrt{\qquad +2)}\quad \sqrt{35}\quad 5.92$ BM

2. Option (2) is correct.

In complexes $Ni(CO)_4$ and $Fe(CO)_5$, the metals have zero oxidation state as CO is a neutral ligand. Low oxidation states of metals are stabilized by synergic effect.

3. Option (4) is correct.

Low oxidation state of metals can stabilized by synergic bonding so ligand has to be π-acceptor in addition to the σ–bonding.

4. Option (1) is correct.

$\left[Co(CN)_6\right]^{3-}$ and $\left[Co(H_2O)_6\right]^{3+}$ are diamagnetic but first one is more stable as Δ_0 is high for first complex.

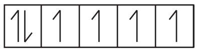
$K_3[Co(CN)_6]$

$+3 + x - 6 = 0$

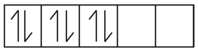
$\boxed{x = +3}$

⇓

$Co^{+3} \rightarrow 3d^6$



∴ CN^- is SFL so pairing occur so



$U_e = 0$

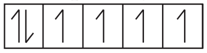
↓

So diamagnetic in nature

5. Option (4) is correct.

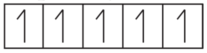
Br^- is a weak ligand while CN^- is a strong ligand. More the number of unpaired electrons, more the value of magnetic moment.

$[CoF_6]^{3-}$
↓
Co^{+3}
F^- is WFL
So no pairing



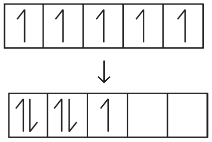
$U_e = 4$

$[MnBr_4]^{2-}$
↓
Mn^{+2}
Br^- is WFL
no pairing



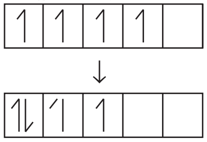
$U_e = 5$

$[Fe(CN)_6]^{3-}$
↓
Fe^{3+}
CN^- is SFL
pairing occur



$U_e = 1$

$[Mn(CN)_6]^{3-}$
↓
Mn^{+3}
CN^- is SFL
no pairing



$U_e = 2$

$[Fe(CN)_6]^{3-} < [Mn(CN)_6]^{3-} < [CoF_6]^{3-} < [MnBr_4]^{2-}$

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

Given reaction, $I_2 \rightarrow IO_3^- + I^-$

Disproportionation reaction is the reaction in which an element under go both oxidation and reduction.

$$\overset{(0)}{I_2} \rightarrow \overset{(+5)}{IO_3^-} + \overset{(-1)}{I}$$

I has oxidised from O to +5 and reduced from 0 to –1.

n factor of IO_3^- and I^- in the given redox reaction are 5 and 1 respectively. Therefore, will always react in the molar ratio 1 : 5 to get I_2 .

$$IO_3^- + 6H^+ + 5I^- \rightarrow 3I_2 + 3H_2O$$

To get 6 molar I_2, multiple equation by 2

$$2IO_3^- + 12H^+ + 10I^- \rightarrow 6I_2 + 6H_2O$$

So, $x = 10$

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

For option A:

The six cyanide ligands are arranged around the chromium ion in an octahedral geometry

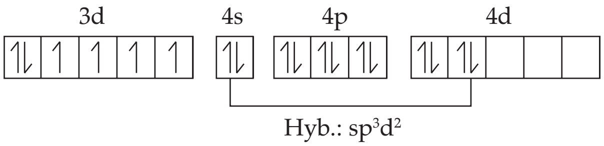
$Cr^{+3} : 3d^3$

$CN^- \rightarrow$ SFL $\Rightarrow$ No. of unpaired electrons = 3

For option B:

$Fe[(H_2O)_6]^{2+}$ is a high spin complex and contains 4 unpaired electrons. And H_2O being a weak field ligand do not pair up electrons and due to the presence of unpaired electrons, it is paramagnetic in nature. Its magnetic moment is 5.4 B.M. It has pale green color.

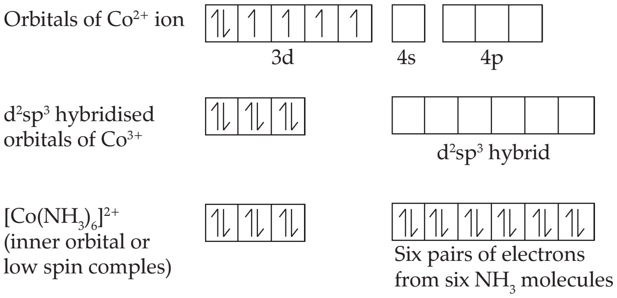
Fe^{2+} in $[Fe(H_2O)_6]^{2+}$



For option C:

In $[Co(NH_3)_6]^{3+}$ the oxidation state of cobalt is +3.Ammonia is a strong field ligand so it pair up 4 unpaired electron and free up 2 3*d* orbitals. These 3*d* orbitals are involved in hybridisation with one 4*s* and three 4*p* orbitals forming an inner orbital complex, so hybridisation of $[Co(NH_3)_6]^{3+}$ is d^2sp^3

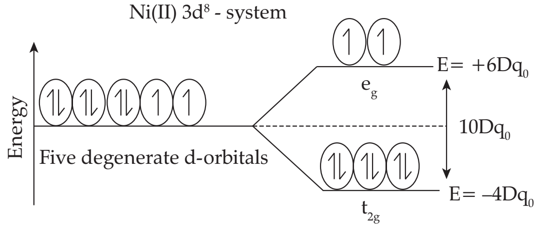
Since it has no unpaired electrons, $[Co(NH_3)_6]^{3+}$ is diamagnetic.



For option D

In case of $[Ni (NH_3)_6]^{2+}$ ion, ligand NH3 act as a weak field ligand as crystal field stabilization energy is less than pairing energy. That is, 10Δq < P.

Therefore, under the influence of octahedral crystal field, the electronic configuration is t_{2g}^6 e_g^2.



From the above electronic configuration, it has been found that the complex has two unpaired electrons. Hence the complex $[Ni (NH_3)_6]^{2+}$ is paramagnetic.

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

(1) Paramagnetic, High Spin & Tetrahedral
(2) Paramagnetic, High Spin & Octahedral
(3) Diamagnetic, Low Spin & Octahedral
(4) Paramagnetic, High Spin & Octahedral

In $[Co(NH_3)_6]^{3+}$ the oxidation state of cobalt is +3. Ammonia is a strong field ligand so it pair up 4 unpaired electron and free up 2 3*d* orbitals.

These 3*d* orbitals are involved in hybridisation with one 4*s* and three 4*p* orbitals forming an inner orbital complex, so hybridisation of $[Co(NH_3)_6]^{3+}$ is d^2sp^3

Since it has no unpaired electrons, $[Co(NH_3)_6]^{3+}$ is diamagnetic.

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

$[Ti(H_2O)_6]^{2+}$

The electronic configuration of $Ti^{2+} = 3d^2 4s^0$

$CFSE = [-0.4 \times t_{2g}e^-s + 0.6 \times e_g e^-s]\Delta_0$

$= [-0.4 \times 2 + 0.6 \times 0]\Delta_0$

$= -0.8\Delta_0$

For $[v(H_2O)_6]^{2+}$

The electronic configuration of $V^{2+} = 3d^3 4s^0$

$CFSE = [-0.4 \times 3 + 0.6 \times 0]\Delta_0$

$= -1.2\Delta_0$

For $[Mn(H_2O)_6]^{3+}$

The electronic configuration of $Mn^{3+} = 4d^4 4s^0$

$CFSE = [-0.4 \times 3 + 0.6 \times 1]\Delta_0$

$= -0.6\Delta_0$

For $[Fe(H_2O)_6]^{3+}$

The electronic configuration of $Fe^{3+} = 3d^5 4s^0$

$CFSE = [-0.4 \times 3 + 0.6 \times 2]\Delta_0 = 0$

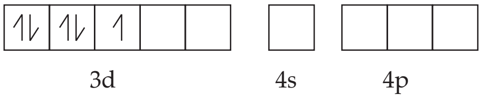
10. **Option (1) is correct.**

(A) $[Fe(CN)_6]^{3-}$

The configuration of $Fe^{3+} = 3d^5 4s^0$

Since CN^- is a strong ligand thus it would pair up the d electrons so it will have 1 unpaired electron.

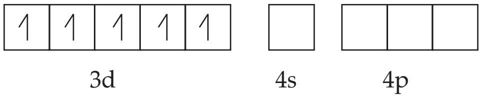
$[Fe(CN)_6]^{3-}$



(B) $[FeF_6]^{3-}$

Since F^- is a weak, so it will not be able to pair up the electron so it will have 5 unpaired electron.

$[FeF_6]^{3-}$



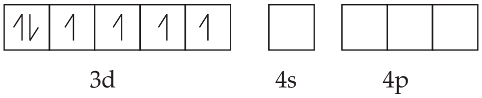
(C) $[COF_6]^{3-}$

The configuration of $CO^{3+} = 3d^6$

F^- is a weak ligand, so it will pair up the electrons.

∴ it will have 4 unpaired electrons

$[COF_6]^{3-}$

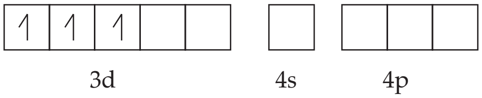


(D) $[Cr(ox)_3]^{3-}$

The configuration of $Cr^{3+} = 3d^3$

ox^- is a strong ligand it will pair up the electrons but in this case it already have vacant orbital . thus it will have 3 unpaired electrons.

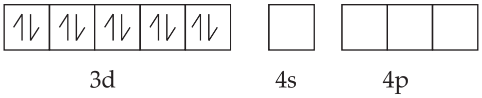
$[Cr(ox)_3]^{3-}$



(E) $[Ni(CO)_4]$

The electronic configuration of Ni is $3d^8 4s^2$ since Co is a strong ligand it will pair up the electrons and will not have any unpaired electrons.

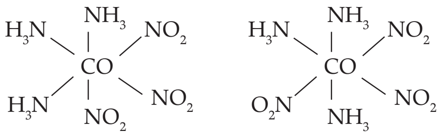
$[Ni(Co)_4]$



Thus the correct order is E < A < D < C < B

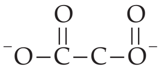
11. **Option (4) is correct.**

The complex which exists as meridional isomer is $[Co(NH_3)_3(NO_2)_3]$. Here both ligand arranged themselves in either facial form or meridional form.



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

$H-O-H$ water is mono dentate ligand.



$^-O-\overset{O}{\overset{\|}{C}}-\overset{O}{\overset{\|}{C}}-O^-$ $C_2O_4^{2-}$ is bidentate ligand.

$H_2N-CH_2-CH_2-NH_2$ ethylene diamine is bidentate ligand.

The set which does not have ambidentate ligand is set (4)

Here $O=N-O^-$ is ambidentate ligand

$N \equiv C-S-$ is ambidentate ligand.

Both of the above ligand are not present in set (4).

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

On addition of silver nitrate drop wise into potassium iodide, formation of silver iodide takes place:

$$AgNO_3(aq) + KI(aq) \rightarrow AgI(s)\downarrow + KNO_3(aq)$$

As the solubility of AgI is very low.

∴ in very small quantity both Ag^+ and I^- ions are present in the solution.

$$AgI \rightleftharpoons Ag^+ + I^-$$

$ksp = 8.3 \times 10^{-17}$

14. Option (1) is correct.

Complex	**Solubility water**
$Fe_4[Fe(CN)_6]$	Insoluble
$K_3[Co(NO_2)_6]$	Insoluble
$(NH_4)3[As(Mo_3O_{10})_4]$	Insoluble
$[Fe_3(OH)_2(OAC)_6]Cl$	Soluble

15. Option (3) is correct.

For $[Fe\ (H_2O)_6]^{3+}$ complex

Central atom is Fe while H_2O is ligand

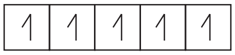
The electronic configuration of

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

(z = 26)

In the given complex, oxidation state of Fe =

Fe^{+3}: $[Ar]3d^5$



Here H_2O is a weak ligand and the value of $\Delta_0 <$ Pairing energy ∴ Pairing of e^- does not take place. So number of unpaired e^- is 5

The value of $\mu = \sqrt{n(n+2)} = \sqrt{5(5+2)}$

$\mu = \sqrt{35} = 5.92$ B.M

For $[Fe\ (CN)_6]^{3-}$ complex

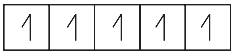
Central atom is Fe while CN– is ligand

The electronic configuration

Fe: $[Ar]3d^64s^2$

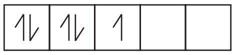
In the given complex, oxidation state of Fe = +3

Fe^{+3}: $[Ar]3d^5$



Here CN– is a strong ligand and the value of $\Delta_0 >$ pairing energy ∴ it pair the unpaired electron.

Fe^{3+}



So, number of unpaired $e^- = 1$

The value of $\mu = \sqrt{n(n+2)} = \sqrt{1(1+2)}$

$\mu = \sqrt{3} = 1.732$ M

So the correct answer is option (3).

16. Option (4) is correct.

List (I)		**List (II)**	
Complex		**Color**	
A.	Mg (NH_4) PO_4	II.	White
B.	$K_3[Co\ (NO_2)_6]$	III.	Yellow
C.	MnO $(OH)_2$	I.	Brown
D.	$Fe_4\ [Fe\ (CN)_6]$	IV.	Blue

17. Option (4) is correct.

If Ni^{2+} is replaced by Pt^{2+} in the complex $[NiCl_2Br_2]^{2-}$, following properties are expected to get changed-

A. Geometry of the complex gets changed when Ni^{2+} is replaced by Pt^{2+}.

$[NiCl_2Br_2]^{2-}$ is tetrahedral in shape while $[PtCl_2Br_2]^{2-}$ is square planar in shape.

Because Pt belongs to 5*d* series while Ni belongs to 3*d* series.

B. Similarly geometrical isomerism is also observed when Ni^{2+} is get replaced by Pt^{2+} because $[NiCl_2Br_2]^{2-}$ is tetrahedral which do not show geometrical isomerism while $[PtCl_2Br_2]^{2-}$ is square planar which show geometrical isomerism.

C. Both $[NiCl_2Br_2]^{2-}$ and $[PtCl_2Br_2]^{2-}$ do not show optical isomerism.

D. Here in $[NiCl_2Br_2]^{2-}$, Nickel is present in Ni^{+2} state and the configuration of Ni^{2+} is $3d^8$ in which 2 unpaired e^- are present.

∴ It is paramagnetic in nature.

While in $[PtCl_2Br_2]^{2-}$, Platinum is present in Pt^{+2} state & the configuration of Pt^{2+} is $3d^8$ in which 2 unpaired e^- are present which get paired up by the ligand and it do not contain any unpaired e^-.

∴ It is diamagnetic in nature.

18. Option (2) is correct.

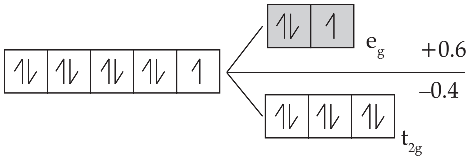
The absorption of the light depends on the strength of the ligand field. The ligand with the strong field strength cause greater splitting of the orbitals which requires a light of high frequency (low wavelength) for the transition.

19. Option (3) is correct.

In $[Cu(NH_3)_6]^{2+}$ complex, oxidation state of copper is +2 i.e, Cu^{2+}

Cu(*z*=29) – $3d^{10}4s^1$

Cu^{2+} — $3d^94s^0$



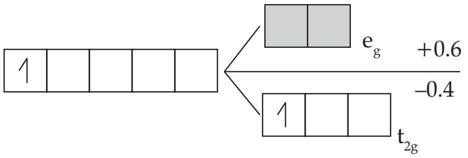
CFSE(Δ_0) = –0.4 × 6 + 3 × +0.6 + ×P

= –2.4 + 1.8 = –0.6

In $[Ti(H_2O)_6]^{3+}$ complex, the oxidation state of metal is +3, i.e, Ti^{3+}

Ti(z = 22) – $3d^24s^2$

Ti^+ – $3d^14s^0$

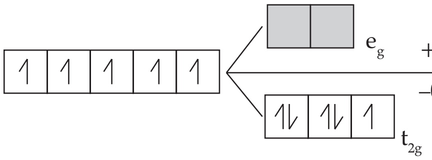


$CFSE(\Delta_0) = -0.4 \times 1 = -0.4$

In $[Fe(CN)_6]^{3-}$ complex, the oxidation state of metal is +3 i.e., Fe^{3+}

$Fe(z=26)$ – $3d^6 4s^2$

Fe^{3+} – $3d^5 4s^0$

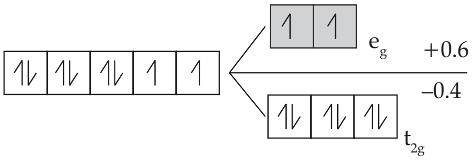


$CFSE(\Delta_0) = -0.4 \times 5 = -2.0$

In $[NiF_6]^{4-}$ the oxidation state of metal is +2 i.e., Ni^{2+}

$Ni(z=28)$ – $3d^8 4s^2$

Ni^{+2} – $3d^8$



$CFSE(\Delta_0) = -0.4 \times 6 + 0.6 \times 2$

$-2.4 + 1.2 = -1.2$

From above the final answer is

A.	$[Cu(NH_3)_6]^{2+}$	I.	–0.6
B.	$[Ti(H_2O)_6]^{3+}$	II.	–0.4
C.	$[Fe(CN)_6]^{3-}$	III.	–2.0
D.	$[NiF_6]^{4-}$	IV.	–1.2

Correct answer is A-1, B-IV, C-II, D-III

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

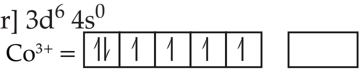
A is incorrect: In chlorophyll Mg-atom is present not cobalt.

C is incorrect: In photography, the developed film is fixed by washing with hypo solution which get dissolved in un decomposed AgBr to form a complex a complex of $[Ag(S_2O_3)_2]^{3-}$ not $[Ag(CN)_2]^-$

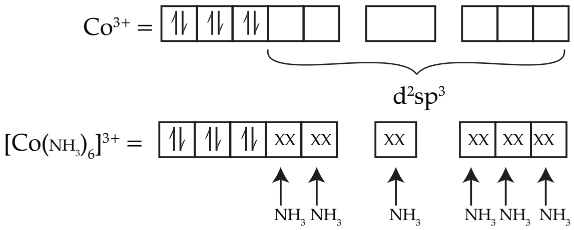
So A and C is incorrect i.e., Option (1)

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

In the complex $[Co(NH_3)_6]^{+3}$ the oxidation state of Co is +3, electronic configuration of Co^{3+} = [Ar] $3d^6 4s^0$



Being a strong ligand NH_3 pair the unpaired e^- and vacant the *d*-orbital for it.



From above it is clear that no unpaired e^- is present in the complex.

Therefore, it is diamagnetic in nature and $\mu = 0$.

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

By the help of experimental value of Δ,

Crystal field theory introduces spectrochemical series but unable to explain its order. Because as per CFT, anionic ligands should exert greatest splitting effect. However they lie lower on lower end of the spectrochemical series.

Similarly crystal field theory explain the stability, colour and magnetic properties of transition metal complexes.

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

Formula : $E(\Delta_0) = \frac{hc}{\lambda}$

From the formula it is clear that, higher the value of Δo, lower will be the λ.

LIST I Coordination entity		**LIST II Wavelength of light absorbed in nm**	
A.	$[CoCl(NH_3)_5]^{2+}$	III.	535
B.	$[Co(NH_3)_6]^{3+}$	II.	475
C.	$[Co(CN)_6]^{3-}$	I.	310
D.	$[Cu(H_2O)_4]^{2+}$	IV.	600

The value of λ depends upon the strength and number of ligand also, if the strength of ligand is high the λ absorbed will be less & vice versa.

strength of ligand $^-CN > NH_3 > H_2O$

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

The metal chloride on reaction with $AgNO_3$ gives a curdy percipitate of AgCl.

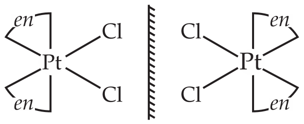
$$MCl + AgNO_3 \xrightarrow[HNO_3]{dil} \underset{\text{(A) (Curdy white ppt)}}{AgCl} + MNO_3$$

The precipitate formed further reacts with NH_4OH to give clear solution.

$$\underset{(A)}{AgCl} + NH_4OH \rightarrow \underset{(B)}{[Ag(NH_3)_2]Cl} + 2H_2O$$

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

Chiral complex are those complex which have non (superimposable) mirror images and form optically active molecule.



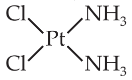
cis – $[Pt\ Cl_2\ (en)_2]^{2+}$ is an optically active molecule

26. Option (2) is correct.

Compound	Electronic Configuration	Number of unpaired electrons	Magnetic moment
$[FeF_6]^{3-}$	$Fe^{3+}: t_{2g}^3, e_g^2$	5	$\mu = \sqrt{35}$B.M
$[CoF_6]^{3-}$	$Co^{3+}: t_{2g}^4, e_g^2$	4	$\mu = \sqrt{24}$B.M
$[Co(C_2O_4)_3]^{3-}$	$Co^{3+}: t_{2g}^6, e_g^0$	0	$\mu = 0$

27. Option (1) is correct.

Cis - Platin is used in chemotherapy to inhibits the growth of tumors.(cis$[Pt(NH_3)_2Cl_2]$)



cis $[Pt(NH_3)_2CL_2]$

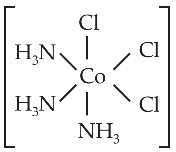
28. Option (3) is correct.

In general, ligands can be arranged in a series in the order of increasing field strength. Such series are known as spectrochemical series which is given below:

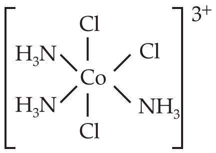
$I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- \; C_2O_4^{2-} < H_2O < NCS^- < edta^{4-} < NH^3 < en < CN^- < CO$

29. Option (1) is correct.

Fac-$[Co(NH_3)_3]$ is an isomer where all NH_3 groups and cl groups occupies adjacent positions.



and



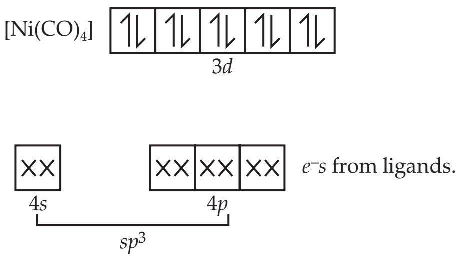
Fac-isomer Mer-isomer

Bond angle = 90° Bond angle = 90° and 180°

30. Option (1) is correct.

(A) $[Ni(Co)_4]$

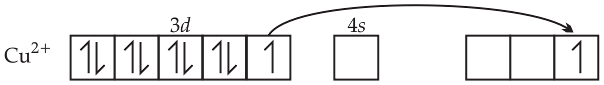
The oxidation state of Ni is 0. The electronic configuration of Ni. is $3d^8 4s^2$. As Co is a Strong rigard it with pairup the electrons.



(B) $[Cu(NH_3)_4]^{2+}$

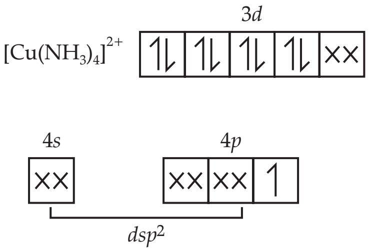
The oxidation state of as is +2. The electronic configuration of Cu^{2+} is $3d^9$.

In this case Cu^{2+}



The electron in $3d_{x^2-y^2}$ orbital is promoted if $4p$ orbital

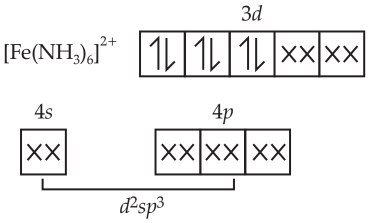
$[Cu(NH_3)_4]$



(C) $[Fe(NH_3)_6]^{2+}$

The oxidation state of Fe is Fe^{2+}. The electronic configuration of Fe^{2+} is $3d^6$ since NH_3 is a strong ligand, it will pair up the electrons.

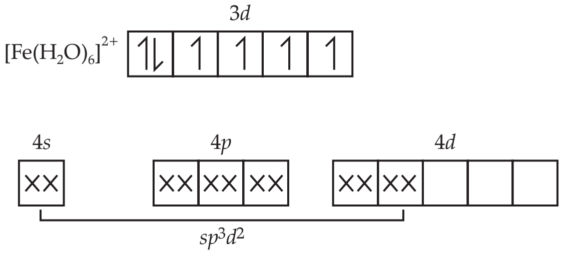
$[Fe(NH_3)_6]^{2+}$



(D) $[Fe(H_2O)_6]^{2+}$

The oxidation state of Fe is 2+. since H_2O is a weak ligand, it will not pair up the electrons.

$[Fe(H_2O)_6]^{2+}$



∴ A-I, B-II, C-IV, D-III

List (Complexes)	List II (Hybridisation)
$[Ni(CO)_4]$	sp^3
$[Cu(NH_3)_4]^{2+}$	dsp^2
$[Fe(NH_3)_6]^{2+}$	d^2sp^3
$[Fe(H_2O)_6]^{2+}$	sp^3d^2

31. Option (1) is correct.

X= $[Co(H_2O)_6]^{2+}$, (Y)= $[CoCl_4]^{2-}$,

(Z)= Tetrahedral

The $[Co(H_2O)_6]^{2+}$ when treated with excess HCl (conc.) turns deep blue in color. This is because the complex absorbs an orange light (low-frequency light). This is due to the lower splitting of d-orbitals of Co^{2+} ions. The tetrahedral complexes have a lower splitting than the octahedral complexes and absorb light of lower frequency. Hence, the geometry of the complex (Y) is tetrahedral.

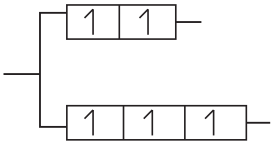
32. Option (3) is correct.

In the ground state, cobalt has 3 unpaired electrons. The crystal field splitting energy of this complex is high because of this. More the unpaired electrons in ground state, more repulsion between electrons of central atom and ligand (like ^-CN), Hence, they have high energy.

33. Option (2) is correct.

2 < 4 < 3 < 1

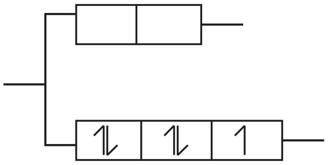
(1) $[FeF_6]^{3-}$



$Fe^{+3} \rightarrow 3d^5\ 4s^0$

$n = 5$

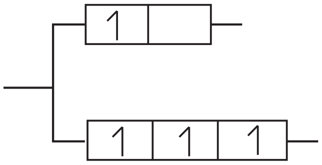
(2) $[Fe(CN)_6]^{3-}$



$Fe^{+3} \rightarrow 3d^5\ 4s^0$

$n = 1$

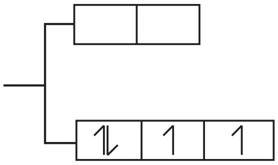
(3) $[MnCl_6]^{3-}$



$Mn^{+3} \rightarrow 3d^4\ 4s^0$

$n = 4$

(2) $[Mn(CN)_6]^{3-}$



$Mn^{+3} \rightarrow 3d^4\ 4s^0$

$n = 2$

34. Option (2) is correct.

$[Ni(CN)_4]^{2-}$: d^8 configuration, CN^- is a strong field ligand and forms a square planar complex with dsp^2 hybridization and do not contain unpaired electrons therefore it is diamagnetic in nature.

$[Ni(CO)_4]$: d^{10} configuration (after excitation), CO is a strong field ligand which forms tetrahedral complex with sp^3 hybridization and it also do not contain any unpaired electron therefore it is also diamagnetic in nature.

$[NiCl_4]^{2-}$: d^8 configuration, Cl^- is a weak field ligand and forms a tetrahedral complex with sp^3 hybridization and it contain unpaired electrons therefore it is paramagnetic in nature.

Both statement I and II is false.

35. Option (1) is correct.

Stronger the ligand, larger the splitting & higher the energy of absorption.

Absorption energy $\propto \Delta_o \propto$ strength of ligand

Strength of ligand $\rightarrow H_2O < NH_3 <$ en

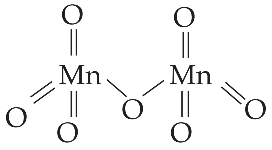
36. Option (1) is ctorrect.

Complex	Oxidation State	Electronic configuration	Unpaired electronic
$K_3[Cu(CN)_4]$	Cu^+	$3d^{10}$	0
$K_2[Cu(CN)_4]$	Cu^{2+}	$3d^9$	1
$K_3[Cu(CN)_4]$	Fe^{+1}	$3d^64s^1$	1
$K_4[FeCl_6]$	Fe^{+2}	$3d^6$	4

The species which is diamagnetic in nature is $K_3[Cu(CN)_4]$ having no unpaired e^-.

37. Option (3) is correct.

The number of Mn = O bond in Mn_2O_7 is 6.



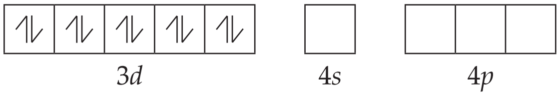
38. Option (1) is correct.

When the oxidation state of metal is low then it forms complexes in which ligands have π -accepting character because it can donate its electron to the ligand.

39. Option (2) is correct.

$Ni(CO)_4$

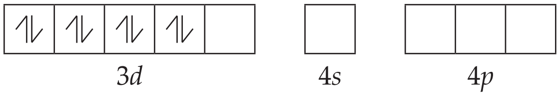
$_{28}Ni \rightarrow [Ar]4s^23d^8$



Hybridization sp^3

$[Ni(CN)_4]^{2-}$

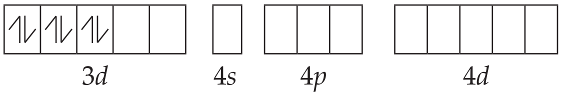
$_{28}Ni^{+2} \rightarrow [Ar]4s^03d^8$



Hybridization dsp^2

$[Co(CN)_6]^{3-}$

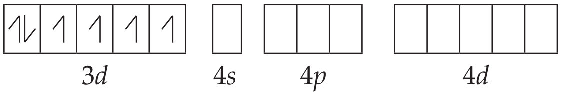
$_{27}Co^{+3} \rightarrow [Ar]4s^0 3d^6$



Hybridization d^2sp^3

$[CoF_6]^{3-}$

$_{27}Co^{+3} \rightarrow [Ar]4s^0 3d^6$

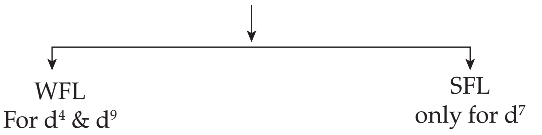


Hybridization sp^3d^2

40. Option (1) is correct.

John teller distortion: Any non-linear compound removes its degeneracy to attain the stability. Extent of John teller distortion depends upon metal ion as well as nature of ligand. Stronger the ligand, more will be the John Teller distortion and more will be the stability.

Jahn-Teller distortion is seen in octahedral complex



Now if we see above, in all option we have Cu^{2+} → which means it has d^9 ion, So the compound which contains W.F.L will show more distortion

Hence, trans $[Cu(en)_2Cl_2]$ will exhibit maximum John Teller distortion.

41. Option (2) is correct.

The species having similar structures are called isostructural.

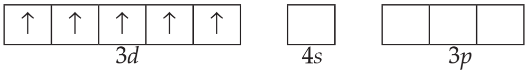
Species (Ion)	**Hybridisation**	**Geometry**
SO_4^{2-}	sp^3	Tetrahedral
CrO_4^{2-}	sp^3	Tetrahedral
$SiCl_4$	sp^3	Tetrahedral
$TiCl_4$	sp^3	Tetrahedral
NH_3	sp^3	Pyramidal
NO_3^-	sp^2	Trigonal planar
BCl_3	sp^2	Trigonal planar
$BrCl_3$	sp^3d	T – shaped

42. Option (2) is correct.

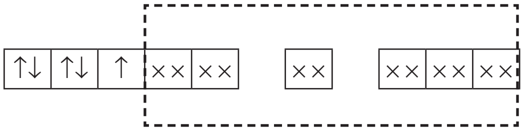
Ruby is the mineral of aluminium oxide with chromium. Red colour of ruby is due to presence of CrO_3 or Cr^{6+} but not the presence of Co^{3+}.

43. Option (1) is correct.

Mn^{2+} : [Ar] $3d^5$

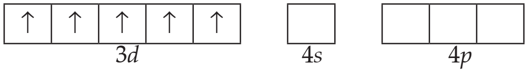


In presence of strong field ligand CN^-

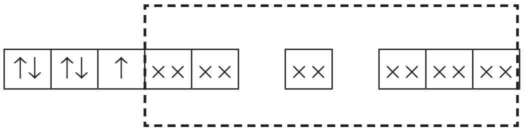


Hybridisation = d^2sp^3 and it is paramagnetic due to presence of unpaired electron.

Fe^{3+} [Ar] $3d^5$



In presence of strong field legend CN^-



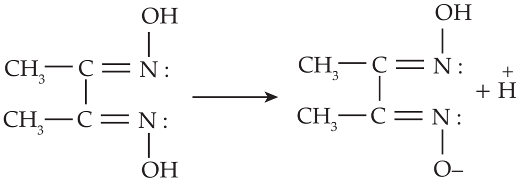
Hybridisation = d^2sp^3 and it in paramagnetic to presence of unpaired electron.

44. Option (4) is correct.

- **(i)** $[FeF_6]^{3-}$; Fe^{3+}: [Ar] $3d^5$; No. of unpaired electrons = 5 (due to presence of weak field ligand F^-)
- **(ii)** $[Co(NH_3)_6]^{3+}$; Co^{3+} : [Ar] $3d^6$; No. of unpaired electrons = 0 (due to presence of strong field ligand NH_3)
- **(iii)** $[NiCl_4]^{2-}$; Ni^{2+} : [Ar] $3d^8$; No. of unpaired electrons = 2 (due to weak field ligand Cl^-)
- **(iv)** $[Cu(NH_3)_4]^{2+}$; Cu^{2+} : [Ar] $3d^9$; No. of unpaired electrons = 1 (According to Huggin's concept)

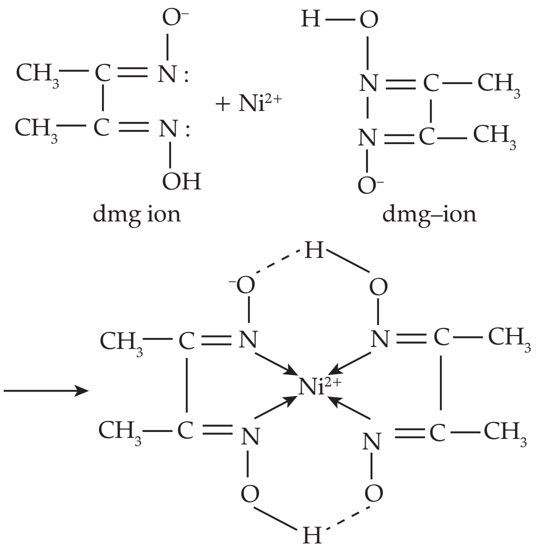
45. Option (4) is correct.

Dimethyl glyoximato ion (dmg^- or DMG^-). This ion is obtained when one OH group attached with N – atom in Hdmg molecule losses a proton and converted into a negative bidentate ligand.



Dimethyl glyoxime (Hdmg or HDMG)

Two dmg^- ions reacts with Ni^{2+} ion in ammonical solution (NH_4OH) and form an insoluble neutral red chelated complex $[M(dmg)_2]^\circ$ [M = Ni^{2+}] which form two 5 – membered and two 6 – membered rings. This formation takes place as follows.



Bis – (dimethyl glyoximato) nickel (II)

chelated complex $[Ni\,(dmg)_2]^\circ$ (red ppt)

46. Option (1) is correct.

The ambident nucleophiles are those which are having more than one donating side.

$\overset{\ominus}{C}\equiv\ddot{N}$ $\qquad$ $\overset{\ominus}{O}-N=\ddot{O}:$

47. Option (1) is correct.

The correct match is:

(1) (iii), **(2)** (i),

(3) (ii), **(4)** (iv)

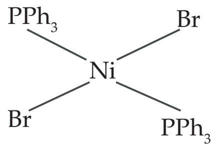
List – I Compound	List – II Type of Isomerism
$[Co(NH_3)_6]\,[Cr(CN)_6]$	Co–ordination isomerism
$[Co(NH_3)_3\,(NO_2)_3]$	Linkage isomerism
$[Cr(H_2O)_6]Cl_3$	Solvate isomerism
cis – $[CrCl_2(ox)_2]^{3-}$	Optical isomerism

48. Option (2) is correct.

Trans $[Ni\,Br_2(PPh_3)_2]$

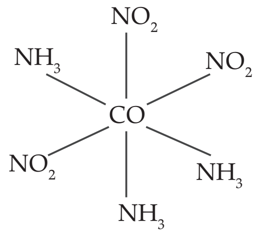
The two same complexes in which same two ligands lie adjacent to each other are called cis and those in which the same two ligands occupy opposite position to each other are called trans-isomer. Four Coordinate Square planar and six coordinate octahedral complexes show geometrical (Cis-Trans) isomerism.

- Trans $[Ni\,Br_2(PPh_3)_2]$



The isomer is called meridional or mer when three ligands and the metal are in the same plane. In this isomer, the ligands are present on different faces of octahedrons.

- Meridonial $[CO(NH_3)_3(NO_2)_3]$



49. Option (2) is correct.

The secondary valency and the number of hydrogen bonded water molecule(s) in $CuSO_4.5H_2O$, respectively, are : 4 and 1.

50. Option (3) is correct.

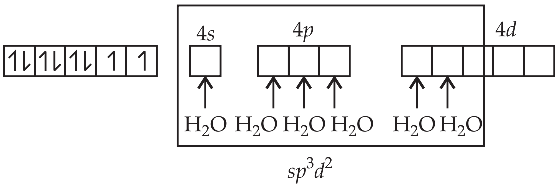
To identify the complex containing central metal atom with dsp^2 hybridization, we have to first identify the coordination number of central metal ion in that complex. From that, we can identify the hybridisation of the central metal ion in coordination complex.

In $Na_2[NiCl_4]$, Ni exists in +2 oxidation state. The Cl^- is a weak field ligand. The coordination number of Ni is 4 hence, it undergoes sp^3 hybridization.

For $NiCl_2{\cdot}6H_2O$

Ni $[Ar]3d^8\,4s^2$

Ni^{2+} $[Ar]3d^8\,4s^0$

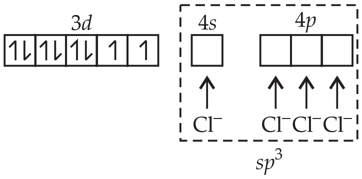


In $NiCl_2.6H_2O$, Ni occurs in +2 oxidation state. The coordination number of Ni is 6.

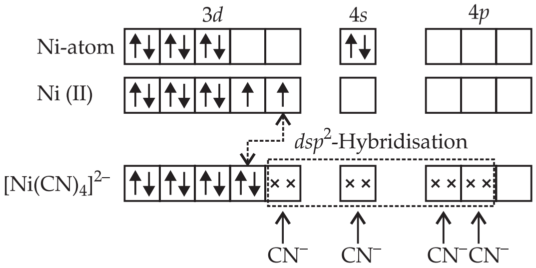
As H_2O is a weak ligand, Ni^{+2} undergoes sp^3d^2 hybridisation as follows:

Ni $[Ar]3d^8\,4s^2$

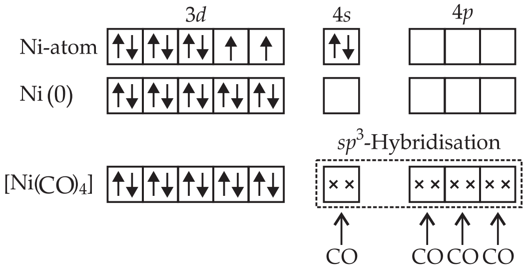
Ni^{2+} $[Ar]3d^8\,4s^0$



In $K_2[Ni(CN)_4]$, Ni occurs in +2 oxidation state. The CN^- is a strong field ligand. The Ni undergoes dsp^2 hybridization as shown below.



In $Ni(CO)_4$, the Ni atom undergoes sp^3 hybridization as shown below.



Therefore, according to valence bond theory the hybridization of central metal atom is dsp^2 for $K_2[Ni(CN)_4]$.

51. Option (3) is correct.

Crystal field theory (CFT) refers to the breaking of orbital degeneracy in transition metal complexes due to the presence of ligands. It also explains the strength of the metal-ligand bonds and how it affects the energy of the system. The energy of system affects the color. This theory was developed by Hans Bethe and John Hasbrouck van Vleck.

The splitting energy refers to the increase in energy due to filling of orbitals by preference. The value of splitting energy is generally less than or equal to 0.

The splitting energy of tetrahedral complex is less than that for octahedral complex which in turn less than that of square planar complexes.

Splitting $\Delta_t < \Delta_0 < \Delta_{sq}$
energy order

The geometry of $[NiCl_4]^{2-}$ is tetrahedral and that of $[Ni(H_2O)_6]^{2+}$ is octahedral. The geometry of $[Ni(CN)_4]^{2-}$ is square planar.

The absorption energy of transition metal complex fall within visible light spectrum, thus the complexes displays variety of colours.

The absorption energy order of the given complexes is:

$[NiCl_4]^{2-} > [Ni(H_2O)_6]^{2+} > [Ni(CN)_4]^{2-}$

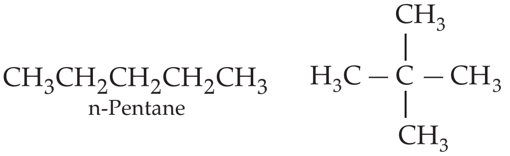
The intensity of colour of the given compounds will follow same order as the absorption energy.

$[NiCl_4]^{2-} > [Ni(H_2O)_6]^{2+} > [Ni(CN)_4]^{2-}$

52. Option (2) is correct.

We will see each pair of compounds to identify the type of isomerism exists between them.

The compounds shown in option 1 are n-pentane and neopentane.

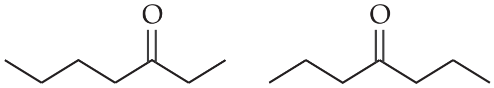


$CH_3CH_2CH_2CH_2CH_3$ $\quad$ $H_3C-\overset{\overset{\large CH_3}{|}}{\underset{\underset{\large CH_3}{|}}{C}}-CH_3$

n-Pentane $\quad$ Neopentane

These two compounds are chain isomers as they have same molecular formula, C_5H_{12} but, different structure.

The compounds shown in option 2 are 3-heptanone and 4-heptanone.

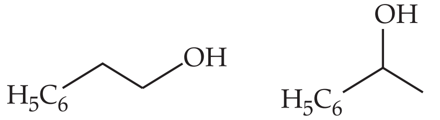


3-Heptanone $\quad$ 4-Heptanone

Both compounds have same molecular formula, $C_7H_{14}O$. The number of carbon present in alkyl groups on either side of functional group (in this case carbonyl group) are different.

In case of 3-heptanone, the number of carbon atoms present either side of functional group are 4 and 2 that is unequal. In case of 4-Heptanone, the number of carbon atoms present either side of functional group are 3 on each side that is equal. This type of isomerism is known as metamerism. Hence, 3-heptanone and 4-heptanone are metamers.

The compounds given in option 3 are Phenylethyl alcohol and 1-phenylethanol.



Phenylethyl alcohol $\quad$ 1-Phenyl ethanol

The compounds contain same functional group that is alcohol but, the position of functional group in the compounds is different. This type of isomers are known as position isomers.

The compounds shown in option 4 are same compounds.

Hence, pair of compounds in option 2 are metamers.

53. Option (1) is correct.

The complex or complex ion which contains unpaired electrons will respond towards external magnetic field.

Complex	Ion	Number of unpaired electrons
$[Fe(H_2O)_6]^{3+}$	Fe^{3+}	5 (Paramagnetic)
$[Ni(CO)_4]$	Ni	0 (due to strong field ligand, unpaired electrons are paired)
$[Co(CN)_6]^{3-}$	Co^{3+}	0 (due to strong field ligand, unpaired electrons are paired)
$[Ni(CN)_4]^{2-}$	Ni^{2+}	0 (due to strong field ligand, unpaired electrons are paired)

Except, all are diamagnetic in nature due to absence of unpaired electrons.

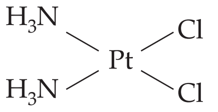
54. Option (2) is correct.

The stability of complex is directly related with the chelation. Higher the number of chelate ring, more will be stability.

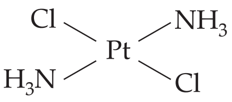
1. $[Co(en)(NH_3)_4]Cl_2$	one ring
2. $[Co(en)_3]Cl_3$	three ring
3. $[Co(en)_2(NH_3)_2]Cl_2$	two ring
4. $[Co(NH_3)_6]Cl_2$	zero ring

55. Option (4) is correct.

- $[PtCl_2(NH_3)_2]$

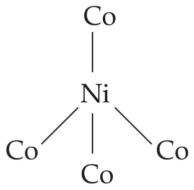


cis

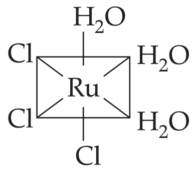


trans

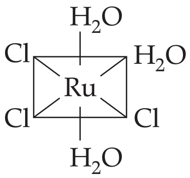
- $[Ni(CO)_4]$



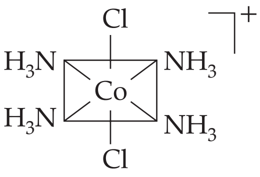
- $[Ru(H_2O)_3Cl_3]$



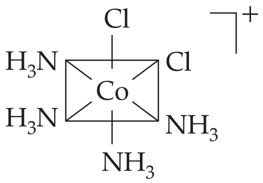
(*fac*)



(*mer*)



trans



cis

56. Option (3) is correct.

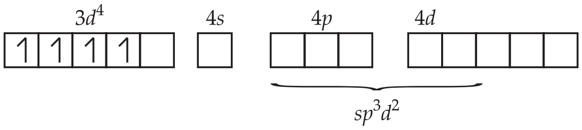
Oxidation state of Mn $= [MnCl_6]^{3-}$

$$= x + (-1) \times 6 = -3$$

$$x = +3$$

$$Mn(Z = 25) = 3d^5\,4s^2$$

$$Mn^{+3} = 3d^4$$



It contains 4 unpaired electron and it is paramagnetic in nature.

57. Option (4) is correct.

Statement (I) is true

Complex	Oxidation state of metal	Nature of ligand	Hydridisation	No. of unpaired e^-
$[Mn(CN)_6]^{3-}$	+ 3	Strong field	d^2sp^3	2
$[Fe(CN)_6]^{3-}$	+ 3	Strong field	d^2sp^2	1
$[Co(C_2O_4)_3]^{3-}$	+ 3	Strong field & cheating	d^2sp^3	0

All have d^2sp^3 hybridisation. So, statement (I) is true.

Statement (II) is true

Complex	Oxidation state of metal	Nature of ligand	No. of unpaired e^-	Magnetic nature
$[MnCl_2]^{3-}$	+ 3	Weak field	4	Paramagnetic
$[Fe(CN)_6]^{3-}$	+ 3	Weak field	5	Paramagnetic

Here both complexes are paramagnetic in nature and they contain 4 and 5 unpaired e^- respectively. So statement II is true.

58. Option (3) is correct.

CFSE value depends upon on the following factor :

CFSE ∝ charge on central atom

∝ strength of ligand.

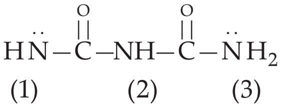
The strength of ligands is as follows :

$$en > \ddot{N}H_3 > H_2\ddot{\underset{..}{O}} > F^-$$

en is a strong ligand while F^- is a weak ligand. So CFSE value of given complex is $[Co(eN)_3]^{+3} > [Co(NH_3)]^{+3} > [CoF_6]^{3-} > [Co(H_2O)_0]^{2+}$

The oxidation state of cobalt is $[Co(H_2O)_6]^{2+}$ is + 2 while rest are + 3.

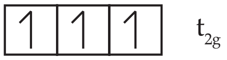
59. Option (3) is correct.

Structure of Biuret = 

$$H\ddot{N}-\overset{\overset{O}{||}}{C}-NH-\overset{\overset{O}{||}}{C}-\ddot{N}H_2$$

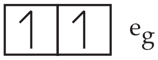
N-atom (1) and (3) donates e^- pair to the metal or metal ion to form coordinate bond. So the denticity is 2.

60. Option (2) is correct.

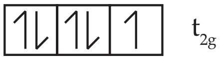
(1) For Mn^{4+} 

3 unpaired e^-

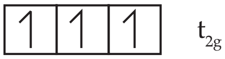
$$\text{CFSE} = -1.2\Delta_0$$
$$\mu = \sqrt{3(3+2)}$$
$$= \sqrt{15}\ \text{B.M.}$$
$$= 3.87\ \text{BM}$$

(2) Co^{2+} 

$$\text{CFSE} = -2.0 + 1.2$$
$$= -0.8\ \Delta_0$$



3 unpaired e^- $\mu = \sqrt{15} = 3.87$ B.M

(3) Cr^{3+} 

$$\text{CFSE} = -1.2\Delta_0\ \text{3 unpaired } e^-$$
$$\mu = \sqrt{15} = 3.87\text{BM}$$

(4) V^{3+} 

$$\text{CFSE} = -0.8\Delta_0\ \text{2 unpaired } e^-$$
$$\mu = \sqrt{8}\ \text{BM} = 2.82\ \text{BM}$$

61. Option (1) is correct.

$[Ni(NH_3)_2Cl_2]$ do not show isomerism. As it is sp^3 hybridised having T_d geometry and adjacent attachment of ligands towards the central metal ion (Ni^{2+}).

62. Option (4) is correct.

Towards common transition element and inner transition metal ion given ligand possesses maximum denticities of 6 and 8 respectively.

63. Option (4) is correct.

These (I & III) are limitation of V.B.T cannot distinguish between weak field ligands and strong field ligands and can not explain the colour of transition metal complexes.

Integer Type Questions (Chapter Based)

1. Number of ambidentate ligands in a representative metal complex $[M(en)(SCN)_4]$ is ______________ [en = ethylenediamine]

[JEE (Main) – 6th April 2023 - Shift-1]

Sol. Correct answer is [4].

Ambident ligands are those ligands which have two ligating sites but at a time only one of the ligand can form a bond with metal.

In the given SCN^- is an ambident nucleophile. Thus number of ambident ligands in $[M(en)(SCN)_4]$ are four.

2. The observed magnetic moment of the complex $[Mn(NCS)_6]^{x-}$ is 6.06 BM. The numerical value of x is ________.

[JEE (Main) – 8th April 2023 - Shift-2]

Sol. Correct answer is [4].

Magnetic moment (μ) is given as $\mu = \sqrt{n}\ (n+2)$

$[Mn(NCS)_6]_x^-$ Number of unpaired electron = 5

So, Mn must be in +2 oxidation state (Mn^{+2})

$\Rightarrow 2 + (-6) = -x$

$\Rightarrow -4 = -x$

$\Rightarrow x = 4$

3. The sum of oxidation state of the metals in $Fe(CO)_5$, VO_{2+} and WO_3 is_______

[JEE (Main) – 8th April 2023 - Shift-2]

Sol. Correct answer is [10].

The charge on a complex is the sum of the oxidation state of the metal center and the charges on the ligands.

CO is a neutral ligand. Hence, the charge on the ligand is 0. The total charge on the complex is also 0.

The oxidation number of Fe in the complex, $Fe(CO)_5$ is as follows;

(Charge on Fe) + 5(Charge on CO) = 0

(Charge on Fe) + 5(0) = 0

(Charge on Fe) = 0

Thus, the oxidation number of Fe in $Fe(CO)_5$is 0.

For VO^{2+}

Here the oxidation state of vanadium is +4.

The steps include:

$x - 2 = 2$

$x = +4$

Therefore, the oxidation state of vanadium in VO^{2+} is 4.

For WO_3

Tungsten trioxide (WO_3) consists of one tungsten atom and three oxygen atoms. Tungsten is a d-block metal from group 6 and has an oxidation state +6 in the compound.

So, Sum of oxidation state = 0 + 4 + 6 = 10

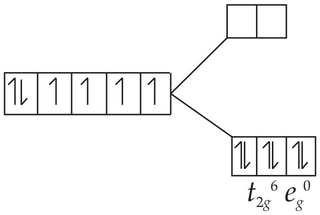
4. In potassium ferrocyanide, there are_______ pairs of electrons in the t_{2g} set of orbitals.

[JEE (Main) – 10th April 2023 - Shift-1]

Sol. Correct answer is [3].

According to crystal field theory, the five degenerate *d* orbitals getting splitted into two sets, t_{2g} (d_{xy}, d_{yz} & d_{zx} of lower energy) and eg ($d_{x^2-y^2}$ & d_{z^2} of higher energy) orbitals in the octahedral environment. Since CN^- is strong ligand, the six d electrons will occupy low energy t_{2g} level.

Potassium ferrocyanide is K_4 $[Fe(CN)_6]$. It contains Fe^{2+} ions with $3d^6$ outer electronic configuration. Since cyanide is strong field ligand, all 3d electrons will be paired. Hence, potassium ferrocyanide will be diamagnetic.



5. In alkaline medium, the reduction of permanganate anion involves a gain of ______ electrons.

[JEE (Main) – 10th April 2023 - Shift-2]

Sol. Correct answer is [3].

In alkaline medium the reduction of permanganate anion involves following reaction.

$$\overset{+7}{Mn}O_4^- + 3e^- + 2H_2O \rightarrow \overset{+4}{Mn}O_2 + 4OH^-$$

6. The ratio of spin-only magnetic moment values $\mu_{eff}[Cr(CN)_6]^{3-}/\mu_{eff}[Cr(H_2O)_6]^{3+}$ is ____

[JEE (Main) – 11th April 2023 - Shift-1]

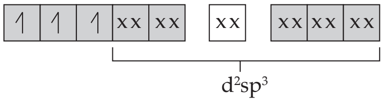
Sol. Correct answer is [1].

The oxidation state of Cr atom in $[Cr(CN)_6]^{3-}$ = +3

$Cr = 3d^5 4s^1$

$Cr^{+3} = 3d^3 4s^0$

$[Cr(CN)_6]^{3-}$ =



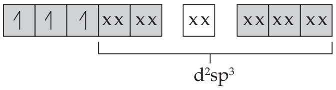
Number of unpaired e^-=3

$$\mu_1 = \sqrt{n(n+2)}\ BM = \sqrt{3(3+2)} = \sqrt{15}\ BM$$

The oxidation state of Cr atom in $[Cr(H_2O)_6]^{3+} = +3$

$Cr = 3d^5 4s^1$, $Cr^{+3} = 3d^3 4s^0$

$[Cr(H_2O)_6]^{3+}$=



Number of unpaired e^-=3

$$\mu_2 = \sqrt{n(n+2)}BM = \sqrt{3(3+2)} = \sqrt{15}\ BM$$

$$\frac{\mu_1}{\mu_2} = \frac{\sqrt{15}}{\sqrt{15}} = 1$$

7. $KMnO_4$ is titrated with ferrous ammonium sulphate hexahydrate in presence of dilute H_2SO_4. Number of water molecules produced for 2 molecules of $KMnO_4$ is_________.

[JEE (Main) – 13th April 2023 - Shift-1]

Sol. Correct answer is [68].

The balanced chemical reaction of $KMnO_4$ with mohr salt is as follows-

$$2KMNnO_4 + 8H_2SO_4 + 10FeSO_4.(NH_4)_2SO_4.6H_2O$$
$$\rightarrow 10(NH_4)_2SO_4 + K_2SO_4 + 2MnSO_4$$
$$+5Fe_2(SO_4)_3 + 68H_2O$$

From the given balanced chemical reaction 68 molecules of H_2O will be produced from 2 molecules of $KMnO_4$

8. How many of the following metal ions have similar value of spin only magnetic moment in gaseous state?

(Given: Atomic number : V, 23; Cr, 24; Fe, 26;Ni, 28)

V^{3+}, Cr^{3+}, Fe^{2+}, Ni^{3+}

[JEE (Main) – 25th Jan 2023 - Shift-1]

Sol. Correct answer is [2].

Formula used $\mu = \sqrt{n(n+2)}BM$

where *n* = number of unpaired electrons

V^{3+} : [Ar] $3d^2\ 4s^0$, 2 unpaired electrons
Cr^{3+} : [Ar] $3d^3\ 4s^0$, 3 unpaired electrons
Fe^{2+} : [Ar] $3d^6\ 4s^0$, 4 unpaired electrons
Ni^{3+} : [Ar] $3d^7\ 4s^0$, 3 unpaired electrons

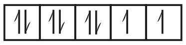
The species having same value of spin only magnetic moment will be those which have same number of unpaired electrons. Thus two species will have same value of μ i.e., Cr^{3+} and Ni^{3+}.

9. The number of paramagnetic species from the following is
$[Ni(CN)_4]^{2-}$,$[Ni(CO)_4]$,$[NiCl_4]^{2-}$
$[Fe(CN)_6]^{4-}$,$[Cu(NH_3)_4]^{2+}$
$[Fe(CN)_6]^{3-}$ and $[Fe(H_2O)_6]^{2+}$

[JEE (Main) – 25th Jan 2023 - Shift-1]

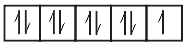
Sol. Correct answer is [4].

$[NiCl_4]^{2-}$ Ni^{2+} : $3d^8$



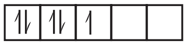
Cl^- is a weak ligand so e^-s remain unpaired
∴ it is paramagnetic in nature.

$[Cu(NH_3)_4]^{2+}$ Cu^{2+} : $3d^9$



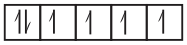
Here one unpaired e^- is a present
∴ it is paramagnetic in nature.

$[Fe(CN)_6]^{3-}$ Fe^{3+} : $3d^5$



Here one unpaired e^- is a present
∴ it is paramagnetic in nature.

$[Fe(H_2O)_6]^{2+}$ Fe^{2+} : $3d^6$



Here, H_2O is a weak ligand so e^- remain unpaired
∴ it is paramagnetic in nature.
The other species do not contain unpaired e^-s
∴ they are diamagnetic in nature.

10. Total number of moles of AgCl precipitated on addition of excess of $AgNO_3$ to one mole each of the following complexes $[Co(NH_3)_4Cl_2]Cl$, $[Ni(H_2O)_6]Cl_2$, $[Pt(NH_3)_2Cl_2]$ and $[Pd(NH_3)_4]Cl_2$ is **[JEE (Main) – 25th Jan 2023 - Shift-2]**

Sol. Correct answer is [5].

Number of moles of AgCl formed = 5

$[CO(NH_3)_4Cl_2]\ Cl + AgNO_3 \rightarrow [CO(NH_3)_4Cl_2] + AgCl$
1mole

$[N:(H_2O)_6]Cl_2 + AgNO_3 \rightarrow [Ni(H_2O)_6]^{2+} + AgCl$
2mole

$[Pt(NH_3)_2Cl_2] + AgNO_3 \rightarrow$ No reaction

$[Pd(NH_3)_4]\ Cl_2 + AgNO_3 \rightarrow [Pd(NH_3)_4]^{2+} + 2AgCl$
2mole

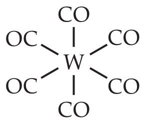
Total 5 moles AgCl are formed.

11. The sum of bridging carbonyls in $W(CO)_6$ and $Mn_2(CO)_{10}$ is_______.

[JEE (Main) – 29th Jan 2023 - Shift-1]

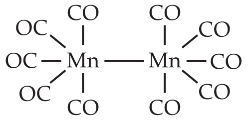
Sol. Correct answer is [0].

The structure of W $(CO)_6$



Number of bridge CO = zero (0)

The structure of $Mn_2\ (CO)_{10}$



Number of bridge CO = Zero (0)

The sum of bridging carbonyl in W $(CO)_6$ and $Mn_2(CO)_{10}$ are zero.

12. The number of electrons involved in the reduction of permanganate to manganese dioxide in acidic medium is

[JEE (Main) – 30th Jan 2023 - Shift-1]

Sol. Correct answer is [3].

Conversion of permanganate into manganese dioxide (MnO_2) in acidic medium.

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$$

$x + (-2) \times 4 = -1;$ $x + (-2)2 = 0$
$x = +7$ $x - 4 = 0$
$x = +4$

Change in number of electrons = 7 – 4 = 3

13. If the CFSE of $[Ti(H_2O)_6]^{3+}$ is −96.0 kJ/mol, this complex will absorb maximum wavelength at nm. (Nearest integer)

Assume Planck's constant (h) = 6.4×10^{-34}Js, Speed of light (c) = 3.0×10^8 m/s and Avogadro's Constant $(N_A) = 6 \times 10^{23}$/mol

[JEE (Main) – 31th Jan 2023 - Shift-2]

Sol. Correct answer is [480].

The configuration of Ti^{3+} is $t^2g^1\ eg^0$

$$CFSE = (-0.4x + 0.6y)\,\Delta_0$$

$$-96 = (-0.4(1) + 0.6(0))\,\Delta_0$$

$$\Delta_0 = 240\ kJmol^{-1} = \frac{hc}{\lambda}$$

$$\frac{240}{6\times10^{23}} = \frac{6.4\times10^{-34}\times3\times10^{8}}{\lambda}$$

$$\lambda = 480\,nm$$

14. If $[Cu(H_2O)_4]^{2+}$ absorbs a light of wavelength 600 nm for d-d transition, then the value of octahedral crystal field splitting energy

for $[Cu(H_2O)_6]^{2+}$ will be ________ $\times 10^{-21}$ J. [Nearest Integer]
[Given: $h = 6.63 \times 10^{-34}$ Js and $c = 3.08 \times 10^8$ ms^{-1}] **[JEE (Main) – 25th June 2022 - Shift-1]**

Sol. Correct answer is [1021].

Object has a particular color for one of two reasons:

1st It reflects or transmits light of that color

2nd It absorbs light of the complementary color.

$[Cu(H_2O)_6]^{2+} \rightarrow Cu^{2+}\ 3d^9\ t^6\ eg^3$

$$\text{CFSE} = \left(6 \times \frac{2}{5} - 3 \times \frac{3}{5}\right)\Delta°$$

$$= \frac{3}{5} \times \frac{hv}{\gamma}$$

Given: $h = 6.63 \times 10^{-34}$ Js and
$c = 3.08 \times 10^8$ ms^{-1}

$$\frac{3}{5} \times \frac{6.63 \times 10^{-34}\,\text{Js}}{3.08 \times 10^8\,\text{ms}^{-1}} = 10^{21} \times 10^{-21}$$

If $[Cu(H_2O)_4]^{2+}$ absorbs a light of wavelength 600 nm for *d-d* transition, then the value of octahedral crystal field splitting energy for $[Cu(H_2O)_6]^{2+}$ will be $10^{21} \times 10^{-21}$ J

15. Amongst $FeCl_3.3H_2O$, $K_3[Fe(CN)_6]$ and $[Co(NH_3)_6]Cl_3$, the spin-only magnetic moment value of the inner-orbital complex that absorbs light at shortest wavelength is ___________ B.M. [Nearest integer]

[JEE (Main) – 25th June 2022 - Shift-2]

Sol. Correct answer is [2].

$[Fe(H_2O)_3Cl_3] \rightarrow$ Outer-orbital complex

$K_3[Fe(CN)_6] \rightarrow$ Inner-orbital complex

$[Co(NH_3)_6]Cl_3 \rightarrow$ Inner-orbital complex

CN^- is a strong field ligand than NH_3. $K_3[(Fe(CN)_6]$ due to high spin splitting absorbs light at shortest wavelength.

$Fe^{3+}\ (3d^5) \rightarrow CN^-$ is strong field ligand.

$t_{2g}^5\, e_g^0 \rightarrow n = 1$

$= \sqrt{3}$

$= 1.73$

$= 2$

16. The spin-only magnetic moment value of the most basic oxide of vanadium among V_2O_3, V_2O_4 and V_2O_5 is _________ B.M. (Nearest integer) **[JEE (Main) – 26th June 2022 - Shift-1]**

Sol. Correct answer is [3].

Most basic oxide is V_2O_3

$V^{+3} \rightarrow [Ar]3d^2$

$$\sqrt{n\quad n+2)} \quad n \quad 2,$$

$$\sqrt{\quad +2)} \quad 2.84\text{MB} \quad 3$$

17. The spin only magnetic moment value of an octahedral complex among $CoCl_3.4NH_3$, $NiCl_2.6H_2O$ and $PtCl_4.2HCl$, which upon reaction with excess of $AgNO_3$ gives 2 moles of AgCl is ____________ B.M. (Nearest integer)

[JEE (Main) – 26th June 2022 - Shift-1]

Sol. Correct answer is [3].

$CoCl_3.4NH_3 \rightarrow [CoCl_3(NH_3)_4.Cl_2] + AgCl$

$NiCl_2.6H_2O \rightarrow [Ni(H_2O)_6]^{2+} + 2AgCl$

$PtCl_4.2HCl \rightarrow [PtCl_6]^- +$ No ppt of AgCl

$[Ni^{+2}(H_2O)_6] = d^8 t_{2g}^6 e_g^2 = 2$ unpaired

$$\text{Magnetic moment } (\mu) = \sqrt{2(2+}$$

$$= \sqrt{8} = 2\sqrt{2} = 184$$

$$= \sqrt{8} = 2\sqrt{2}d$$

$$= 2.84$$

$$\approx 3$$

$$[Ni^{+2}(H_2O)_6] = d^8 t_{2g}^6 e^2{}_g = 2 \text{ unpaired}$$

$$\text{Magnetic moment } (\mu) = \sqrt{2(2+}$$

$$= \sqrt{8} = 2\sqrt{2} = 184$$

$$= \sqrt{8} = 2\sqrt{2}$$

$$= 2.84$$

$$\approx 3$$

18. Reaction of $[Co(H_2O)_6]^{2+}$ with excess ammonia and in the presence of oxygen results into a diamagnetic product. Number of electrons present in t_{2g}-orbitals of the product is ________.

[JEE (Main) – 26th June 2022 - Shift-2]

Sol. Correct answer is [6].

$[Co(H_2O)_6]^{2+}$ has Co^{2+} ion and its valence $3d^7$ electronic configuration and has 3 unpaired electrons as it is high spin complex. It reacts with molecular oxygen in the presence of liquid NH_3 to give a new complex Y, $[Co(NH_3)_6]^{3+}$. It has Co^{3+} ion with $3d^6$ outer electronic configuration and has 0 unpaired electrons as it is low spin or spin paired complex.

$$[Co(H_2O)_6]^{2+} + NH_3(\text{excess}) \rightarrow [Co(NH_3)_6]^{3+} + 6H_2O$$

Diamagnetic
↓
Low spin complex

$Co^{3+} \Rightarrow 3d^6 4s^0$

$\Rightarrow t_{2g}{}^6 e_g{}^0$

Number of electrons present in t_{2g}-orbitals of the product is 6.

19. The number of statement(s) **correct** from the following for Copper (at. No. 29) is/are ....

(1) Cu (II) complexes are always paramagnetic.

(2) Cu(I) complexes are generally colourless.

(3) Cu(I) is easily oxidized.

(4) In Fehling solution, the active reagent has Cu(I). **[JEE (Main) – 27th June 2022 - Shift-1]**

Sol. Correct answer is [2].

(1) Cu (II) complexes are always paramagnetic as they have one unpaired electron due to d^9 configuration of Cu (II).

(2) Cu (I) generally colourless.

Cu(I) complexes are generally colourless due to d^{10} configuration.

20. Number of complexes which will exhibit synergic bonding amongst,

$[Cr(CO)_6]$, $[Mn(CO)_5]$ and $[Mn_2(CO)_{10}]$ is_________ .

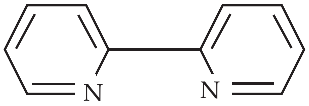
[JEE (Main) – 28th June 2022 - Shift-1]

Sol. Correct answer is [3].

Carbonyl ligand is also known as non classical ligand which not only donates electron pair to the metal atom but also accept the electron pair from metal atom to form π bond and this type of bonding is called synergic bond, in which there is a double bond is present between metal atom and carbon atom of CO ligand.

Here, all the carbonyl complex undergo synergic bonding.

21. Sum of oxidation state (magnitude) and coordination number of cobalt in $Na[Co(bpy)Cl_4]$ is ______.

(Given : bpy = )

[JEE (Main) – 29th June 2022 - Shift-2]

Sol. Correct answer is [9].

$Na\,[Co(bpy)Cl_4]$

Oxidation state of cobalt = + 3

Coordination number of cobalt = 6 [As bpy is bidentate]

Bidentate ligand is a ligand which has two atoms that can coordinate directly with the central atom.

So, sum = 9

22. **(1)** $CoCl_3 \,.\, 4\,NH_3$,

(2) $CoCl_3 \,.\, 5NH_3$,

(3) $CoCl_3 \,.\, 6NH_3$ and

(4) $CoCl(NO_3)_2 \,.\, 5NH_3$

Number of complex(es) which will exist in cis-trans form is/are ___________.

[JEE (Main) – 28th June 2022 - Shift-2]

Sol. Correct answer is [1].

Type of complex	Central metal ion	Type of complex	Geometrical isomerism
$CoCl_3.4NH_3$	Co	$[Co(NH_3)_4Cl_2]Cl$	Yes
$CoCl_3.5NH_3$	Co	$[Co(NH_3)_5Cl]Cl_2$	No
$CoCl_3.6NH_3$	Co	$[Co(NH_3)_6]Cl_3$	No
$CoCl(NO_3)_2.5NH_3$	Co	$[Co(NH_3)_5Cl](NO_3)_2$ or $[Co(NH_3)_4(NO_3)]Cl(NO_3)$	No

23. Consider the following metal complexes:

$[Co(NH_3)_6]^{3+}$

$[CoCl(NH_3)_5]^{2+}$

$[Co(CN)_6]^{3-}$

$[Co(NH_3)_5(H_2O)]^{3+}$

The spin-only magnetic moment value of the complex that absorbs light with shortest wavelength is _________________ B.M. (Nearest integer)

[JEE (Main) – 25th June 2022 - Shift-1]

Sol. Correct answer is [0].

CN^- is a strong field ligand and Δ_0 >P. Hence, pairing of electrons is preferred. Outer shell electronic configuration of Co^{3+} can bet $t_{2g}^6\, e_g^\circ$ Thus, $[Co(CN)_6]^{3-}$ has no unpaired electrons and will be in a low–spin configuration. $[Co(CN)_6]^{3-}$ absorbs light with shortest wave length because CN^- is strong field ligand so more splitting takes place and t_{2g} and e_g orbital have more energy difference.

24. The spin-only magnetic moment value of M^{3+} ion (in gaseous state) from the pairs Cr^{3+}/Cr^{2+}, Mn^{3+}/Mn^{2+}, Fe^{3+}/Fe^{2+} and Co^{3+}/Co^{2+} that has negative standard electrode potential, is_____B.M. [Nearest integer]

[JEE (Main) – 25th July 2022 - Shift-2]

Sol. Correct answer is [4].

	Ti	V	Cr	Mn	Fe	Co
$E^0_{M^{3+}/M^{2+}}$	–0.37	–0.26	–0.41	1.57	0.77	1.97

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

$Cr^{3+} = 3d^3\,4s^0$

$\mu = \sqrt{n(n+2)}$ B.M. $= \sqrt{3(3+2)}$ B.M.

$= \sqrt{15}$ B.M. $= 3.87$ B.M. ≈ 4 B.M.

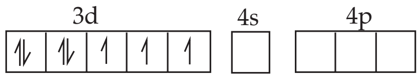
25. The difference between spin only magnetic moment value of $[CO(H_2O)_6]Cl_2$ and $[Cr(H_2O)_6]Cl_3$ is_______(Nearest Integer)

[JEE (Main) – 26th July 2022 - Shift-1]

Sol. Correct answer is [0].

In the complex $[CO(H_2O_6)]^{2+}$, central metal ion is cobalt having oxidation state = +2

CO^{+2}:



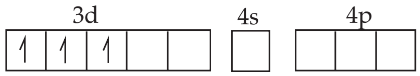
In the above ion, number of unpaired electron are 3 therefore, the magnetic moment value of Co^{2+} ion is

$\mu = \sqrt{n\ n+2)}$, where n represent number of unpaired electrons

$\mu = \sqrt{3(3+2)} = \sqrt{15}BM$

In the complex $[Cr(H_2O_6)]^{3+}$, central metal ion is chromium ion having oxidation state +3.

Cr^{+3}:



In the above ion, number of unpaired electron are 3 therefore the magnetic moment value of Cr^{3+} ion is

$\mu = \sqrt{n\ n+2)}$, where n represent number of unpaired electrons

$\mu = \sqrt{3(3+2)} = \sqrt{15}BM$

Difference in the spin only magnetic moment is zero(0).

26. The conductivity of a solution of complex with formula $CoCl_3\,(NH_3)_4$ corresponds to 1:1 electrolyte, then the primary valency of central metal ion is ______ .

[JEE (Main) – 27th July 2022 - Shift-1]

Sol. Correct answer is [3].

In the given complex $[Co(NH_3)_4Cl_2]Cl$, the oxidation state of the central metal ion is +3 which represents the primary valency of the central atom. So, the correct answer for the primary valency is 3.

27. Optical activity of an enantiomeric mixture is + 12.6° and the specific rotation of (+) isomer is + 30°. The optical purity is _____ %

[JEE (Main) – 27th July 2022 - Shift-1]

Sol. Correct answer is [42].

$$\%\text{optical purity} = \frac{\text{observed rotation of mixture} \times 100}{\text{rotation of pure enantiomer}}$$

$$\%\text{ optical purity} = \frac{+12.6^\circ \times 100}{+30^\circ} = 42\%$$

28. The oxidation state of manganese in the product obtained in a reaction of potassium permanganate and hydrogen peroxide in basic medium is _______ .

[JEE (Main) – 27th July 2022 - Shift-2]

Sol. Correct answer is [4].

The reaction of potassium permagnate with hydrogen peroxide in basic medium is shown as below:

$$\underset{+7}{2KMnO_4} + 3H_2O_2 \xrightarrow{\text{basic}} \underset{+4}{2MnO_2} + 3O_2 + 2H_2O + 2KOH$$

The oxidation state of Mn changes from +7 to +4 in a reaction. The final oxidation state of Manganese in the product is +4 i.e., MnO_2.

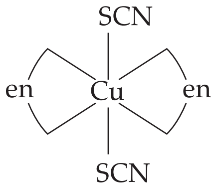
29. Total number of relatively more stable isomer(s) possible for octahedral complex $[Cu(en)_2(SCN)_2]$ will be ___________.

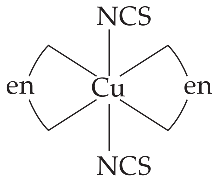
[JEE (Main) – 28th July 2022 - Shift-1]

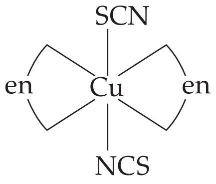
Sol. Correct answer is [3].

SCN is an ambidentate ligand.

$[Cu(en)_2(SCN)_2]$







30. $[Fe(CN)_6]^{3-}$ should be an inner orbital complex. Ignoring the pairing energy, the value of crystal field stabilization energy for this complex is (–) ________ Δ_0 (Nearest integer)

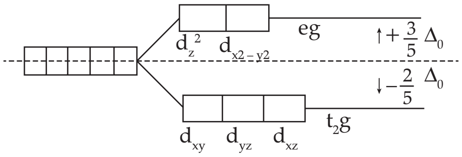
[JEE (Main) – 29th July 2022 - Shift-1]

Sol. Correct answer is [2].

The crystal field stabilisation energy (CFSE) is the gain in the energy achieved by preferential filling up of orbitals by electrons. It is usually less than or equal to 0. When it is equal to 0, the complex is unstable. The magnitude of CFSE depends on the number and nature of ligands and the geometry of the complex. Consider octahedral d^4 system. Three electrons are in lower t_{2g} level. Fourth electron will enter into higher e_g level if $\Delta_0 < P$. Fourth electron will enter into lower t_{2g} level if $\Delta_0 > P$. Here, P is the pairing energy. It is the energy required to pair two electrons against electron electron repulsion in the same orbital.

$[Fe(CN)_6]^{3-}$

C.N. = 6 → as in question it is mentioned inner d complex Means hybridization is d^2sp^3 (octahedral) Splitting of octahedral complex



as ligand approaches along the axis in octahedral complex; so the orbitals who are present along the axis will get repulsion. Hence along the axis orbitals i.e. dz^2 and $dx^2 - y^2$ get more energy.

Now, O.N of Fe here is

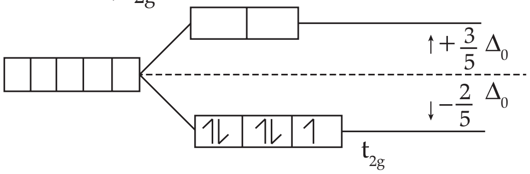
$[Fe(CN)_6]^{3-} \Rightarrow -3 - (-1 \times 6) = +3$

$Fe \rightarrow [Ar]3d^64s^2$

$Fe^{+3} \rightarrow [Ar]3d^54s^0$

⇒ as here S.F.L. so hunds rule will not followed here, so $\Delta_0 >$ P. E.

⇒ Hence, t_{2g} will first filled



$$C.F.S.E = (-2/5)\,\Delta_0 \times 5 + np + \left(\frac{3}{5}\Delta_0\right) \times 0$$

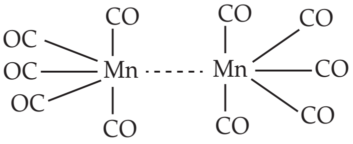
C.F.S.E = $-2\Delta_0$ here paring energy is said to ignore in question. So, the numerical value is 2.

31. Number of bridging CO ligands in $[Mn_2(CO)_{10}]$ is _____. **[JEE (Main) – 26th Feb 2021 - Shift-1]**

Sol. Correct answer is [0].

All transition metals with odd atomic number which form carbonyls give only polynuclear carbonyls.

In $Mn_2(CO)_{10}$ have carbonyl bridges. In this molecule there is also significant metal to metal bonding interaction.



Structure of binuclear $Mn_2(CO)_{10}$ carbonyl.

Hence, no bridging CO ligands is present in $Mn_2(CO)_{10}$.

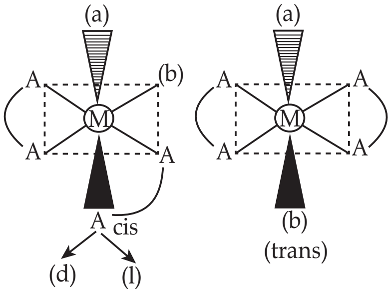
32. The number of stereoisomers possible for $[Co(ox)_2(Br)(NH_3)]^{2-}$ is ____________ [*ox* = oxalate]

[JEE (Main) – 26th Feb 2021 - Shift-2]

Sol. Correct answer is [3].

Total number of stereoisomers in $[Co(ox)_2Br\ NH_3]^{2-}$

i.e ≈ $[M\ (Ab)_2\,ab]^{2-}$



→ cis isomer is optically active isomer whereas trans isomer is optically inactive isomer.

→ Hence total isomers = 2 + 1 = 3

33. The total number of unpaired electrons present in the complex $K_3[Cr(oxalate)_3]$ is _________.

[JEE (Main) – 18th March 2021 - Shift-1]

Sol. Correct answer is [3].

$K_3\ [Cr(oxalate)_3]$

Chromium is in + 3 oxidation state

$Cr \rightarrow 3d^5\ 4s^1$

$Cr^{3+} \rightarrow 3d^3$, 3 unpaired electron

The hybridization of chromium in the complex is d^2sp^3

34. The spin-only magnetic moment value for the complex $[Co(CN_6)]^{4-}$ is __________BM

[At. no. of Co = 27]

[JEE (Main) – 20th July 2021 - Shift-1]

Sol. Correct answer is [1.73].

The given complex is $[Co(CN)_6]^{4-}$. The atomic number of Co is 27.

The electron when moves freely generates a magnetic field and is generated by the motion of electrons, hence termed as magnetic moment. The rotation of electron in its own axis producing a magnetic field it is known as a spin-only magnetic moment.

The spin-only magnetic moment can be calculated by, spin only magnetic moment (μ)

$$= \sqrt{n(n+2)}\text{B.M} \qquad \text{...(i)}$$

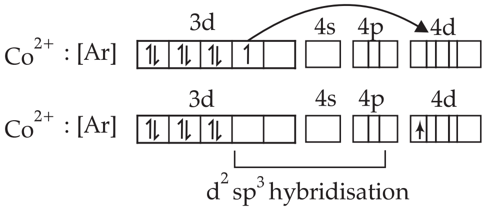
Here, μ denotes the spin-only magnetic moment and n represents the number of unpaired electrons in the given complex.

To calculate spin only magnetic moment, we first need to calculate the number of unpaired electrons in the complex. We also need to find out whether the CN^- is a strong or weak field ligand.

The electronic configuration of Co is,

Co : [Ar] $3d^7\ 4s^2$

In $[Co(CN)_6]^{4-}$, Co exists in +2 oxidation states. The CN^- is a strong filed ligand and is responsible for pairing of electrons.



The one unpaired electrons in $3d$ orbital of Co^{2+} gets transferred to $4d$ orbital. The Co^{2+} undergoes d^2sp^3 hybridization.

As shown above, the number of unpaired electrons in $[Co(CN)_6]^{4-}$ is 1 in its $4d$-subshell.

$\therefore \qquad n = 1$

Substituting respective values in equation (i), we get,

$$\mu = \sqrt{1(1+2)} = \sqrt{3} = 1.73 \text{ B.M.}$$

The spin-only magnetic moment value for the complex $[Co(CN)_6]^{4-}$ is 1.73 B.M.

35. An aqueous solution of $NiCl_2$ was heated with excess sodium cyanide in presence of strong oxidizing agent to form $[Ni(CN)_6]^{2-}$. The total change in number of unpaired electrons on metal centre is ______.

[JEE (Main) – 20th July 2021 - Shift-2]

Sol. Correct answer is [2].

Shortcut : To determine the change in number of unpaired electrons on metal centre, we need to find out the oxidation state of Ni in both complexes. From oxidation state, we can predict the electronic configuration of Ni in both complexes.

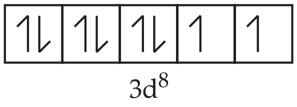
The aqueous solution of $NiCl_2$ on heating with excess of sodium cyanide in presence of strong oxidizing agent, produces$[Ni(CN)_6]^{-2}$.

In $NiCl_2$, Ni exists as Ni^{2+}.

Ni (ground state) : [Ar] $3d^8\ 4s^2$

Ni^{+2} : [Ar] $3d^8$

As Cl^- is a weak field ligand, no pairing of electrons will occur.

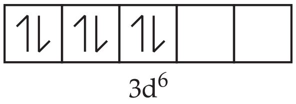


The number of unpaired electrons in Ni^{+2} are 2.

In$[Ni(CN)_6]^{-2}$, Ni exists in +4 oxidation state.

Ni^{+4} : [Ar] $3d^6$

The CN^- is a strong field ligand thus, pairing of electrons will occur.



The number of unpaired electrons in Ni^{+4} are 0.

An aqueous solution of $NiCl_2$ was heated with excess sodium cyanide in presence of strong oxidizing agent to form $[Ni(CN)_6]^{-2}$. The total change in number of unpaired electrons on metal centre is 2.

36. The total number of unpaired electrons present in $[Co(NH_3)_6]Cl_2$ and $[Co(NH_3)_6]Cl_3$ is ______.

[JEE (Main) – 22nd July 2021 - Shift-2]

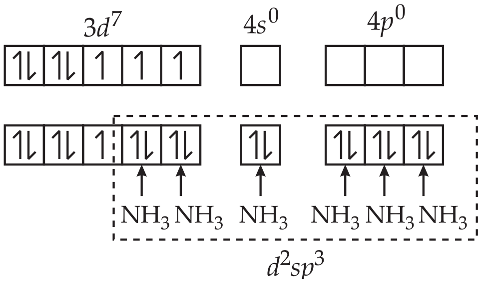
Sol. Correct answer is [1].

Hint : In $[Co(NH_3)_6]Cl_2$, NH_3 acts as weak fields ligand and in case of $[Co(NH_3)_6]Cl_3$, NH_3 acts as a strong field ligand.

In complex $[Co(NH_3)_6]Cl_2$, Co exists in +2 state. The Co^{+2} undergoes d^2sp^3 hybridization as shown below.

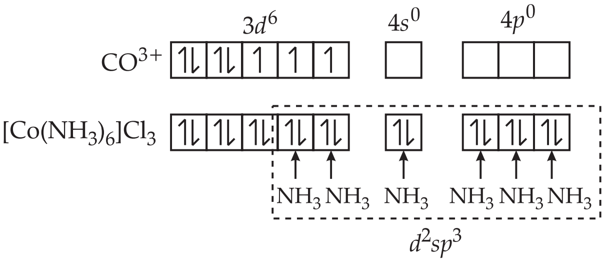
$[Co(NH_3)_6]Cl_2$

Co^{2+} = [Ar] $3d^7\ 4s^0\ 4p^0$



For complex $[Co(NH_3)_6]Cl_2$, the NH_3 ligand acts as a weak field ligand and Δ_0<Pairing energy. The number of unpaired electrons in $[Co(NH_3)_6]Cl_2$ is 1 as pairing does not occur.

In complex $[Co(NH_3)_6]Cl_3$, Co exists in +3 state. The Co^{+3} undergoes d^2sp^3 hybridization as shown below.



For complex $[Co(NH_3)_6]Cl_2$, the NH_3 ligand acts as a strong field ligand and Δ_0>Pairing energy. Thus pairing of electrons occur and thus, number of unpaired electrons in this case is 0.

The number of unpaired electrons in $[Co(NH_3)_6]Cl_2$ and $[Co(NH_3)_6]Cl_3$ are 1 and 0 respectively.

Final Answer: Therefore, the total number of unpaired electrons present in $[Co(NH_3)_6]Cl_2$ and $[Co(NH_3)_6]Cl_3$is 1.

37. Three moles of AgCl get precipitated when one mole of an octahedral co–ordination compound with empirical formula $CrCl_3.3NH_3.3H_2O$ reacts with excess of silver nitrate. The number of chloride ions satisfying the secondary valency of the metal ion is ________.

[JEE (Main) – 25th July 2021 - Shift-1]

Sol. Correct answer is [0].

Here number of moles of Cl^- ion

= Number of Cl^- present in ionization sphere

$$[Cr(H_2O)_3 (NH_3)_3]Cl_3 \longrightarrow [Cr(H_2O)(OH_3)_3] + 3Cl^{(-)}$$

$$\downarrow AgNO_3 \text{ (excess)}$$

$$3\ AgCl$$

None of the Cl^- ion present in the coordination there.

38. Number of electrons present in 4*f* orbital of Ho^{3+} ion is __________.

(Given Atomic No. of Ho = 67)

[JEE (Main) – 25th July 2021 - Shift-2]

Sol. Correct answer is [10]

Electronic configuration of Ho = $[Xe]\ 4f^{11}\ 6s^2$

Ho^{3+} = $[Xe]\ 4f^{10}$

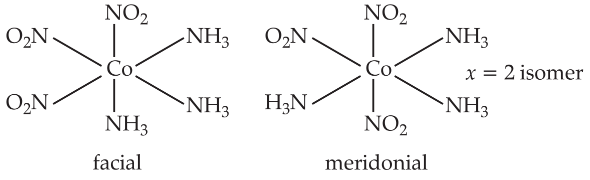
The number of e^- present in Ho^{3+} is 10.

39. The number of geometrical isomers possible in triamminetrinitrocobalt (III) is X and in trioxalatochromate (III) is Y. Then the value of X + Y is _____________.

[JEE (Main) – 27th July 2021 - Shift-1]

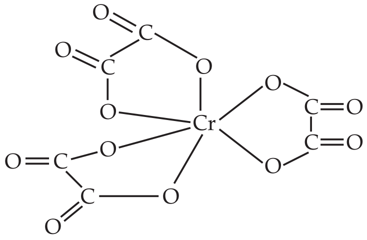
Sol. Correct answer is [2]

Triammine trinitrocobalt (III) : $[Co(NO_2)_3(NH_3)_3]$



X = 2 isomer

Trioxalatochromate (III) ion : $[Cr(C_2O_4)_3]^{3-}$



Y = 0 isomer

X + Y = 2 + 0 = 2

40. 3 moles of metal complex with formula $Co(en)_2Cl_3$ gives 3 moles of silver chloride on treatment with excess of silver nitrate. The secondary valency of Co in the complex is ________. (Round off to the nearest integer)

[JEE (Main) – 27th July 2021 - Shift-2]

Sol. Correct answer is [6].

$$3[CO(en)_3Cl_2]Cl + \underset{\text{(excess)}}{AgNO_3} \longrightarrow 3AgCl + [Co(en)_2Cl_2]$$

From above it is clear that the secondary valency is 6.

41. 1 mole of an octahedral metal complex with formula MCl_3 2L on reaction with excess of $AgNO_3$ gives 1 mol of AgCl. The denticity of Ligand L is _____. (Integer answer)

[JEE (Main) – 27th Aug 2021 - Shift-1]

Sol. Correct answer is [2].

Given, Octahedral complex = $MCl_3.2L$

On reaction with excess of $AgNO_3$ = 1 mole AgCl produced *i.e.*, 1 Cl^- ion is present in the ionization sphere and 2 Cl^- ions are present in coordination sphere.

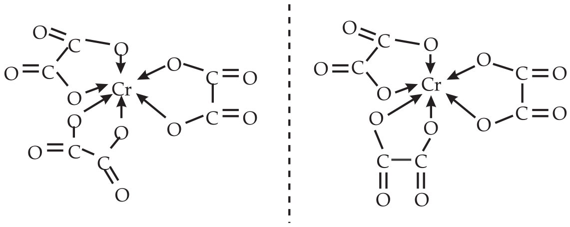
We know in octahedral complex, six ligands are required, here 2Cl are present in coordination complex and 2L are also present with it which indicate that L is a bidentate ligand.

42. The number of optical isomers possible for$[Cr(C_2O_4)]^{-3}$ is ______.

[JEE (Main) – 27th Aug 2021 - Shift-2]

Sol. Correct answer is [2].

$C_2O_4^{2-}$ is a symmetrical ligand which forms 2 optical isomers.



2 optical isomers are obtained as they both are asymmetrical.

43. The sum of oxidation states of two silver ions in $[Ag(NH_3)_2]$ $[Ag(CN)_2]$ complex is _____.

[JEE (Main) – 1st Sep 2021 - Shift-2]

Sol. Correct answer is [2].

NH_3 is neutral ligand while CN^- is negative ligand having – 1 charge

for $[Ag(NH_3)_2]^+ \Rightarrow x = +1$

$[Ag(CN)_2]^- \Rightarrow y = +1$

So, sum of oxidation state = 1 + 1 = 2

44. The co-ordination numbers of Co and Al in

$[CoCl(en)_2]Cl$ and $K_3[Al(C_2O_4)_3]$ respectively, are (en = ethane –1, 2 – diamine)

[JEE (Main) – 12th Jan 2019 - Shift-2]

Sol. Correct answer is [5 & 6]

en = Ethylene diamine is a bidentate as well as $C_2O_4^{2-}$ (oxalate) acts as a bidentate ligand. Therefore is $[CoCl(en)_2]Cl$ C.N. = 5 and $K_3[Al(C_2O_4)_3]$ CN = 6.

❑❑❑