

CHAPTER

Co-ordination Compounds

23

- A square planar complex is formed by hybridisation of which atomic orbitals?
[2002]
(a) s, p_x, p_y, d_{yz} (b) $s, p_x, p_y, d_{x^2-y^2}$
(c) s, p_x, p_y, d_{z^2} (d) s, p_y, p_z, d_{xy}
- The type of isomerism present in nitropentammine chromium (III) chloride is
[2002]
(a) optical (b) linkage
(c) ionization (d) polymerisation.
- $\text{CH}_3 - \text{Mg} - \text{Br}$ is an organo metallic compound due to
[2002]
(a) $\text{Mg} - \text{Br}$ bond (b) $\text{C} - \text{Mg}$ bond
(c) $\text{C} - \text{Br}$ bond (d) $\text{C} - \text{H}$ bond.
- One mole of the complex compound $\text{Co}(\text{NH}_3)_5\text{Cl}_3$, gives 3 moles of ions on dissolution in water. One mole of the same complex reacts with two moles of AgNO_3 solution to yield two moles of AgCl (s). The structure of the complex is
[2003]
(a) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3] \cdot 2 \text{NH}_3$
(b) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2] \text{Cl} \cdot \text{NH}_3$
(c) $[\text{Co}(\text{NH}_3)_4\text{Cl}] \text{Cl}_2 \cdot \text{NH}_3$
(d) $[\text{Co}(\text{NH}_3)_5\text{Cl}] \text{Cl}_2$
- In the coordination compound, $\text{K}_4[\text{Ni}(\text{CN})_4]$, the oxidation state of nickel is
[2003]
(a) 0 (b) +1
(c) +2 (d) -1
- The coordination number of a central metal atom in a complex is determined by
[2004]
(a) the number of ligands around a metal ion bonded by sigma and pi-bonds both
(b) the number of ligands around a metal ion bonded by pi-bonds
(c) the number of ligands around a metal ion bonded by sigma bonds
(d) the number of only anionic ligands bonded to the metal ion.
- Which one of the following complexes is an outer orbital complex?
[2004]
(a) $[\text{Co}(\text{NH}_3)_6]^{3+}$ (b) $[\text{Mn}(\text{CN})_6]^{4-}$
(c) $[\text{Fe}(\text{CN})_6]^{4-}$ (d) $[\text{Ni}(\text{NH}_3)_6]^{2+}$
(Atomic nos. : Mn = 25; Fe = 26; Co = 27, Ni = 28)
- Coordination compounds have great importance in biological systems. In this context which of the following statements is **incorrect**?
[2004]
(a) Cyanocobalamin is B_{12} and contains cobalt
(b) Haemoglobin is the red pigment of blood and contains irons
(c) Chlorophylls are green pigments in plants and contain calcium
(d) Carboxypeptidase - A is an exzyme and contains zinc.
- Which one of the following has largest number of isomers?
[2004]
(a) $[\text{Ir}(\text{PR}_3)_2\text{H}(\text{CO})]^{2+}$
(b) $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$
(c) $[\text{Ru}(\text{NH}_3)_4\text{Cl}_2]^+$
(d) $[\text{Co}(\text{en})_2\text{Cl}_2]^+$
(R = alkyl group, en = ethylenediamine)
- The oxidation state Cr in $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$ is
[2005]
(a) 0 (b) +1
(c) +2 (d) +3
- The IUPAC name of the coordination compound $\text{K}_3[\text{Fe}(\text{CN})_6]$ is
[2005]
(a) Tripotassium hexacyanoiron (II)
(b) Potassium hexacyanoiron (II)
(c) Potassium hexacyanoferrate (III)
(d) Potassium hexacyanoferrate (II)

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Chemistry

12. Which of the following compounds shows optical isomerism? [2005]
 (a) $[\text{Co}(\text{CN})_6]^{3-}$ (b) $[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$
 (c) $[\text{ZnCl}_4]^{2-}$ (d) $[\text{Cu}(\text{NH}_3)_4]^{2+}$
13. Which one of the following cyano complexes would exhibit the lowest value of paramagnetic behaviour? [2005]
 (a) $[\text{Co}(\text{CN})_6]^{3-}$ (b) $[\text{Fe}(\text{CN})_6]^{3-}$
 (c) $[\text{Mn}(\text{CN})_6]^{3-}$ (d) $[\text{Cr}(\text{CN})_6]^{3-}$
 (At. Nos : Cr = 24, Mn = 25, Fe = 26, Co = 27)
14. The IUPAC name for the complex $[\text{Co}(\text{NO}_2)(\text{NH}_3)_5]\text{Cl}_2$ is : [2006]
 (a) pentaammine nitrito-N-cobalt(II) chloride
 (b) pentaammine nitrito-N-cobalt(III) chloride
 (c) nitrito-N-pentaamminecobalt(III) chloride
 (d) nitrito-N-pentaamminecobalt(II) chloride
15. Nickel ($Z = 28$) combines with a uninegative monodentate ligand X^- to form a paramagnetic complex $[\text{NiX}_4]^{2-}$. The number of unpaired electron(s) in the nickel and geometry of this complex ion are, respectively : [2006]
 (a) one, square planar (b) two, square planar
 (c) one, tetrahedral (d) two, tetrahedral
16. In $\text{Fe}(\text{CO})_5$, the Fe – C bond possesses [2006]
 (a) ionic character
 (b) σ -character only
 (c) π -character
 (d) both σ and π characters
17. How many EDTA (ethylenediaminetetraacetic acid) molecules are required to make an octahedral complex with a Ca^{2+} ion? [2006]
 (a) One (b) Two
 (c) Six (d) Three
18. Which of the following has a square planar geometry? [2007]
 (a) $[\text{PtCl}_4]^{2-}$ (b) $[\text{CoCl}_4]^{2-}$
 (c) $[\text{FeCl}_4]^{2-}$ (d) $[\text{NiCl}_4]^{2-}$
 (At. nos.: Fe = 26, Co = 27, Ni = 28, Pt = 78)
19. The coordination number and the oxidation state of the element 'E' in the complex $[\text{E}(\text{en})_2(\text{C}_2\text{O}_4)]\text{NO}_2$ (where (en) is ethylene diamine) are, respectively, [2008]
 (a) 6 and 2 (b) 4 and 2
 (c) 4 and 3 (d) 6 and 3
20. In which of the following complexes of the Co (at. no. 27), will the magnitude of Δ_0 be the highest? [2008]
 (a) $[\text{Co}(\text{CN})_6]^{3-}$ (b) $[\text{Co}(\text{C}_2\text{O}_4)_3]^{3-}$
 (c) $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$ (d) $[\text{Co}(\text{NH}_3)_6]^{3+}$
21. Which of the following has an optical isomer [2009]
 (a) $[\text{Co}(\text{en})(\text{NH}_3)_2]^{2+}$
 (b) $[\text{Co}(\text{H}_2\text{O})_4(\text{en})]^{3+}$
 (c) $[\text{Co}(\text{en})_2(\text{NH}_3)_2]^{3+}$
 (d) $[\text{Co}(\text{NH}_3)_3\text{Cl}]^+$
22. Which of the following pairs represent linkage isomers? [2009]
 (a) $[\text{Pd}(\text{PPh}_3)_2(\text{NCS})_2]$ and $[\text{Pd}(\text{PPh}_3)_2(\text{SCN})_2]$
 (b) $[\text{Co}(\text{NH}_3)_5\text{NO}_3]\text{SO}_4$ and $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{NO}_3$
 (c) $[\text{PtCl}_2(\text{NH}_3)_4]\text{Br}_2$ and $[\text{PtBr}_2(\text{NH}_3)_4]\text{Cl}_2$
 (d) $[\text{Cu}(\text{NH}_3)_4][\text{PtCl}_4]$ and $[\text{Pt}(\text{NH}_3)_4][\text{CuCl}_4]$
23. A solution containing 2.675 g of $\text{CoCl}_3 \cdot 6\text{NH}_3$ (molar mass = 267.5 g mol^{-1}) is passed through a cation exchanger. The chloride ions obtained in solution were treated with excess of AgNO_3 to give 4.78 g of AgCl (molar mass = 143.5 g mol^{-1}). The formula of the complex is (At. mass of Ag = 108 u) [2010]
 (a) $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$
 (b) $[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$
 (c) $[\text{CoCl}_3(\text{NH}_3)_3]$
 (d) $[\text{CoCl}(\text{NH}_3)_5]\text{Cl}_2$
24. Which one of the following has an optical isomer? [2010]
 (a) $[\text{Zn}(\text{en})(\text{NH}_3)_2]^{2+}$ (b) $[\text{Co}(\text{en})_3]^{3+}$
 (c) $[\text{Co}(\text{H}_2\text{O})_4(\text{en})]^{3+}$ (d) $[\text{Zn}(\text{en})_2]^{2+}$
 (en = ethylenediamine)
25. Which one of the following complex ions has geometrical isomers? [2011]
 (a) $[\text{Ni}(\text{NH}_3)_5\text{Br}]^+$ (b) $[\text{Co}(\text{NH}_3)_2(\text{en})_2]^{3+}$
 (c) $[\text{Cr}(\text{NH}_3)_4(\text{en})_2]^{3+}$ (d) $[\text{Co}(\text{en})_3]^{3+}$
 (en ethylenediamine)

Co-ordination Compounds

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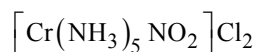
26. Which among the following will be named as dibromidobis(ethylene diamine) chromium (III) bromide? [2012]
 (a) $[\text{Cr}(\text{en})_3]\text{Br}_3$ (b) $[\text{Cr}(\text{en})_2\text{Br}_2]\text{Br}$
 (c) $[\text{Cr}(\text{en})\text{Br}_4]^-$ (d) $[\text{Cr}(\text{en})\text{Br}_2]\text{Br}$
27. Which of the following complex species is not expected to exhibit optical isomerism? [2013]
 (a) $[\text{Co}(\text{en})_3]^{3+}$
 (b) $[\text{Co}(\text{en})_2\text{Cl}_2]^+$
 (c) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$
 (d) $[\text{Co}(\text{en})(\text{NH}_3)_2\text{Cl}_2]^+$
28. The octahedral complex of a metal ion M^{3+} with four monodentate ligands L_1 , L_2 , L_3 and L_4 absorb wavelengths in the region of red, green, yellow and blue, respectively. The increasing order of ligand strength of the four ligands is: [2014]
 (a) $L_4 < L_3 < L_2 < L_1$
 (b) $L_1 < L_3 < L_2 < L_4$
 (c) $L_3 < L_2 < L_4 < L_1$
 (d) $L_1 < L_2 < L_4 < L_3$
29. Which of the following compounds is not colored yellow? [JEE M 2015]
 (a) $(\text{NH}_4)_3[\text{As}(\text{Mo}_3\text{O}_{10})_4]$
 (b) BaCrO_4
 (c) $\text{Zn}_2[\text{Fe}(\text{CN})_6]$
 (d) $\text{K}_3[\text{Co}(\text{NO}_2)_6]$
30. The number of geometric isomers that can exist for square planar complex $[\text{Pt}(\text{Cl})(\text{py})(\text{NH}_3)(\text{NH}_2\text{OH})]^+$ is (py = pyridine): [JEE M 2015]
 (a) 4 (b) 6
 (c) 2 (d) 3
31. Which one of the following complexes shows optical isomerism? [JEE M 2016]
 (a) *trans* $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$
 (b) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
 (c) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$
 (d) *cis* $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$
 (en = ethylenediamine)
32. The pair having the same magnetic moment is: [At. No.: Cr = 24, Mn = 25, Fe = 26, Co = 27] [JEE M 2016]
 (a) $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$
 (b) $[\text{CoCl}_4]^{2-}$ and $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$
 (c) $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{CoCl}_4]^{2-}$
 (d) $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$
33. On treatment of 100 mL of 0.1 M solution of $\text{CoCl}_3 \cdot 6\text{H}_2\text{O}$ with excess AgNO_3 ; 1.2×10^{22} ions are precipitated. The complex is: [2017]
 (a) $[\text{Co}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl} \cdot 2\text{H}_2\text{O}$
 (b) $[\text{Co}(\text{H}_2\text{O})_3\text{Cl}_3] \cdot 3\text{H}_2\text{O}$
 (c) $[\text{Co}(\text{H}_2\text{O})_6]\text{Cl}_3$
 (d) $[\text{Co}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$

Answer Key

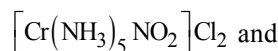
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(b)	(b)	(b)	(d)	(a)	(c)	(d)	(c)	(d)	(d)	(c)	(b)	(a)	(b)	(d)
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
(d)	(a)	(a)	(d)	(a)	(c)	(a)	(a)	(b)	(b)	(b)	(c)	(b)	(c)	(d)
31	32	33												
(d)	(d)	(d)												

SOLUTIONS

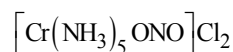
1. (b) A square planar complex is formed by hybridisation of s, p_x, p_y and $d_{x^2-y^2}$ atomic orbitals
2. (b) The chemical formula of nitropentammine chromium (III) chloride is



It can exist in following two structures



nitropentammine chromium (III) chloride

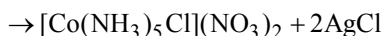


Nitropentammine chromium (III) chloride
Therefore the type of isomerism found in this compound is linkage isomerism as nitro group is linked through N as $-\text{NO}_2$ or through O as $-\text{ONO}$.

3. (b) Compounds that contain at least one carbon metal bond are known as organometallic compounds. In $\text{CH}_3\text{-Mg-Br}$ (Grignard's reagent) a bond is present between carbon and Mg (Metal) hence it is an organometallic compound.

4. (d) $\text{Co}(\text{NH}_3)_5\text{Cl}_3 \rightleftharpoons [\text{Co}(\text{NH}_3)_5\text{Cl}]^{+2} + 2\text{Cl}^-$
 \therefore Structure is $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$.

Now $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2 + 2\text{AgNO}_3$



5. (a) Let the O. No. of Ni in $\text{K}_4[\text{Fe}(\text{CN})_6]$ be x then

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

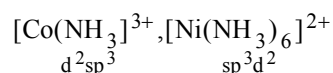
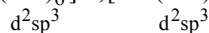
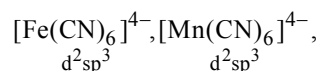
$$\Rightarrow 4 + x - 4 = 0$$

$$x = 0$$

6. (c) The coordination number of central metal atom in a complex is equal to number of monovalent ligands, twice the number of bidentate ligands and so on, around the metal ion bonded by coordinate bonds.

Hence coordination number = no. of σ bonds formed by metals with ligands

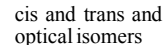
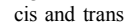
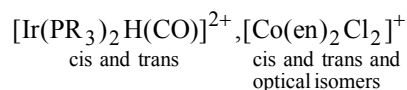
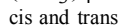
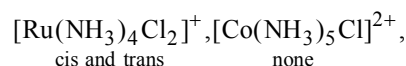
7. (d) Hybridisation



Hence $[\text{Ni}(\text{NH}_3)_6]^{2+}$ is outer orbital complex.

8. (c) The chlorophyll molecule plays an important role in photosynthesis, contain porphyrin ring and the metal Mg not Ca.

9. (d) Isomers

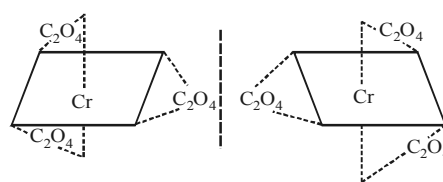


10. (d) Oxidation state of Cr in $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$.

Let it be x , $1 \times x + 4 \times 0 + 2 \times (-1) = 1$
Therefore $x = 3$.

11. (c) $\text{K}_3[\text{Fe}(\text{CN})_6]$ is potassium hexacyanoferrate (III).

12. (b)



Non-superimposable mirror images, hence optical isomers.

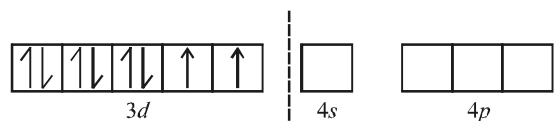
13. (a) No. of unpaired electron



The effective magnetic moment is given by the number of unpaired electrons in a substance, the lesser the number of unpaired electrons lower is its magnetic moment in Bohr – Magneton and lower shall be its paramagnetism

14. (b) $[\text{Co}(\text{NO})_2(\text{NH}_3)_5]\text{Cl}_2$
pentaammine nitrito-N-cobalt (III) chloride

15. (d) $[\text{Ni X}_4]^{2-}$, the electronic configuration of Ni^{2+} is



It contains two unpaired electrons and the hybridisation is sp^3 (tetrahedral).

16. (d) Due to some backbonding by sidewise overlapping of between d-orbitals of metal and p-orbital of carbon, the Fe–C bond in $\text{Fe}(\text{CO})_5$ has both σ and π character.

17. (a) EDTA has hexadentate four donor O atoms and 2 donor N atoms and for the formation of octahedral complex one molecule is required

Co-ordination Compounds

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18. (a) Complexes with dsp^2 hybridisation are square planar. So $[\text{PtCl}_4]^{2-}$ is square planar in shape.

19. (d) In the given complex we have two bidentate ligands (i.e en and C_2O_4), so coordination number of E is 6

$$(2 \times 2 + 1 \times 2 = 6)$$

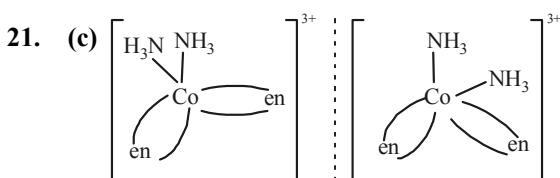
Let the oxidation state of E in complex be x, then

$$[x + (-2) = 1] \text{ or } x - 2 = 1$$

or $x = +3$, so its oxidation state is +3

Thus option (d) is correct.

20. (a) In octahedral complex the magnitude of Δ_o will be highest in a complex having strongest ligand. Of the given ligands CN^- is strongest so Δ_o will be highest for $[\text{Co}(\text{CN})_6]^{3-}$. Thus option (a) is correct.



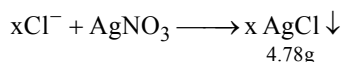
Enantiomers of $\text{cis-}[\text{Co}(\text{en})_2(\text{NH}_3)_2]^{3+}$

22. (a) The SCN^- ion can coordinate through S or N atom giving rise to linkage isomerism

$\text{M} \leftarrow \text{SCN}$ thiocyanato

$\text{M} \leftarrow \text{NCS}$ isothiocyanato.

23. (a) $\text{CoCl}_3 \cdot 6\text{NH}_3 \longrightarrow x\text{Cl}^-$
2.675g



Number of moles of the complex

$$= \frac{2.675}{267.5} = 0.01 \text{ moles}$$

Number of moles of AgCl obtained

$$= \frac{4.78}{143.5} = 0.03 \text{ moles}$$

\therefore No. of moles of AgCl obtained

$$= 3 \times \text{No. of moles of complex}$$

$$\therefore n = \frac{0.03}{0.01} = 3$$

24. (b) For a substance to be optical isomer following conditions should be fulfilled

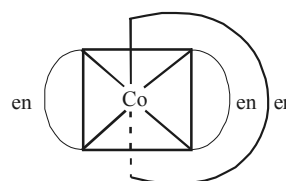
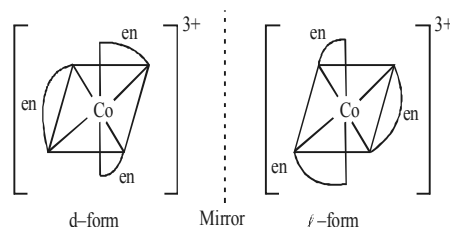
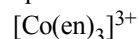
(a) A coordination compound which can rotate the plane of polarised light is said to be optically active.

(b) When the coordination compounds have same formula but differ in their abilities to rotate directions of the plane of polarised light are said to exhibit optical isomerism and the molecules are optical isomers. The optical isomers are pair of molecules which are non-superimposable mirror images of each other.

(c) This is due to the absence of elements of symmetry in the complex.

(d) Optical isomerism is expected in tetrahedral complexes of the type Mabcd .

Based on this only option (2) shows optical isomerism



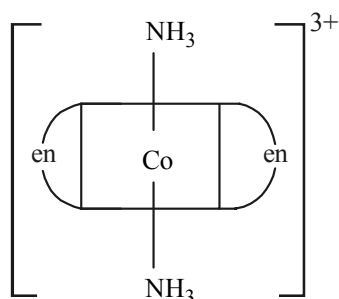
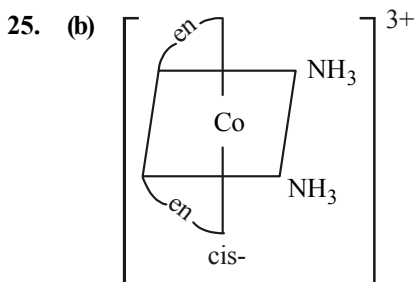
'Meso' or optically inactive form

Complexes of Zn^{++} cannot show optical isomerism as they are tetrahedral complexes with plane of symmetry.

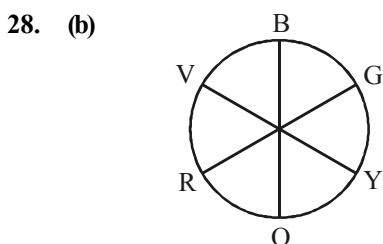
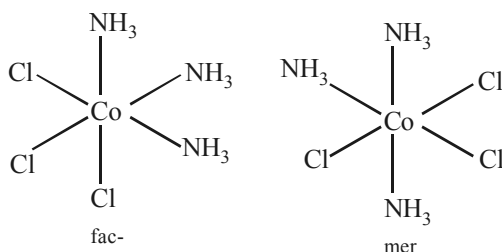
$[\text{Co}(\text{H}_2\text{O})_4(\text{en})]^{3+}$ have two planes of symmetry hence it is also optically inactive. Hence the formula of the complex is $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

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Chemistry



26. (b) $[\text{Cr}(\text{en})_2\text{Br}_2]\text{Br}$
dibromidobis(ethylenediamine)chromium (III) Bromide.
27. (c) Octahedral coordination entities of the type Ma_3b_3 exhibit geometrical isomerism. The compound exists both as facial and meridional isomers, both contain plane of symmetry



For a given metal ion, weak field ligands

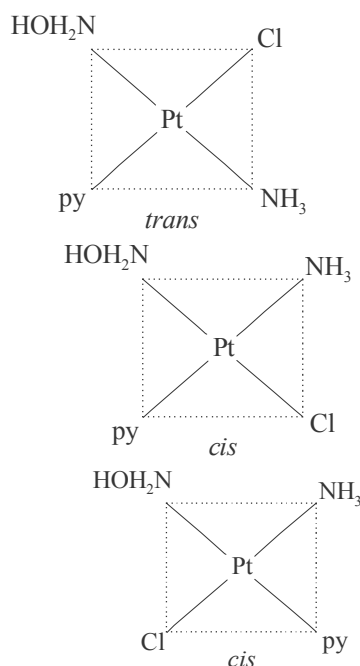
create a complex with smaller Δ , which will absorb light of longer λ and thus lower frequency. Conversely, stronger field ligands create a larger Δ , absorb light of shorter λ and thus higher ν i.e. higher energy.

$$\begin{array}{cccc} \text{Red} & < & \text{Yellow} & < & \text{Green} & < & \text{Blue} \\ \lambda = 650 \text{ nm} & & 570 \text{ nm} & & 490 \text{ nm} & & 450 \text{ nm} \end{array}$$

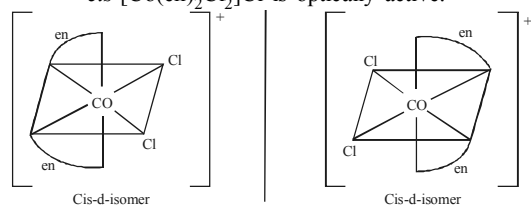
So order of ligand strength is

$$L_1 < L_3 < L_2 < L_4$$

29. (c)
30. (d) Square planar complexes of type $\text{M}[\text{ABCD}]$ form three isomers. Their position may be obtained by fixing the position of one ligand and placing at the *trans* position any one of the remaining three ligands one by one.



31. (d) Optical isomerism occurs when a molecule is non-super imposable with its mirror image hence the complex $\text{cis}-[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$ is optically active.



Co-ordination Compounds

c-115

32. (d)

Complex Configuration	Metal ion Magnetic moment
	$\mu = \sqrt{n(n+2)}$
(a) $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$ d ⁴	Cr^{+2} $\sqrt{24}$
(b) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ d ⁶	Fe^{2+} $\sqrt{24}$
(c) $[\text{CoCl}_4]^{2-}$ d ⁷	Co^{2+} $\sqrt{15}$
(d) $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$ Mn^{2+} d ⁵	$\sqrt{35}$

Since (a) and (b), each has 4 unpaired electron they will have same magnetic moment

33. (d) Moles of complex

$$= \frac{\text{Molarity} \times \text{Volume(ml)}}{1000}$$

$$= \frac{100 \times 0.1}{1000} = 0.01 \text{ mole}$$

Moles of ions precipitated with excess of

$$\text{AgNO}_3 = \frac{1.2 \times 10^{22}}{6.02 \times 10^{23}} = 0.02 \text{ moles}$$

$$0.01 \times n = 0.02$$

$$\therefore n = 2$$

It means 2Cl^- ions present in ionization sphere

$$\therefore \text{complex is } [\text{Co}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$$