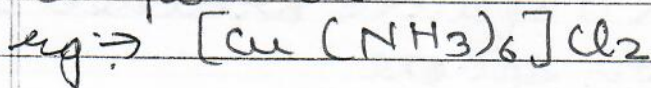
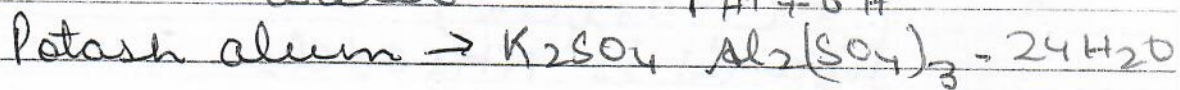
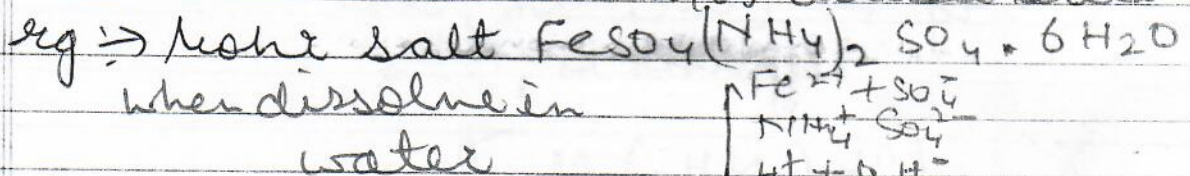


## Coordination Compounds

Coordination compounds  $\rightarrow$  The compound in which ion or neutral molecule is attached with metal ion by a coordinate bond and retain their identity both in solid state as well as in liquid state are called as coordination compounds.



Double salt  $\rightarrow$  The compounds which are formed by the addition of two or more simple salts but lose their identity when dissolve in solution or water are called as double salt.



\* Difference b/w double salt and coordination compounds  $\rightarrow$

Double salts	Coordination compounds
1) Double salts exists only in solid state.	Coordination compounds exists in both solid and liquid state.
2) Double salt loose their identity in solution.	Coordination compound can maintain their identity in solution.
3) The properties of double salt are	The properties of coordination compounds



similar to their constituent compounds.

are different to their from their constituent compounds.

\* Complex ion  $\rightarrow$  The ion in which metal ion is bonded to  $-ve$  ion or a neutral molecule by a coordinate bond;  
For eg  $\rightarrow [Cu(NH_3)_6]^{2+}$   $[Fe(CN)_6]^{3-}$

Coordination sphere  $\rightarrow$  The sphere metal ion and the  $-ve$  ion or neutral molecule enclosed in a square bracket is called coordination sphere.

Ligands  $\rightarrow$  The ion or the neutral molecule attached to metal ion by a coordinate bond within a coordination compound is called ligands.

eg.  $\Rightarrow [Cu(NH_3)_6]Cl_2$   
ligands is  $NH_3$

$[Pt(NH_3)_4Cl_2]$   
ligands is  $NH_3$  and  $Cl_2$

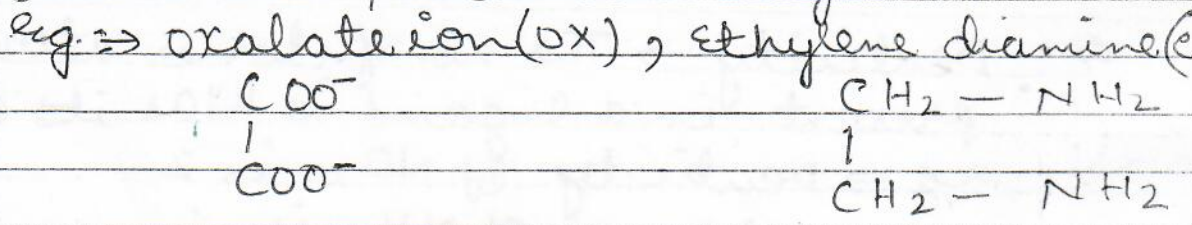
Types of ligands  $\Rightarrow$

Depending upon the no. of donor atoms we have following types of ligands-

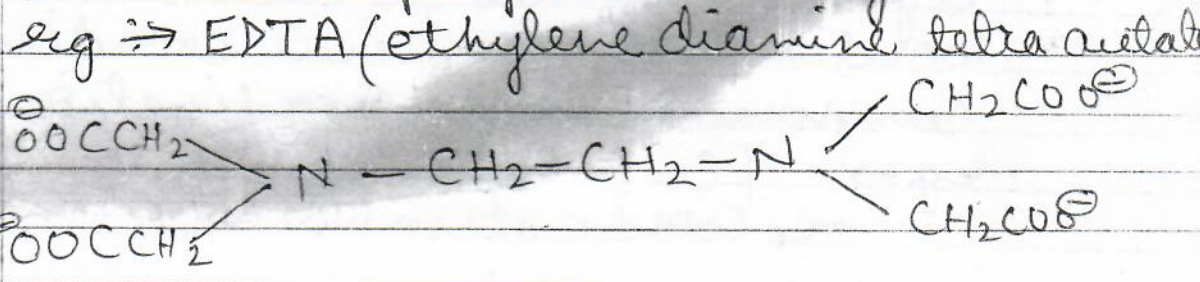
- 1) unidentate / bidentate ligand  $\rightarrow$  The ligands containing only one donor atom which can donate  $e^-$  to metal ion is called monodentate or unidentate ligands. eg  $\rightarrow NH_3, H_2O, CN^-, Cl^-$  etc.
- 2) ~~bidentate~~ bidentate / ~~didentate~~ didentate ligand  $\rightarrow$  The



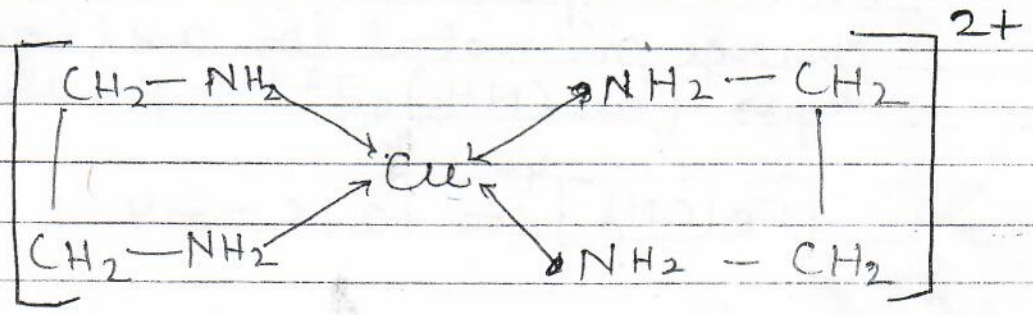
ligand which contains two donor atoms which can donate  $e^-$  to metal ion is called didentate / bidentate ligand.



3) Polydentate ligand  $\rightarrow$  The ligands containing ~~only~~ more than two donor atoms which can donate  $e^-$  to metal ion is called polydentate ligand.



$\Rightarrow$  Chelating ligand / chelate  $\rightarrow$  when didentate or bidentate ligands combine with metal ion and forms a ring or cyclic structure coordination compounds then the ligand is called chelating ligand and the coordination compounds forms is called chelate.



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Ambident ligand  $\rightarrow$  The monodentate or unidentate ligand which contain more



than one donor atom is called ambident ligand.

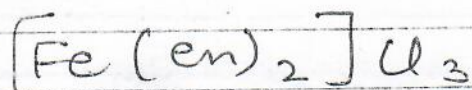
eg  $\Rightarrow$   $\text{NO}_2$

$\text{M} \leftarrow \text{NO}_2$  N donates atom to metal ion

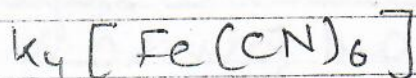
$\text{M} \leftarrow \text{ONO}$  O donates atom to metal ion

$\Rightarrow$  Denticity  $\rightarrow$  The no. of donor atoms present in a ligand is called its denticity  
 eg  $\Rightarrow$  Denticity of  $\text{NO}_2$  is 2  
           "          of  $\text{NH}_3$  is 1  
           "          " EDTA is 6

\* Coordination number  $\rightarrow$  The no. of ligand attached to metal ion by a coordination bond in a coordination compound is called coordination number.  
 eg  $\Rightarrow$   $[\text{Cu}(\text{NH}_3)_4\text{Cl}_2]$   
 The coordination no. is 6



The coordination no. is 4



The coordination no. is 6

\* Charge on complex ion  $\rightarrow$  The charge on the complex ion is the sum of the charge on metal ion and ligand.  
 eg  $\Rightarrow$   $[\text{Cu}(\text{NH}_3)_4]^{2+} = +2 + 0 = +2$





\* Oxidation number  $\rightarrow$  Oxidation number of a central metal atom is the charge it would carry if all the ligands are removed along with electron pairs.

\* IUPAC naming of coordination compound  $\rightarrow$  Rules

- ① Order of naming ions - During naming of coordination compounds cation is named first than anion.
- ② Naming of coordination sphere - In complex the ion ligand is named first than metal ion.
- ③ Naming of ligands - There are two types of ligands  $\rightarrow$  negative and neutral  
Negative ligand  $\rightarrow$  the name of -ve ligand ends with O.

$F^- \rightarrow$  fluoro

$Cl^- \rightarrow$  chlorido

$Br^- \rightarrow$  bromido

$NO_2^- \rightarrow$  Nitrito

$NO_3^- \rightarrow$  Nitrate

$CN^- \rightarrow$  ~~Cyano~~ cyanido

$OH^- \rightarrow$  hydroxo

$SO_4^{2-} \rightarrow$  sulphato

$NH_2^- \rightarrow$  amido

$NH^{2-} \rightarrow$  imido

$COO^- \rightarrow$  oxalato

$SCN^-$  - Thiocyanato

Neutral ligands  $\rightarrow$  Neutral ligand have special name.

$H_2O \rightarrow$  aquo



$\text{NH}_3 \rightarrow$  amine  
 $\text{CO} \rightarrow$  carbonyl  
 $\text{NO} \rightarrow$  nitrosyl  
 $\text{en} \rightarrow$  ethane 1,2 diamine  
 $\text{CH}_3 \rightarrow$  methyl

Order of naming different ligands  $\rightarrow$  The naming of different ligands is done in alphabetical manner.

Numerical prefixes to indicate the no. of ligand  $\rightarrow$  Prefixes such as di, tri, tetra, penta, hexa etc. are used to indicate the no. of ligands.

Suppose prefix such as di, tri, tetra etc. are present in the name of ligand then for these ligand prefix is bis, tris, tetrakis.

④ Naming of metal ion  $\rightarrow$  If complex ion is +ve i.e. cation then there is no special name for the metal.

If the complex ion is -ve i.e. anion then the name of metal ends with ate.

$\text{Cu} \rightarrow$  Cuprate       $\text{Hg} \rightarrow$  Mercurate  
 $\text{Pt} \rightarrow$  Platinate  
 $\text{Fe} \rightarrow$  Ferrate  
 $\text{Ag} \rightarrow$  Argenate  
 $\text{Zn} \rightarrow$  Zincate  
 $\text{Au} \rightarrow$  Aurate



eg  $\Rightarrow K_4 [Fe (CN)_6] \rightarrow$  Potassium hexacyanido ferrate(II)

$[Cu (NH_3)_6] SO_4 \rightarrow$  hexa ammine copper(II) sulphate -

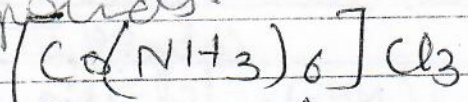
IUPAC name

- ①  $K_3 [Fe (CN)_6] \rightarrow$  Potassium hexacyanoferrate(III)
- ②  $Na_3 [Cr(OH)_2F_4] \rightarrow$  sodium tetrafluoridodihydroxochromate(III)
- ③  $K_3 [Fe (CN)_5 NO] \rightarrow$  Potassium pentacyanonitrosyl ferrate(III)
- ④  $[Cr Cl_2(en)_2] Cl \rightarrow$  dichlorido bis(ethane-1,2-diamine)chromium(III) chloride
- ⑤  $Na [Au(CN)_2] \rightarrow$  sodium dicyanoaurate(I)
- ⑥  $[Co(NH_3)_4(H_2O)Cl] Cl_2 \rightarrow$  tetraammine aquachloridocobalt(III) chloride
- ⑦  $[Pt Cl(NH_2CH_3)(NH_3)_2] Cl \rightarrow$  diaminechlorido(methylamine)platinum(II) chloride
- ⑧  $Hg [Co(SCN)_4] \rightarrow$  Mercury tetrathiocyanatocobaltate(II)
- ⑨  $[Co(en)_3] Cl_3 \rightarrow$  Tris(ethane-1,2-diamine)cobalt(III) chloride
- ⑩  $[CoCl(NH_3)_5] Cl_2 \rightarrow$  pentaamminechloridocobalt(III) chloride
- ⑪  $[CoCO_3(NH_3)_5] Cl \rightarrow$  pentaamminecarbonatocobalt(III) chloride
- ⑫  $[CoONO(NH_3)_5] SO_4 \rightarrow$  pentaammine nitrito-O-cobalt(III) sulphate
- ⑬  $[Co(NH_3)_5(NO_2)](NO_3)_2 \rightarrow$  pentaammine nitrito-N-cobalt(III) nitrate
- ⑭  $[CoBr_2(en)_2]^+ \rightarrow$  dibromido bis(ethane-1,2-diamine)cobalt(III) ion
- ⑮  $K_4 [Ni(CN)_4] \rightarrow$  Potassium tetracyanonickelate(0)

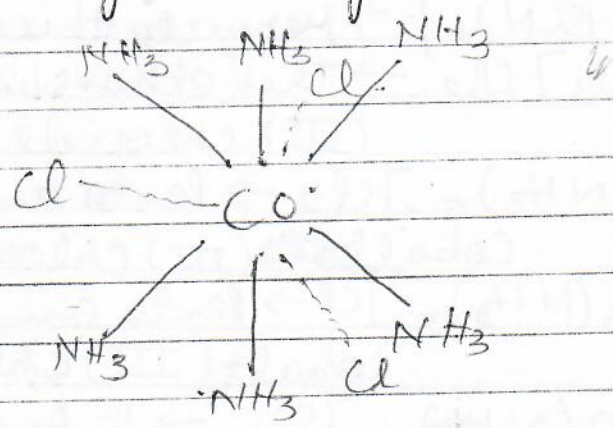


\* Werner's theory of coordination compounds  
→ The main points of this theory are:

- ① In coordination compound metal ion exhibit two types of valency primary valency and secondary valency.
- ② The primary valency is ionizable and is  $K/a$  oxidation state whereas the secondary valency is non ionizable and  $K/a$  coordination number.
- ③ Every metal atom has two satisfied both these valencies. The primary valency is satisfied by  $-ve$  ion whereas the secondary valency is satisfied by both  $-ve$  ion and neutral molecules.
- ④ The secondary valency is always directed in space in certain fix geometry which gives the geometry of coordination compounds.



Primary valency → +3  
secondary valency → 6



\* Isomerism in coordination compound  
→ Isomerism → Two or more compound

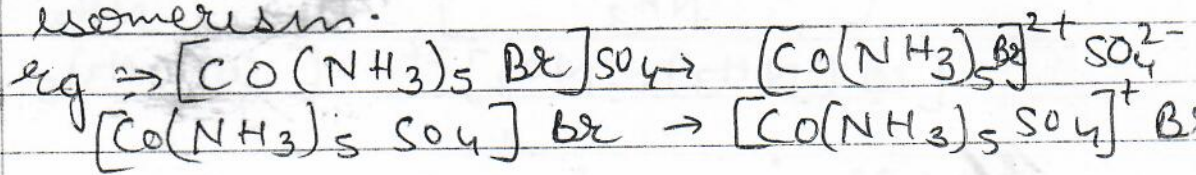


having same molecular formula and different properties is called isomerism and this phenomenon is called isomerism. Coordination compound shows two types of isomer  $\Rightarrow$

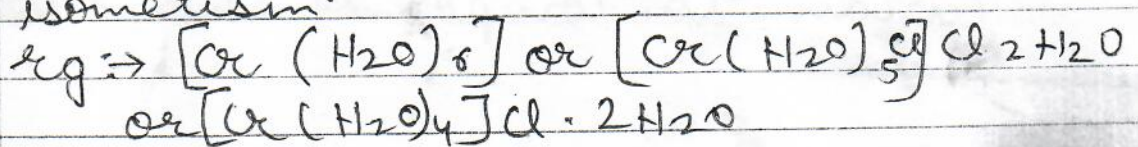
Structural isomerism  $\rightarrow$  Two or more compounds having same molecular formula and different in structure formula called structural isomer and this phenomenon is called structural isomerism.

Coordination compound shows different types of structural isomerism:

(i) Ionisation isomerism  $\rightarrow$  Two or more compounds having same molecular formula but gives different ions in solution are called ionisation isomer and this phenomenon is called ionisation isomerism.



(ii) Hydrate or solvate isomerism  $\rightarrow$  Two or more compounds having same molecular formula but differ in the number of water molecules as a ligand are called hydrate or solvate isomers and this phenomenon is called hydrate or solvate isomerism.





following types of  $\pm$  stereoisomerism:  $\rightarrow$

- 1) Geometrical isomerism
- 2) Optical isomerism

Geometrical isomerism  $\rightarrow$  In coordination compounds, this arises due to ligands occupying different positions around central atom. If same type of ligands are present on the same side then the geometrical isomerism is called as cis isomer.

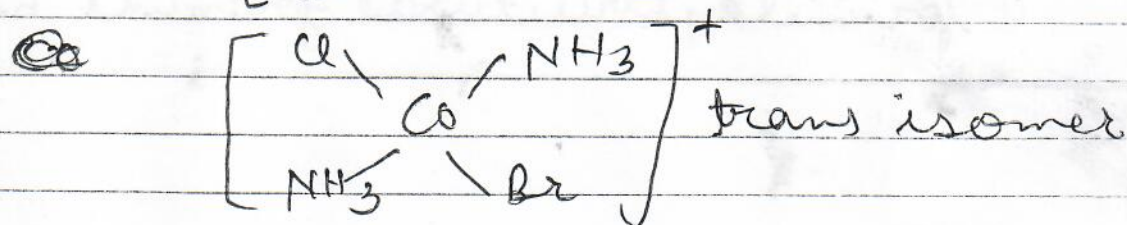
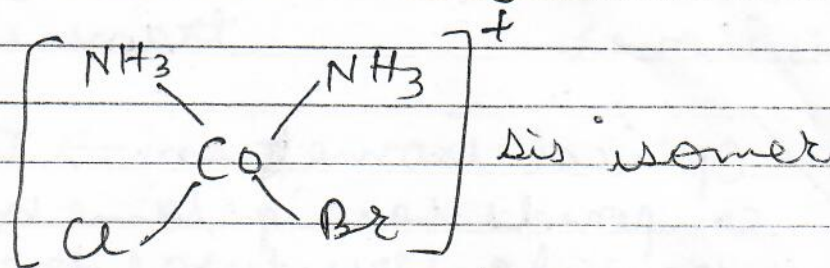
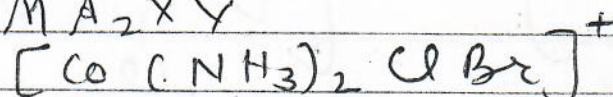
If the same type of ligands are present in different ~~side~~ in opposite directions. Then the geometrical isomerism is called as trans isomer.

Coordination compounds with coordination number 4 and 6 show geometrical isomerism.

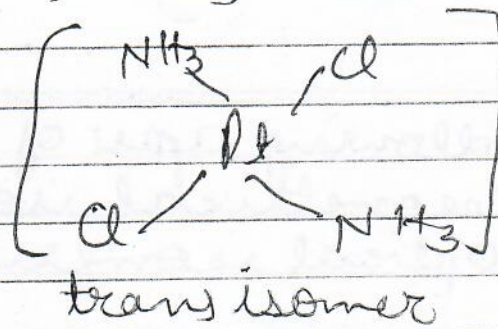
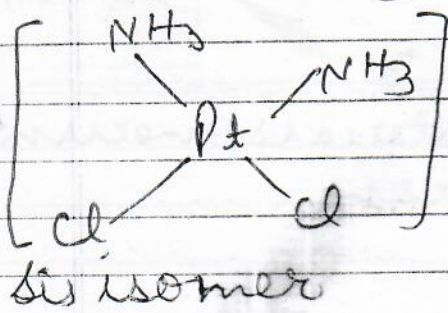
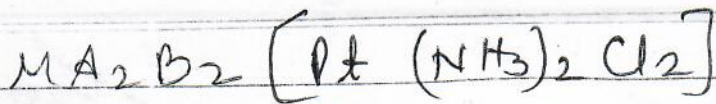
Coordination compounds with coordination number 4  $\Rightarrow$

Coordination compound having general formula  $MA_2XY$  or  $MA_2B_2$  shows geometrical isomerism.

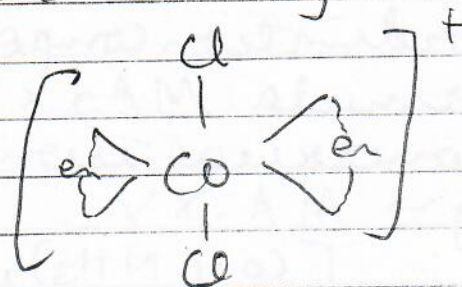
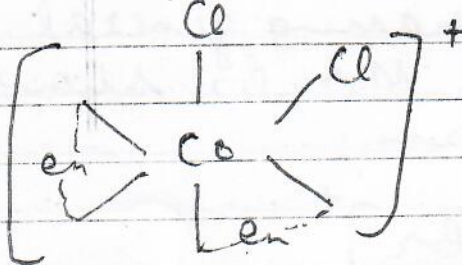
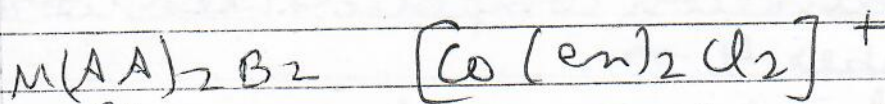
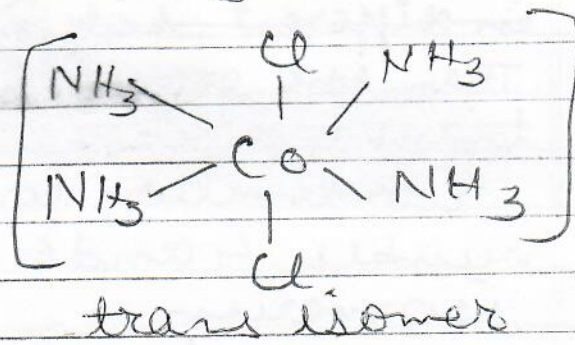
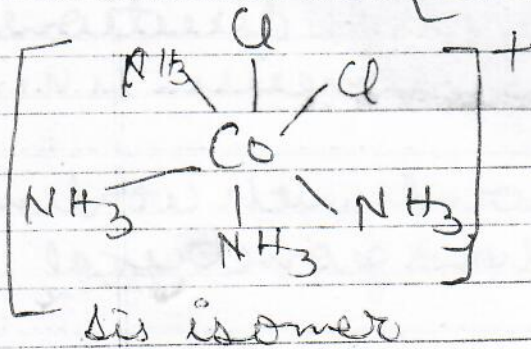
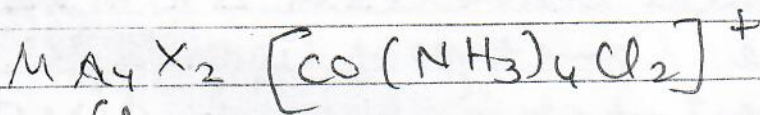
eg  $\rightarrow MA_2XY$







Coordination compounds with coordination number 6  $\rightarrow$  coordination compounds with a general formula  $MA_4X_2$  and  $M(AA)_2B_2$  shows geometrical isomerism



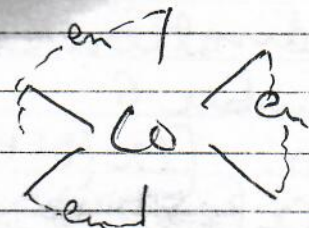
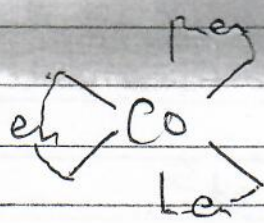
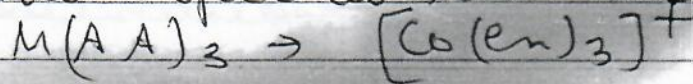
Optical isomerism  $\rightarrow$  Two or more compounds having same molecular formula, structural formula but



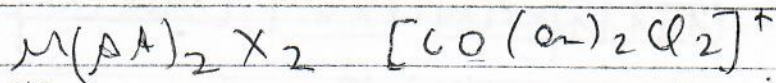
differ in their behaviour towards plane polarise light as optical isomers and this phenomenon is called as optical isomerism.

Optical isomers are non superposable mirror image of each other.

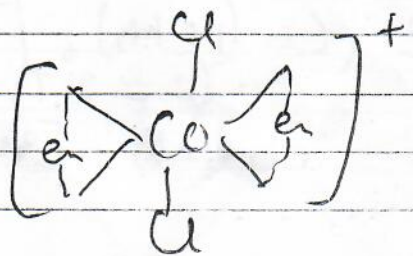
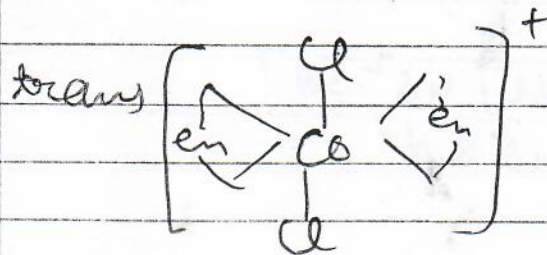
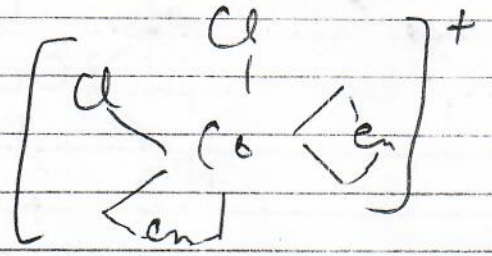
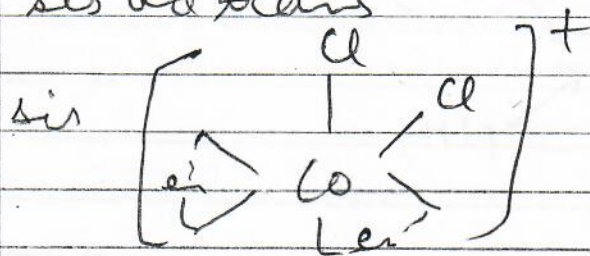
Coordination compounds with coordination number 6 and having at least one didentate ligand shows optical isomerism. Coordination compounds with general formula  $M(AA)_3$ ,  $M(AA)_2X_2$ ,  $MA_4X_2$  shows optical isomerism.



mirror image



This can has 2 geometrical isomerism and trans

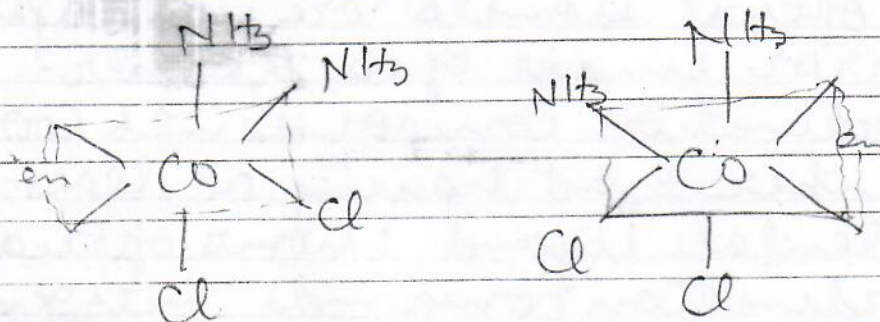
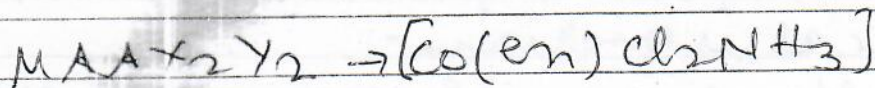


Since the mirror image of trans isomer



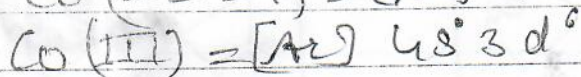
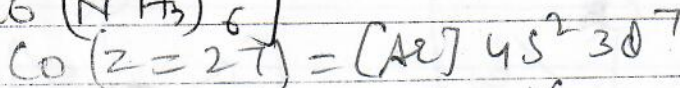
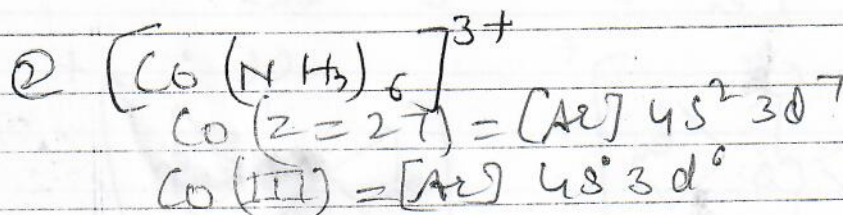
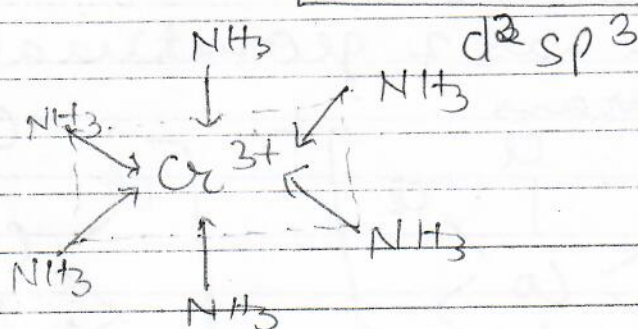
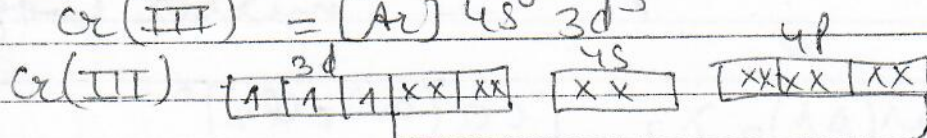
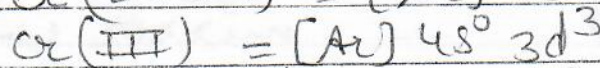
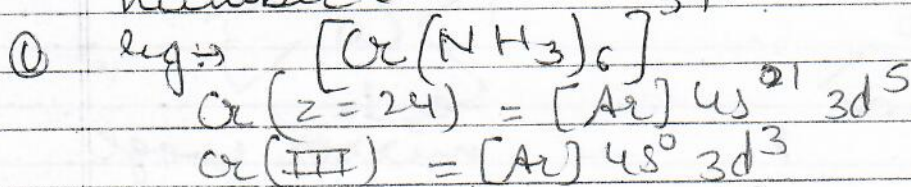
is superimposable. Therefore it does not show optical isomerism.

Hence, the mirror image of this isomer is non-superimposable. Therefore it shows optical isomerism.

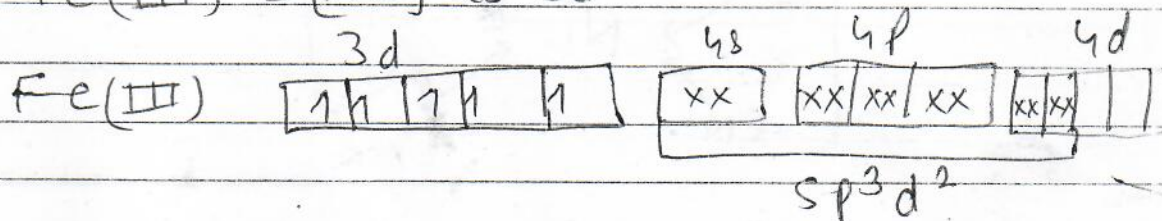
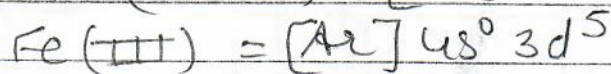
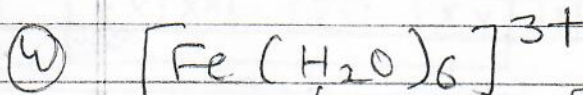
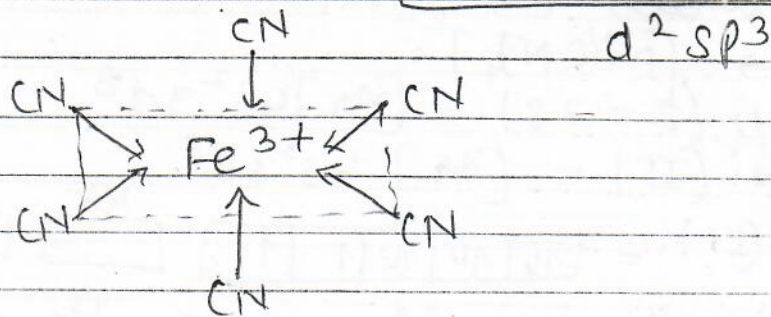
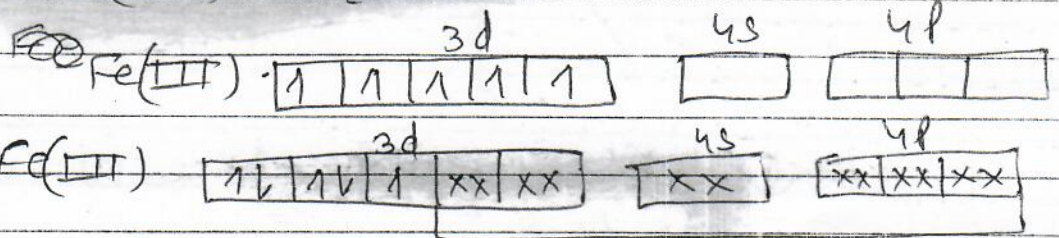
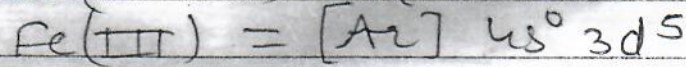
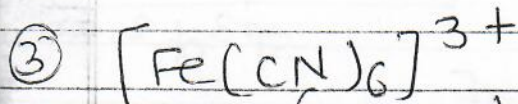
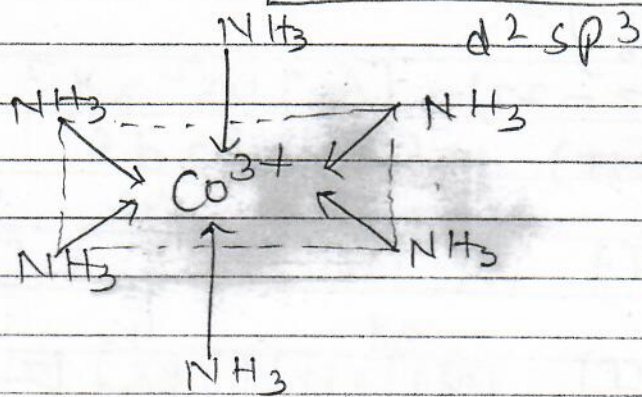
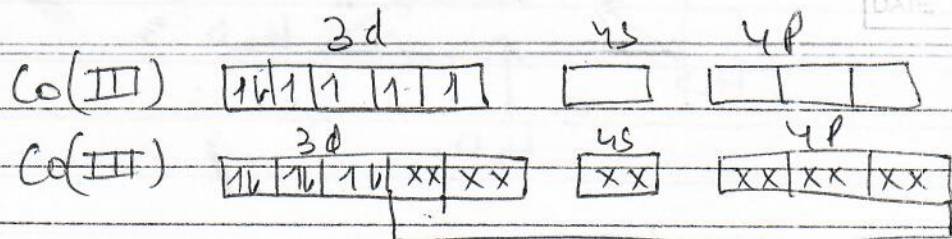


\* Bonding in Coordination Compounds

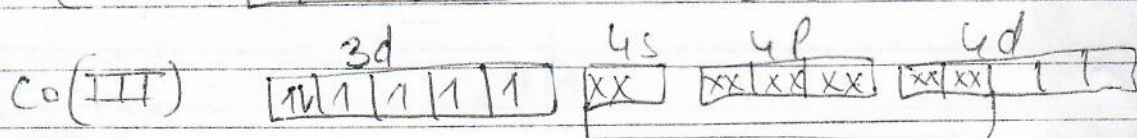
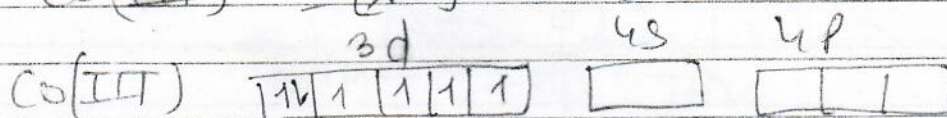
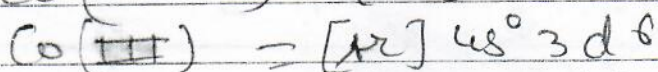
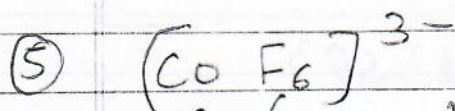
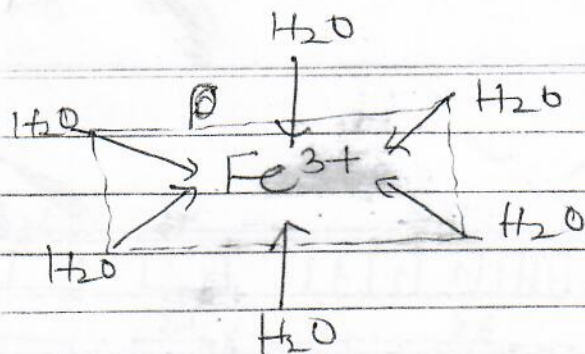
Coordination Compounds with Coordination number 6



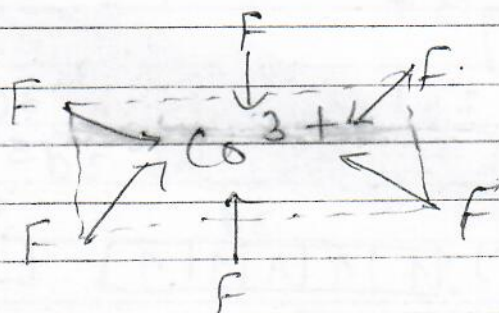




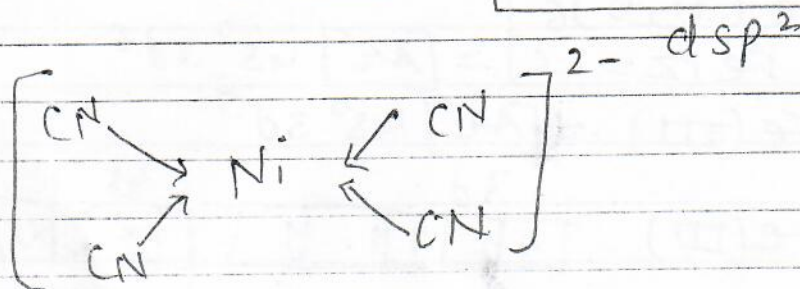
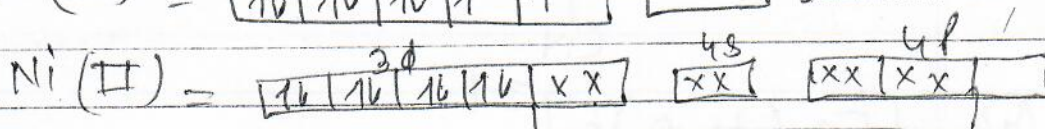
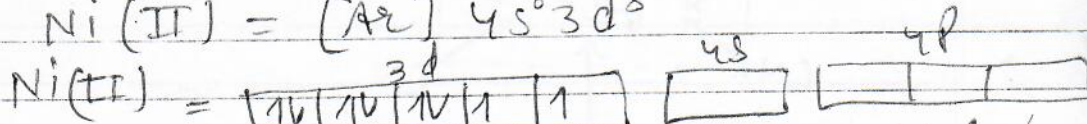
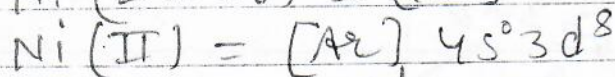
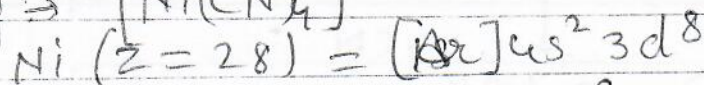
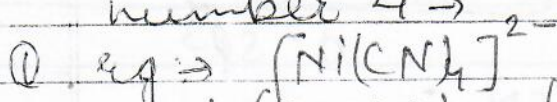




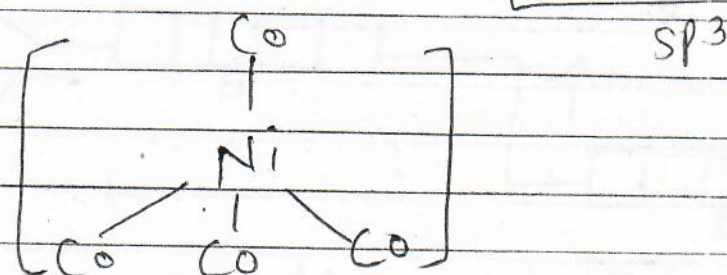
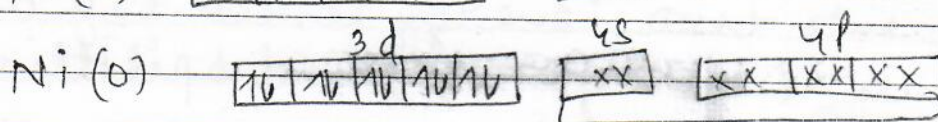
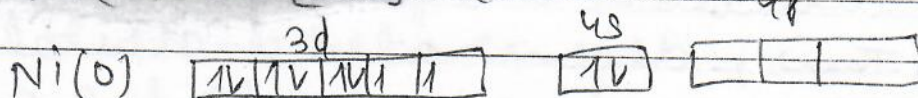
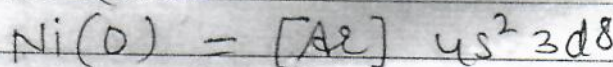
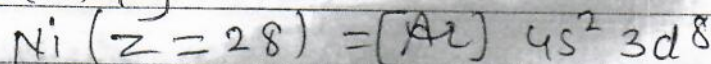
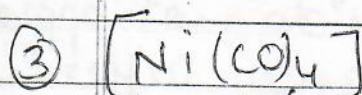
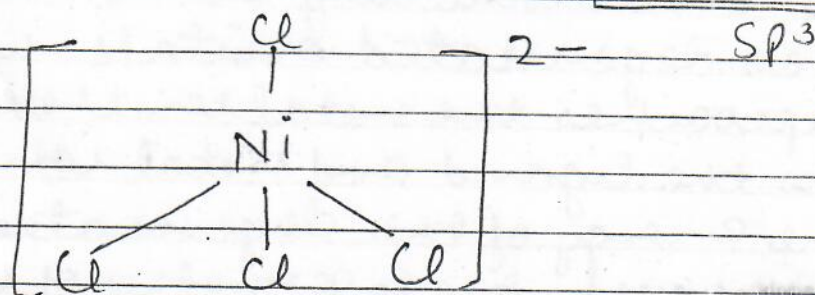
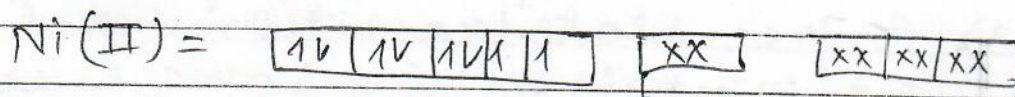
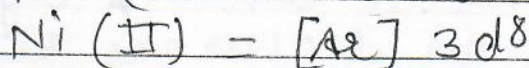
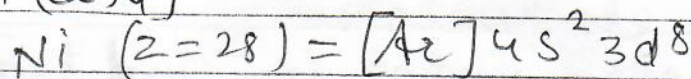
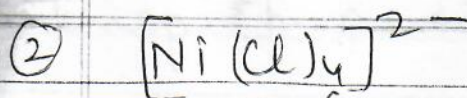
$sp^3d^2$



Coordination compounds with coordination number 4  $\rightarrow$







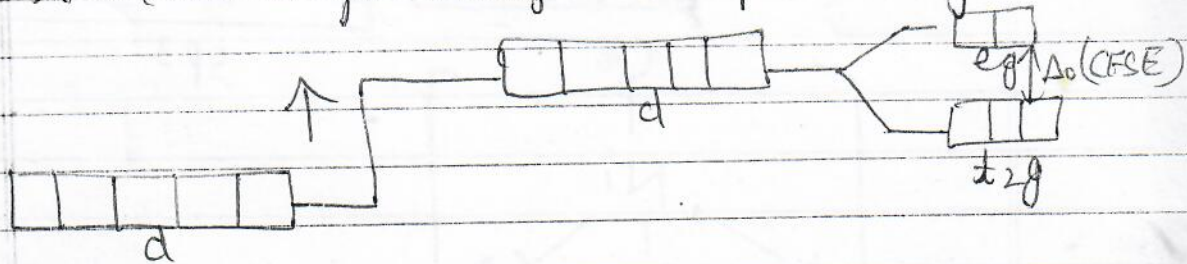
- Limitations of valence bond theory
- (1) It cannot explain the colour of the coordination compound.
  - (2) It cannot distinguish the weak and strong bond ligand.
  - (3) Some of the magnetic properties of coordination compound are misleading.

\* Crystal field theory  $\rightarrow$

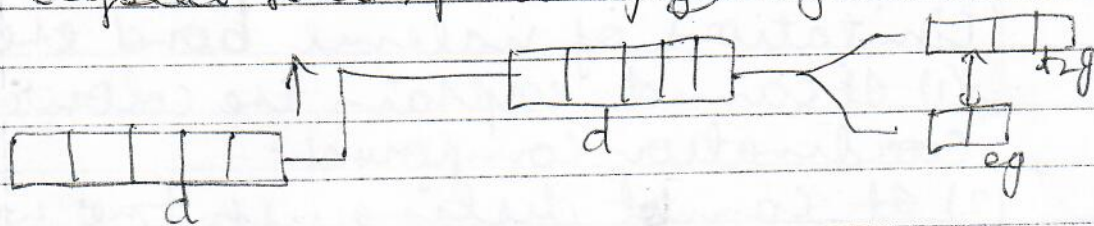


The main points of this theory are:

- 1) Crystal field theory ~~are~~ consist the bond b/w the metal ion and ligand as purely electrostatic.
- 2) It treated metal ion and ligand as +ve and -ve point charges respectively.
- 3) In free state transition metal ions have 5d orbitals having same energy and  $\therefore$  as degenerated orbitals. When ligands approaches the metal ion there is interaction b/w the ligand and metal ion ~~there~~ and the energy of the degenerated orbitals increases. Due to geometry of coordination compounds all the ligands do not approach through the same distance. Different orbitals approaches from different directions and faces different interaction thus, degenerated d-orbital split up into two energy levels  $t_{2g}$  and  $e_g$ . This is  $\therefore$  as crystal field splitting -



Crystal field splitting ~~from~~ for octahedral



Crystal field splitting for tetrahedral