

# 12th hacker series

## Coordination compounds

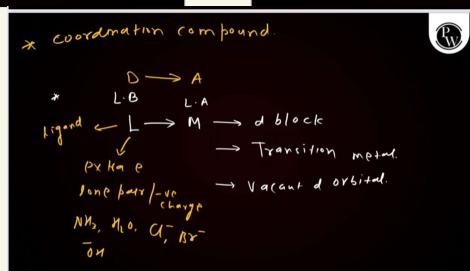
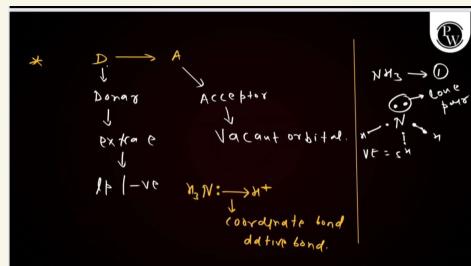
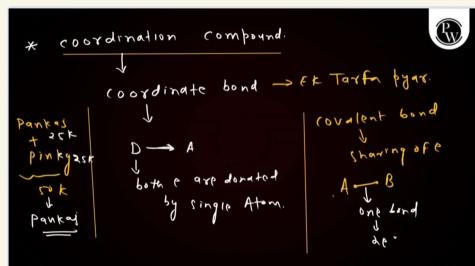
### Introduction

A compound containing coordinate bonds between a central metal atom and a number of other atoms or groups

The transition metal ion are considered for coordinate compounds because

- they have small size
- They have vacant orbitals
- They can accept lone pairs of electrons

Chlorophyll, haemoglobin and vitamin B<sub>12</sub> are coordination compounds of magnesium, iron and cobalt, respectively



**QUESTION**

Vitamin B-12 contains: ✓

A cobalt

B magnesium

C iron

D nickel

**QUESTION**
**Chlorophyll contains:**

- A magnesium
- B iron
- C cobalt
- D nickel

**QUESTION – NCERT EXEMPLAR**

**Match the coordination compounds given in Column I with the central metal atoms given in Column II and assign the correct code :**

Column I (Coordination Compound)	Column II (Central metal atom)
A. Chlorophyll	1. rhodium
B. Blood pigment	2. cobalt
C. Wilkinson catalyst	3. calcium
D. Vitamin B12	4. iron
	5. magnesium

**Code:**

- A (5)    B (4)    C (1)    D (2)
- B (3)    B (4)    C (5)    D (1)
- C (4)    B (3)    C (2)    D (1)
- D (3)    B (4)    C (1)    D (2)

## Double salt

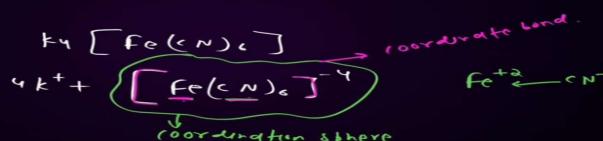
- Double salt dissociate into simple ions completely when dissolved in water



The carnallite gives the test for  $\text{K}^+$ ,  $\text{Cl}^-$ ,  $\text{Mg}^{+2}$  ions in aqueous solutions.

## Complex salt

→ Complex ions such as  $[\text{Fe}(\text{CN})_6]^{4-}$  of  $\text{K}_4[\text{Fe}(\text{CN})_6]$  do not dissociate into  $\text{Fe}^{2+}$  and  $\text{CN}^-$  ions.


**QUESTION**
**Mohr's salt is**

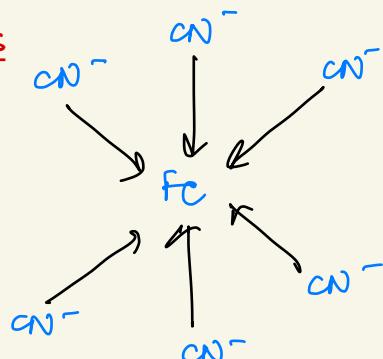
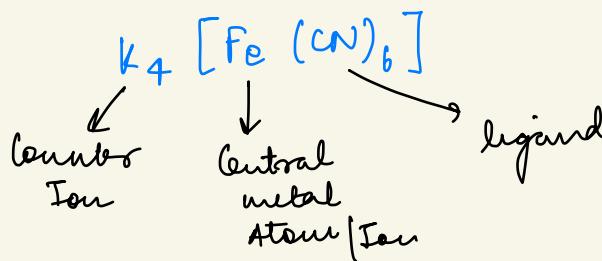
- A  $\underline{\text{Fe}(\text{NH}_4)\text{SO}_4 \cdot 6\text{H}_2\text{O}}$  ×
- B  $\underline{\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}}$  ×
- C  $(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}$
- D  $\left( \text{FeSO}_4 \cdot 7\text{H}_2\text{O} \right) \cdot \text{Fe}^{+2} \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$

### QUESTION

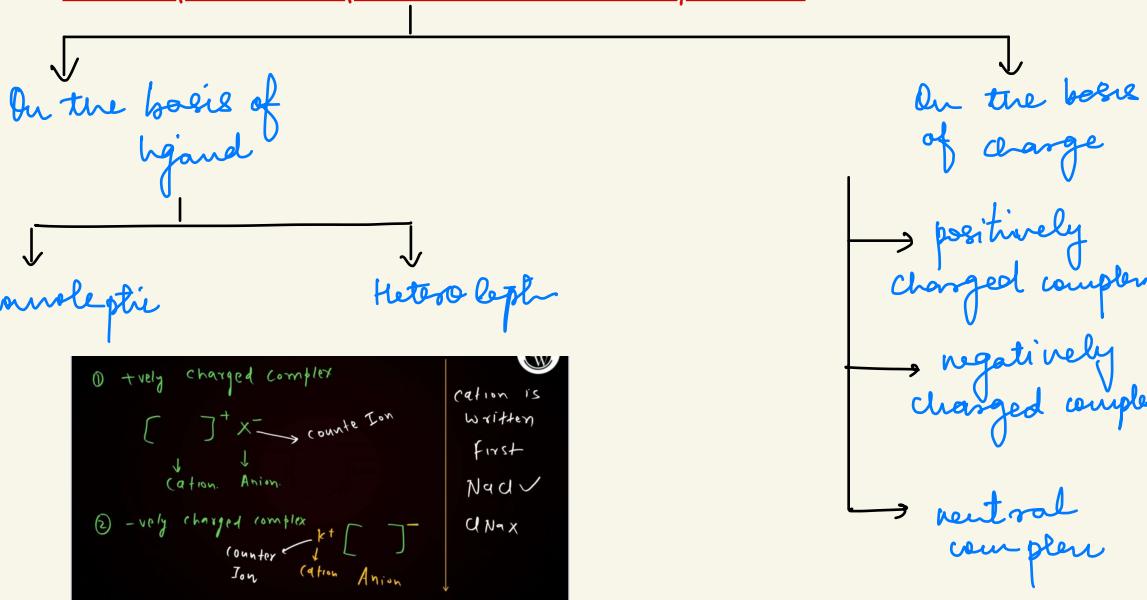
An aqueous solution of potash alum gives

- A Two types of ions
- B Only one type of ion
- C Four types of ions
- D Three types of ions

### Terminology of coordination compounds



### Classification of coordination compounds



## Terminology of coordination compound

### • coordination sphere

→ Central metal atom and all ligands are enclosed in square brackets along with the total charge on this sphere is known as coordination sphere. Eg -  $[\text{Fe}(\text{CN})_6]^{4-}$

→ In the complex  $\text{K}_4[\text{Fe}(\text{CN})_6]$ , the coordination sphere is  $[\text{Fe}(\text{CN})_6]^{4-}$  and the counter ion is  $\text{K}^+$

### • counterion

Counter ion is written outside of square brackets to neutralise the charge of the coordination sphere. In  $\text{K}_4[\text{Fe}(\text{CN})_6] \rightarrow \text{K}^+$  is counter ion

### • central atom/ion

Central metal is the atom inside the coordination entity, which accept the pair of electrons from all the ligands. Central metal atom in  $[\text{Ni}(\text{CO})_4]$ ,  $[\text{PtCl}_2(\text{NH}_3)_2] \rightarrow \text{Ni}^{\circ} \& \text{ Pt}^{+2}$

Central metal acts as Lewis acid because they are electron acceptor

### • ligands

A molecule which can donate pair of electrons to a metal atom or a metal ion and form native bond is called ligand

#### Classification of ligands

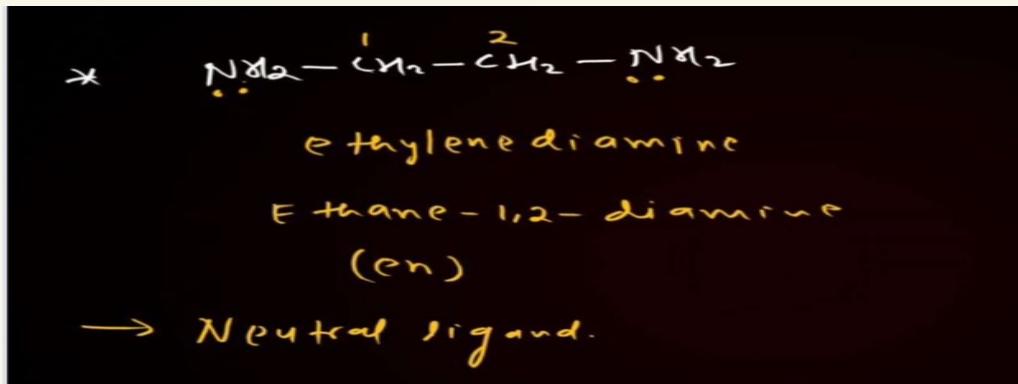
↓  
Based upon  
charges

↓  
Based upon  
denticity

↓  
Based upon  
site on which  
ligand & central  
atom

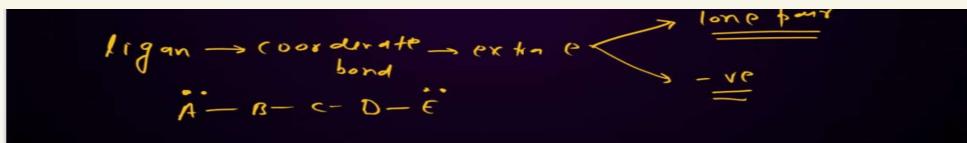
<u>charge</u>		
<u>negative</u>	<u>positive</u>	<u>neutral</u>
$\text{Cl}^-$ , $\text{CN}^-$ , $\text{Br}^-$ , $\text{OH}^-$	$\text{O}^-$ $\text{NH}_2\text{NH}_3^+$ , $\text{NO}_2^+$ , $\text{NO}^+$	$\text{O}^-$ , $\text{H}_2\text{O}$ , $\text{NH}_3$

* $\text{Cl}^- \rightarrow \text{chlorido}$	$\text{SO}_4^{2-}$ Sulphato	
* $\text{Br}^- \rightarrow \text{bromido}$	$\text{CN}^-$ cyanido	
* $\text{OH}^- \rightarrow \text{hydroxido}$	$\text{SCN}^-$ thiocyanato	
* $\text{CO}_3^{2-} \rightarrow \text{carbonato}$	$\text{NO}_2^-$ nitrito-N.	
* $\text{C}_2\text{O}_4^{2-} \rightarrow \text{oxalato}$ (or)	$\begin{array}{l} \text{--CH}_2-\text{CH}_3 \quad \text{Ethane} \\ -\text{CH}_2-\text{CH}_3 \quad \text{Ethyl} \\ -\text{CH}_2-\text{CH}_2-\text{Ethylene} \\ \text{--NH}_2-\text{CH}_2-\text{CH}_2-\text{NH}_2 \quad \text{Ethylenediamine} \end{array}$	



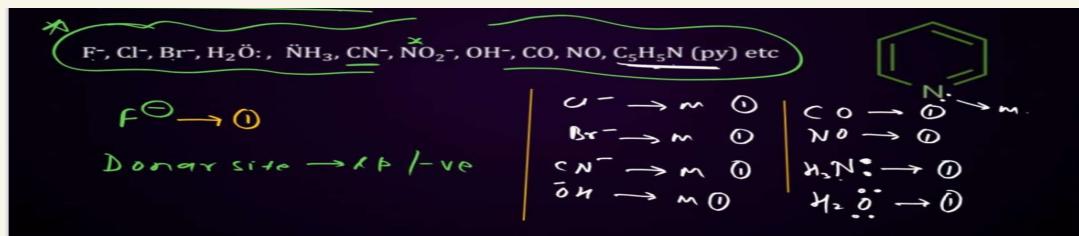
### Denticity of a ligand

Number of donor site present in a ligand is called denticity of a ligand. In other words, we can say that number of coordinate bond a ligand can make with a central metal atom is called the denticity of that Ligand



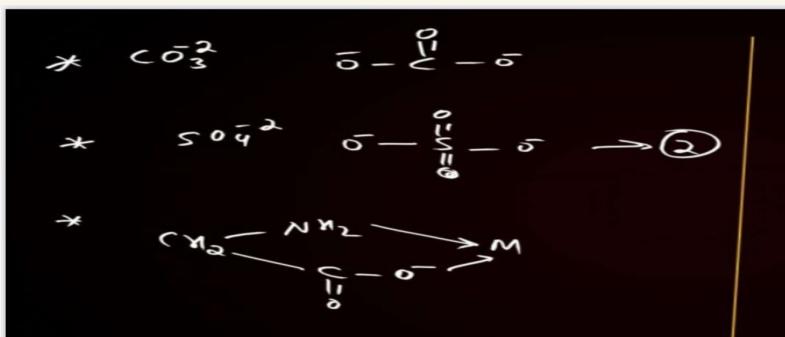
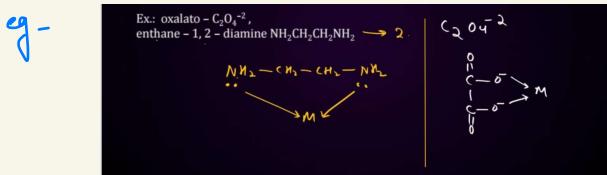
## Unidentate ligand

If ligand is bonded to the central metal through single donor atom  
 eg -  $\text{F}^-$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{H}_2\ddot{\text{O}}$ ,  $\text{NH}_3$ ,  $\text{CN}^-$ ,  $\text{NO}_2^-$ ,  $\text{OH}^-$ ,  $\text{CO}$ ,  $\text{NO}$ ,  $\text{C}_5\text{H}_5\text{N}$  (py) etc

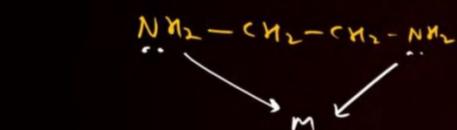


## Didentate ligand

When a ligand can donate electrons through two atoms to the central metal, or we can say when a ligand is bonded to Central metal through two atoms



## Symmetrical didentate Ligand

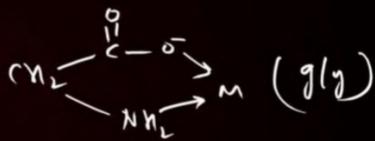


→ So the donor Atom are

Symr

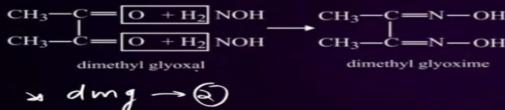
→ (AA)

## Unsymmetrical ligand



→ (AB)

### Didentate Ligands



→  $\text{dmg} \rightarrow \text{②}$



(1, 2 propanediamine) (pn)



### QUESTION

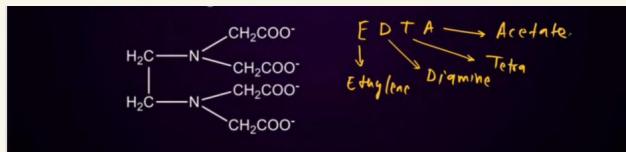
Ethylene diamine is an example of a \_\_\_\_\_ ligand.

- A monodentate
- B bidentate
- C tridentate
- D hexadentate

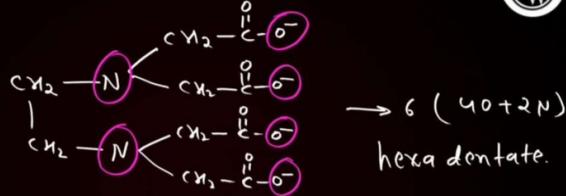
## Polydentate ligand

When a ligand is bonded to the central metal through more than two atoms or bonds

Example- EDTA

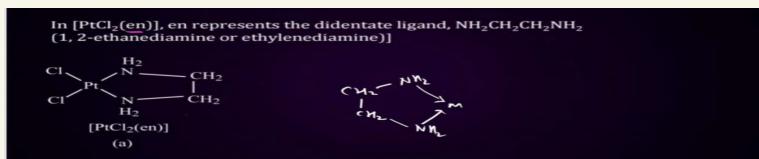


# EDTA



## Chelate Ligand

- it is a di or polydentate ligand, which uses its two or more donor atom to bind to single metal ion and producing a ring
- Complex formed is referred to as chelate complex, and the process of formation is known as chelation
- Chelate rings may have any number of atoms, the most common 5 or 6 atoms, including the metal iron, smaller rings have angles and distances that lead to strain. Larger frequently result in crowding both within the ring and between the adjoining like ligands.



### QUESTION - NCERT EXEMPLAR

The stabilization of coordination compounds due to chelation is called the chelate effect. Which of the following is the most stable complex species?

- A  $[Fe(CO)_5]$        $CO \rightarrow 1$   
 B  $[Fe(CN)_6]^{3-}$        $CN^- \rightarrow 1$   
 C  $\cancel{[Fe(C_2O_4)_3]^{3-}}$        $C_2O_4^{2-} \rightarrow 2$   
 D  $[Fe(H_2O)_6]^{3+}$

↓  
chelating ligand  
↓  
denticity  
minimum  
③

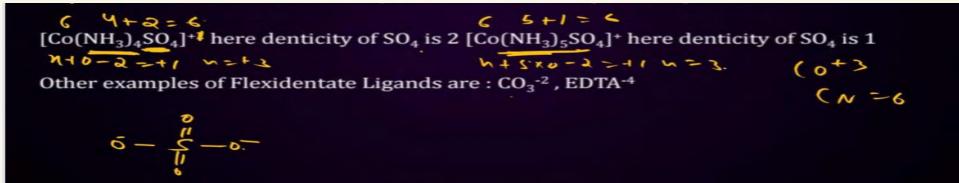
### QUESTION - NCERT EXEMPLAR

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

- A ~~thiosulphato~~  
 B oxalato →  $C_2O_4^{2-} \rightarrow 2$   
 C glycinate →  $NH_2-CH_2-COO^- \rightarrow 2$   
 D ethane-1,2-diamine  
 ↓  
④

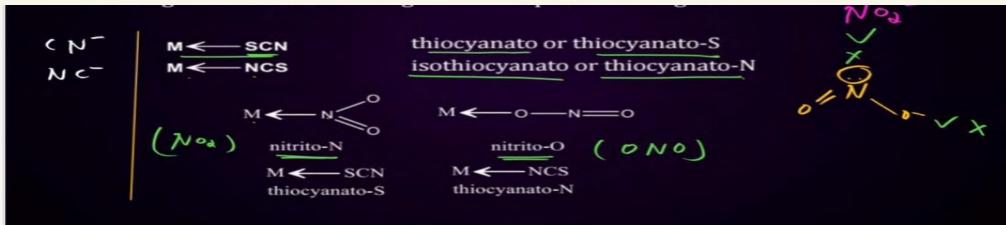
## Flexidentate ligand

- They are the types of ligands which can vary their denticity according to the type of the complex compound
- For example-  $\text{SO}_4^{2-}$  has two oxygen atom having negative charge on it so denticity of  $\text{SO}_4^{2-}$  is two, but it can show denticity one also in some complex compound.



### - Ambidentate ligand

- if a ligand has two donor atom and it can donate through either of them, then it is called ambidentate ligand
- example-  $\text{NO}_2^- \rightarrow$  can donate through either oxygen or nitrogen  
 $\text{SCN}^-$



**QUESTION CB 2024**

Define ambidentate ligand with an example.

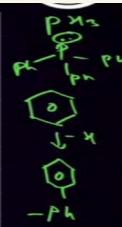
**QUESTION (1 mark)**

Giving a suitable example, explain the following: Ambidentate ligand

[AI 2009]

## Some common monodentate ligand

Common name	IUPAC Name	Formula
Triphenyl Phosphine	Triphenyl Phosphine / triphenyl phosphane	$\text{PPh}_3$
Pyridine	Pyridine	$\text{C}_5\text{H}_5\text{N}$ (py)
Ammonia	Ammine	$\text{NH}_3$
Water	Aqua	$\text{H}_2\text{O}$
Carbonyl	Carbonyl	$\text{CO}$
Nitrosyl	Nitrosyl	$\text{NO}$
Fluoro	Fluoro or fluorido	$\text{F}^-$
Chloro	Chloro or chlorido	$\text{Cl}^-$
Bromo	Bromo or bromido	$\text{Br}^-$
Iodo	Iodo or iodido	$\text{I}^-$



Common name	IUPAC Name	Formula
Cyano	Cyanido or cyanido-C (C-bonded)	$\text{CN}^-$
Isocyano	Isocyanido or cyanido-N (N-bonded)	$\text{NC}^-$
Thiocyanato	Thiocyanato-S (S-bonded)	$\text{SCN}^-$
Iothiocyanato	Thiocyanato-N (N-bonded)	$\text{NCS}^-$
Hydroxo	Hydroxo or hydroxido	$\text{OH}^-$
Nitro	Nitro, nitrito-N (N-bonded)	$\text{NO}_2^-$
Nitrito	Nitrito-O (O-bonded)	$\text{ONO}^-$
Nitrate	Nitrato	$\text{NO}_3^-$

Common name	IUPAC Name	Formula
Azide	Azido	$\text{N}_3^-$
Hydride	Hydrido	$\text{H}^-$
Oxide	Oxido	$\text{O}^{2-}$
Peroxide	Peroxydo	$\text{O}_2^{2-}$
Superoxide	Superoxido	$\text{O}_2^-$
Sulphate	Sulphato	$\text{SO}_4^{2-}$
Nitrosylum	Nitrosylum or nitrosonium	$\text{NO}^+$



## Coordination number

- number of coordinate covalent bonds formed by the central metal atom is called coordination number

In  $\text{K}_4[\text{Fe}(\text{CN})_6]$  coordination number of Fe is 6 because there are 6 co-ordinate bonds formed by 6  $\text{CN}^-$  Ligands with central metal ion  $\text{Fe}^{2+}$ .

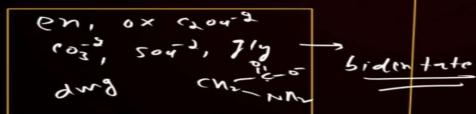
$[\text{Co}(\text{en})_3]^{2+}$  here coordination number of Co is 6 because denticity of en is 2 so one en can make two coordinate bonds with Co so  $3 \times 2 = 6$   
 $\text{CN} = 3 \times 2 = 6$

$[\text{Cr EDTA}]^{3+}$  here coordination number of Cr is 6 because of EDTA is 6 so it can form total 6 co-ordinate bonds with Cr  
 $\text{CN} = 6 \times 1 = 6$



\* ligand  $\rightarrow CN^-$

\* Denticity = 1



$CN = \text{no. of ligand} \times$

Denticity

$$= 6 \times 1 \\ = 6 \checkmark$$

- the coordination number is generally 2, 4 or 6, occasionally 8 (in osmium complexes)
- Shape of the complex species depends on its coordination number
- Note: only sigma bonds are counted in coordination number, if pie bonds are formed between central metal and ligand that will not be counted in coordination number

Metal ion	C.N.
Ag <sup>+</sup>	2
Fe <sup>3+</sup>	6
Co <sup>3+</sup>	6
Zn <sup>2+</sup>	4
Sc <sup>3+</sup>	6
Cr <sup>3+</sup>	6
Pt <sup>2+</sup>	4
Pt <sup>4+</sup>	6

BKT

gF Element is from 3d series.

$$M^{+3} \quad CN = 6$$

$$M^{+2} \quad CN = 4$$

### QUESTION

Coordination number of Ni in  $[Ni(C_2O_4)_3]^{4-}$  is

A 3

Ligand =  $C_2O_4^{2-}$

B 4

Denticity = 2

C 5

$$CN = 2 \times 2 \\ = 4 \checkmark$$

D 6



## Shape of the complexes, depending on their coordination number

coordination number.

2

3

4

5

6

7

Shape.

Linear

Trigonal planar

Tetrahedral or Square planar

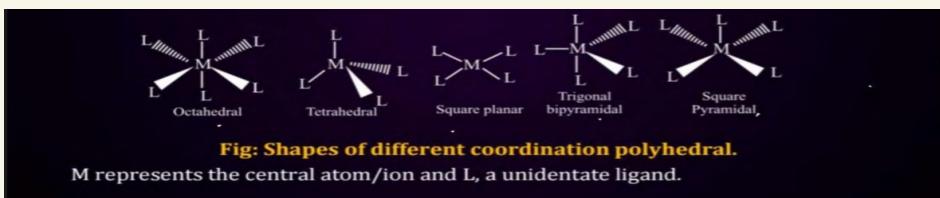
Square pyramidal

Octahedral

Pentagonal bipyramidal

## Coordination polyhedron

- The special arrangement of the Ligand atom, which are directly attached to the central atom defines a coordination polyhedron about the central atom
- The most common coordination polyhedra are octahedral, square planar and tetrahedral



## Oxidation number of central atom

Oxidation number is actual charge on the central metal atom when all ligand and along with donated electrons are removed

For example oxidation number of Fe in  $K_4[Fe(CN)_6]$  is 2  
To calculate oxidation number follow following steps  
Let assume oxidation number be  $x$

Total charge on compound = 0

$$4 + x - 6 = 0$$

$$x = 2$$

$$\begin{array}{c} \text{O}^- \quad (\text{N} \equiv \text{N}) \\ \downarrow \\ \text{Oxidation number of Pt in } [\text{PtCl}_2(\text{NH}_3)_2] \text{ is 2} \\ \downarrow \\ x + 2(-1) + 2 \times (-2) = 0 \\ x - 2 = 0, \quad x = 2. \end{array}$$

$K_4[Fe(CN)_6]$

$$4x + n + 6(-1) = 0$$

$$n + 6 - 6 = 0$$

$$n = 2$$

**QUESTION**

What is the oxidation state of iron in  $K_4[Fe(CN)_6]$ ?

- A 6+  
B 4+  
C 3+  
 D 2+

$$4 + n - 6 = 0$$

$$n = 2 \quad \checkmark$$



**QUESTION**The oxidation state of Ni in  $\text{Ni}(\text{CO})_4$  is:

- A 0  
 B 1  
 C 2  
 D 4

$$x + 4 \times 0 = 0$$

$$x = 0$$

**QUESTION**Coordination number of Ni in  $[\text{Ni}(\text{C}_2\text{O}_4)_3]^{4-}$  is:

- A 3  
 B 6  
 C 4  
 D 5

$$\begin{aligned} \text{CN} &= \text{no. of ligands} \times \text{Denticity} \\ &= 3 \times 2 \\ &= 6 \end{aligned}$$

**QUESTION**Oxidation number of Co in  $[\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})\text{Cl}]^{2+}$  is:

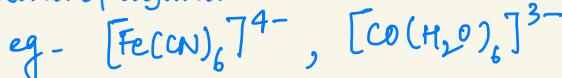
- A 1  
 B 2  
 C 3  
 D 4

$$\begin{aligned} \text{NH}_3 &\quad \text{H}_2\text{O} \quad \text{Cl}^- \\ \downarrow & \\ x + 3 \times 0 + 2 \times 0 - 1 &= +1 \\ x &= 2 \checkmark \end{aligned}$$

## Homoleptic and heteroleptic complex compound

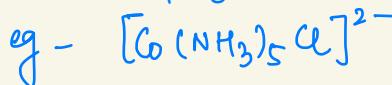
### Homoleptic complex

The complex in which the central metal atom or ion bond with only one kind of ligand



### Heteroleptic complex

The complex in which the central metal atom or ion bond with more than one kind of ligand

**QUESTION - NCERT EXEMPLAR**

Which of the following complexes are homoleptic?

(A, C)

- A  $[\text{Co}(\text{NH}_3)_6]^{3+}$  Homoleptic  
 B  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$  Heteroleptic  
 C  $[\text{Ni}(\text{CN})_4]^{2-}$  Homoleptic  
 D  $[\text{Ni}(\text{NH}_3)_4\text{Cl}_2]$  Heteroleptic

**QUESTION - NCERT EXEMPLAR**

Which of the following complexes are heteroleptic?

- A  $[\text{Cr}(\text{NH}_3)_6]^{3+}$
- B  $[\text{Fe}(\text{NH}_3)_4\text{Cl}_2]^+$  (b, d)
- C  $[\text{Mn}(\text{CN})_6]^{4-}$
- D  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]$

Q Which of following is not bidentate?

- (a)  $\text{C}_2\text{O}_4^{2-}$
- (b) en
- (c)  $\text{CH}_2-\overset{\text{C}}{\underset{\text{N}\text{H}_2}{\text{C}}} \text{O}^-$
- (d)  $\text{H}_2\text{O}$ .

### IUPAC nomenclature of coordination compounds

To write name of anionic ligand replace E with O like chloride will be converted to chlorido or chloro and bromide will be converted to Bromido or Bromo

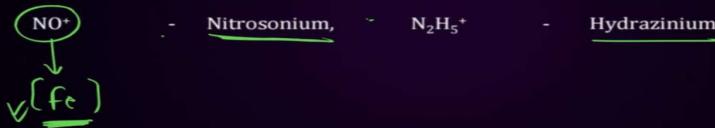
Cl <sup>-</sup>	Chlorido or Chloro ✓	NC <sup>-</sup>	Isocyanido ✓
Br <sup>-</sup>	Bromido or Bromo ✓	S <sup>2-</sup>	Sulphido
OH <sup>-</sup>	Hydroxido ✓	SO <sub>3</sub> <sup>2-</sup>	Sulphito
H <sup>+</sup>	Hydrido ✓	SO <sub>4</sub> <sup>2-</sup>	Sulphato ✓
CN <sup>-</sup>	Cyanido / Cyano ✓	CH <sub>3</sub> COO <sup>-</sup>	Acetato ✓
O <sup>2-</sup>	Oxido ✓	C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	Oxalato ✓
O <sub>2</sub> <sup>2-</sup>	Peroxido ✓	CO <sub>3</sub> <sup>2-</sup>	Carbonato ✓
NH <sub>2</sub> <sup>-</sup>	Amido ✓	SCN <sup>-</sup>	Thioscyanato ✓
N <sub>3</sub> <sup>-</sup>	Azido ✓	NO <sub>2</sub> <sup>-</sup>	Nitrito -N
N <sup>3-</sup>	Nitrido		

### Name of Some Neutral Ligands

NH <sub>3</sub>	Ammine
H <sub>2</sub> O	Aqua
CO	Carbonyl
NO	Nitrosyl
C <sub>6</sub> H <sub>5</sub> N	Pyridine
NH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> NH <sub>2</sub>	Ethylenediammine
PPh <sub>3</sub>	Triphenyl Phosphene

### Cationic Ligands

For naming of cationic Ligands add ium at the end



## Rules for writing name of central metal of coordination compound

If central metal atom is present in an anionic coordination sphere, then add "ate" at the end of the name

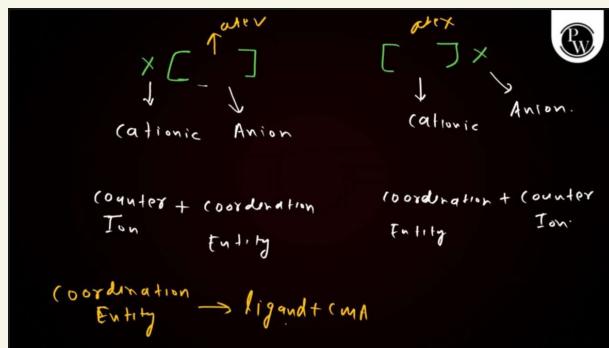


Fe Iron - Ferrate  
Pb Lead - plumbate  
Au Gold - Aurate  
Pt Platinum - Platinate  
Al Aluminium - Aluminate

Ag Silver - Argentate  
Co Cobalt - Cobaltate  
Sn Tin - Stannate  
Zn Zinc - Zincate  
Cu Copper - Cuprate

## Rules for writing name of coordination compounds

- we write name of cation first
- Name of the ligand should be written before writing the name of the central metal ion with oxidation number
- cationic counter ion + name of coordination entities
- name of coordination entity + anionic counter ion
- Name of coordination entities- ligand + central metal atom/ ion



## Rules for writing name of coordination compounds

- 1) 1<sup>st</sup> write the name of ligands and use prefix di, tri, tetra, penta, hexa, etc. for numbers of ligands 2, 3, 4, 5 & 6 respectively.
- 2) write name of ligands in alphabetical order ignore the prefix di, tri, tetra while deciding

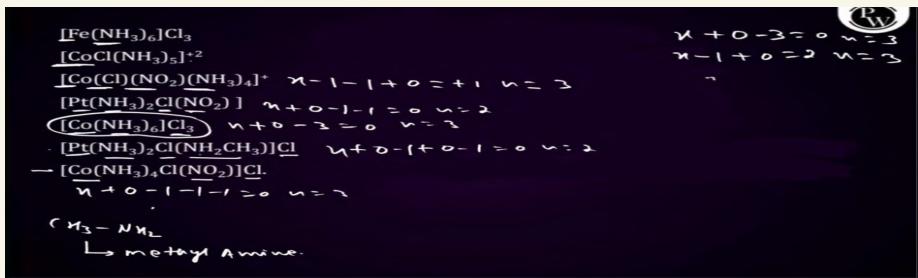
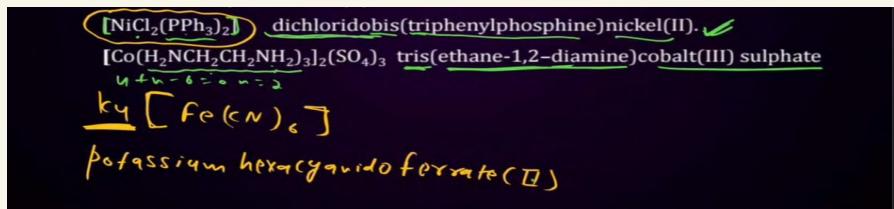
the priority order

- 3) If multiple polydental ligands are present in the complex use prefix bis, tri, tetraakis, etc.
- 4) After writing the name of ligands write the name of central metal atom & oxidation no. in Roman numeral in bold

(c) Like we write the name of NaCl As sodium chloride-cation is written first

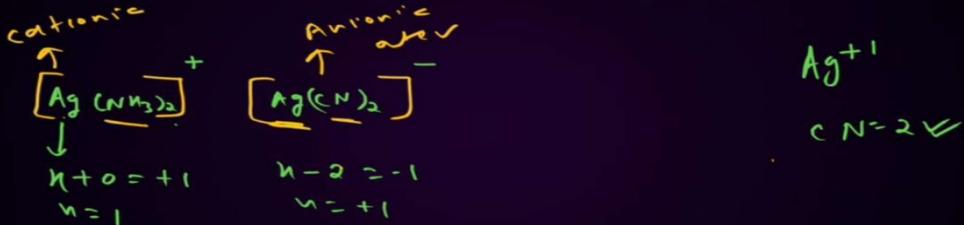
We also follow same rule for complex compound- cation is written first

Ex -  $\text{K}_4[\text{Fe}(\text{CN})_6]$  here it is cation so that should be written 1st as POTASSIUM HEXACYANOFERRATE(II)



$[\text{Fe}(\text{NH}_3)_6]\text{Cl}_3$	Hexaammine Iron(III) Chloride
$[\text{CoCl}(\text{NH}_3)_5]^{+2}$	Pentaamminechlorocobalt (III) Ion
$[\text{Co}(\text{Cl})(\text{NO}_2)(\text{NH}_3)_4]^+$	Tetraamminechloronitrocobalt(III) Ion
$[\text{Pt}(\text{NH}_3)_2\text{Cl}(\text{NO}_2)]$	Diamminechloronitrito-N-Platinum(II)
$[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$	Hexaammine Cobalt (III) Chloride
$[\text{Pt}(\text{NH}_3)_2\text{Cl}(\text{NH}_2\text{CH}_3)]\text{Cl}$	Diamminechloromethylamine Platinum(II) Chloride
$[\text{Co}(\text{NH}_3)_4\text{Cl}(\text{NO}_2)]\text{Cl}$	TetraammineChloronitrito-N- Cobalt (III) Chloride

$[\text{Ag}(\text{NH}_3)_2][\text{Ag}(\text{CN})_2]$  diamminesilver(I) dicyanidoargentate(I) ✓



QUESTION

CBSE 2024



Write the IUPAC names of the following coordination compounds (any three):

- (a)  $[\text{Co}(\text{NH}_3)_4\text{Cl}(\text{NO}_2)]\text{Cl}$
- (b)  $[\text{Ni}(\text{NH}_3)_6]\text{Cl}_2$
- (c)  $\text{K}_3[\text{Cr}(\text{C}_2\text{O}_4)_3]$
- (d)  $[\text{Co}(\text{en})_2\text{Br}_2]^+$



QUESTION

The formula of the complex tris (ethylene diamine) cobalt (III) sulphate is:

- A  $[\text{Co}(\text{en})_2\text{SO}_4]$  ×
  - B  $[\text{Co}(\text{en})_3\text{SO}_4]$  ×
  - C  $[\text{Co}(\text{en})_2]\text{SO}_4$
  - D  $[\text{Co}(\text{en})_3]_2(\text{SO}_4)_3 \rightarrow (n + 3 \times 0) \times 2 + 3(-2) = 0$
- $$(n + 3 \times 0) \times 2 - 2 = 0$$
- $$2n - 6 = 0$$
- $$n = 3$$
- $$n = 2$$
- $$n = 1$$

QUESTION (1 mark)

Write the IUPAC name of the complex  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ .

[1/3, AI 2014]



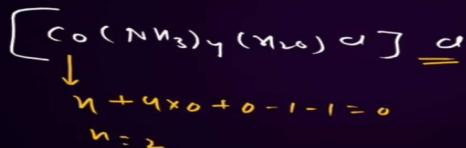
QUESTION

The IUPAC name for the complex  $[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]\text{Cl}_2$  is:

- A Nitro-N-pentaammine cobalt (III) chloride ×
- B nitro-N-pentaammine cobalt (II) chloride ×
- C pentaammine nitrito-N-cobalt (II) chloride
- D pentaammine nitrito-N-cobalt (III) chloride

**QUESTION (1 mark)**

**Write down the formula of:  
Tetraamineaquachloridocoblat(II) chloride.**

**[CBSE PYQ]**

**QUESTION**

The IUPAC name of  $\text{Ni}(\text{CO})_4$  is:

- A tetracarbonyl nickelate (0) ✓
- B tetracarbonyl nickelate (II) ✗
- C tetracarbonyl nickel (0). ✓
- D tetracarbonyl nickel (II)


 $\text{CO} \rightarrow \text{carbonyl}$ 
 $\left[ \text{---} \right]^0 \rightarrow \text{ate x}$ 
**QUESTION (1 mark)**

Write the IUPAC name of  
 $[\text{Pt}(\text{NH}_3)_4\text{Cl}_2\text{Cl}_2]$ .

**[CBSE PYQ]**
**QUESTION (1 mark)**

Using the IUPAC norms, write the systematic name of the following:  
 $[\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{CN})_6]$

**[Delhi 2008 C]**

$$\downarrow \quad \downarrow$$

$$\text{C N} = (\times 6) \quad \text{C N} = 6$$

$$= 6$$



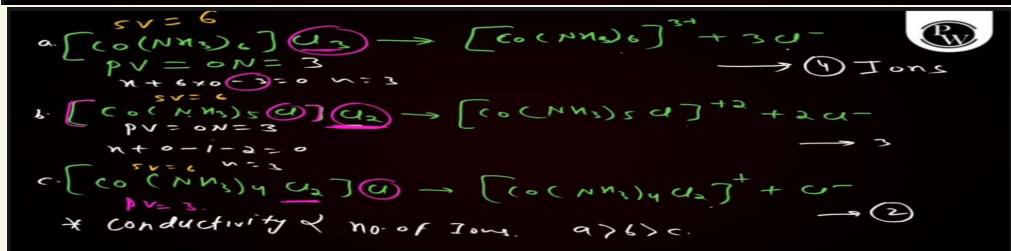
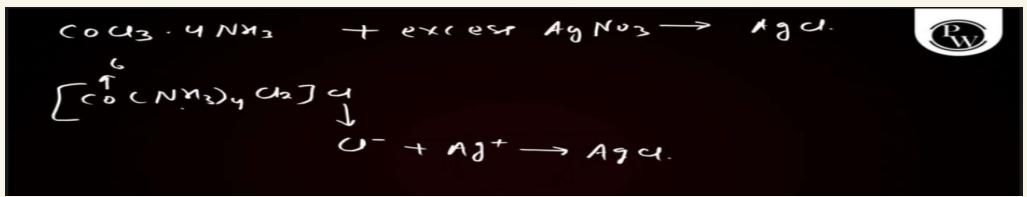
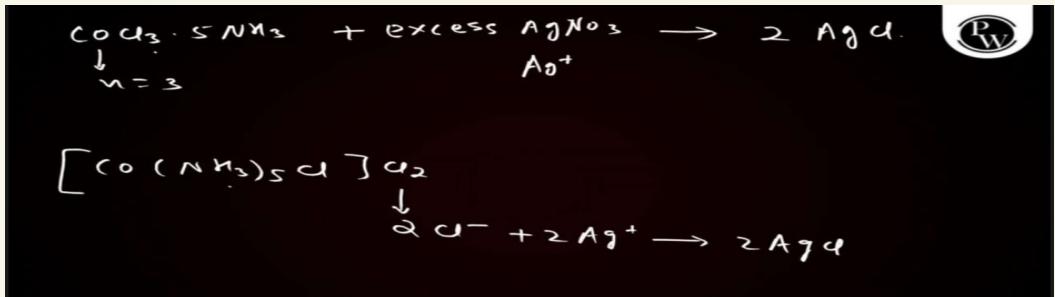
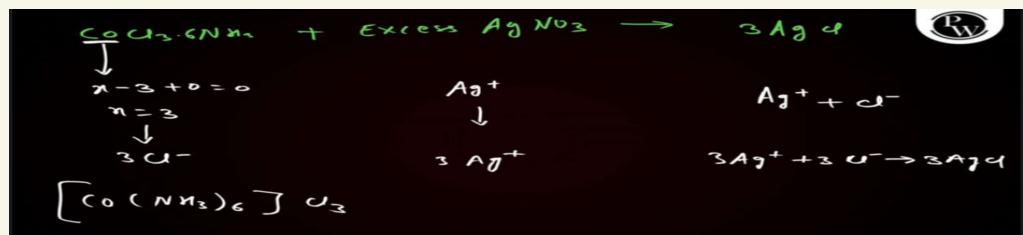
hexaammine cobalt(III) hexacyano  
 chromate(III).



## Werner the theory of coordination compound

- according to Werner (father of coordination chemistry) transition metal possess two types of valencies - (a) primary valence (ionisable valence) (b) secondary valence (non ionisable valence)

1 mol	$\text{CoCl}_3 \cdot 6\text{NH}_3$ (Yellow)	gave	3 mol AgCl	$[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$
1 mol	$\text{CoCl}_3 \cdot 5\text{NH}_3$ (Purple)	gave	2 mol AgCl	$[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$
1 mol	$\text{CoCl}_3 \cdot 4\text{NH}_3$ (Green)	gave	1 mol AgCl	$[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
1 mol	$\text{CoCl}_3 \cdot 4\text{NH}_3$ (Violet)	gave	1 mol AgCl	$[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$



### Formulation of Cobalt (III) Chloride-Ammonia Complexes

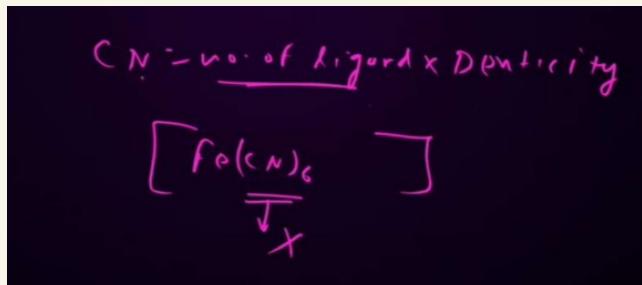
Colour	Formula	Solution conductivity corresponds to
Yellow	$[\text{Co}(\text{NH}_3)_6]^{3+} 3\text{Cl}^-$	1:3 electrolyte
Purple	$[\text{CoCl}(\text{NH}_3)_5]^{2+} 2\text{Cl}^-$	1:2 electrolyte
Green	$[\text{CoCl}_2(\text{NH}_3)_4]^+ \text{Cl}^-$	1:1 electrolyte
Violet	$[\text{CoCl}_2(\text{NH}_3)_4]^+ \text{Cl}^-$	1:1 electrolyte

## Primary valence (ionisable, valence)

- the primary valence are normally ionisable and are satisfied by negative ions
- it is referred to as oxidation state
- it is represented by daughter lines while writing the structure of complex

## Secondary valence

- it is satisfied by anions or neutral molecules or rarely with cations
- The group satisfying secondary valence are called as ligands
- The number of secondary valence is called coordination number
- it is represented by solid lines while writing the structure of the complex
- in some complexes, the same group satisfies both the primary and secondary valence



## Drawbacks

- does not explain the cause of various properties like
- Colour
- Geometry
- Magnetic properties

**QUESTION**

The number of chloride ions which would be precipitated, when  $\text{CrCl}_3 \cdot 4\text{NH}_3$  is treated with silver nitrate solution.

**ANSWER**

$\text{CrCl}_3 \cdot 4\text{NH}_3$  is a complex salt where Cr has a coordination number of 6. It dissociates into  $\text{Cr}^{3+}$  and  $\text{Cl}^-$ . The  $\text{Cr}^{3+}$  ion has a coordination number of 6, which is satisfied by 6 NH<sub>3</sub> molecules. When it reacts with AgNO<sub>3</sub>, it will precipitate Cl<sup>-</sup> ions. Since there are 3 Cl<sup>-</sup> ions associated with each Cr<sup>3+</sup> ion, 3 Cl<sup>-</sup> ions will be precipitated.

**Options:**

- A 3
- B 2
- C 1
- D 0

**ANSWER:** A 3

**QUESTION (1 mark)**

**When a co-ordination compound  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$  is mixed with  $\text{AgNO}_3$ , 3 moles of AgCl are precipitated per mole of the compound. Write structural formula of the complex.**

**QUESTION**

**Which of the following will not give a precipitate with  $\text{AgNO}_3$ ?**

- A  $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$
- B  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl} \rightarrow 4\text{Cl}^- \checkmark$
- C  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2 \rightarrow 2\text{Cl}^- \checkmark$
- D  $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3 \rightarrow 3\text{Cl}^- \checkmark$

**QUESTION**

**Which of the following has the highest molar conductivity in solution?**

- A  $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$
- B  $[\text{Pt}(\text{NH}_3)_5\text{Cl}]\text{Cl}_3$
- C  $[\text{Pt}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}_2$
- D  $[\text{Pt}(\text{NH}_3)_3\text{Cl}_2]\text{Cl}$

**QUESTION – NCERT EXEMPLAR**

**When 0.1 mol  $\text{CoCl}_3(\text{NH}_3)_5$  is treated with excess of  $\text{AgNO}_3$ , 0.2 mol of  $\text{AgCl}$  are obtained. The conductivity of solution will correspond to**

- A 1:3 electrolyte
- B **1:2 electrolyte**
- C 1:1 electrolyte
- D 3:1 electrolyte

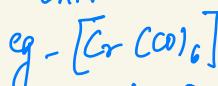
**QUESTION – NCERT EXEMPLAR**

**When 1 mol  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$  is treated with excess of  $\text{AgNO}_3$ , 3 mol of AgCl are obtained. The formula of the complex is :**

- A  $[\text{CrCl}_3(\text{H}_2\text{O})_3] \cdot 3\text{H}_2\text{O}$
- B  $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl} \cdot 2\text{H}_2\text{O}$
- C  $[\text{CrCl}(\text{H}_2\text{O})_5]\text{Cl}_2 \cdot \text{H}_2\text{O}$
- D  **$[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$**

EAN rule and sidgwick theory

$$\text{EAN} = Z - o.N + 2 \times C.N$$



$$oN = 0$$

$$CN = 6$$

$$e^- \text{ gained} = 6 \times 2 = 12$$

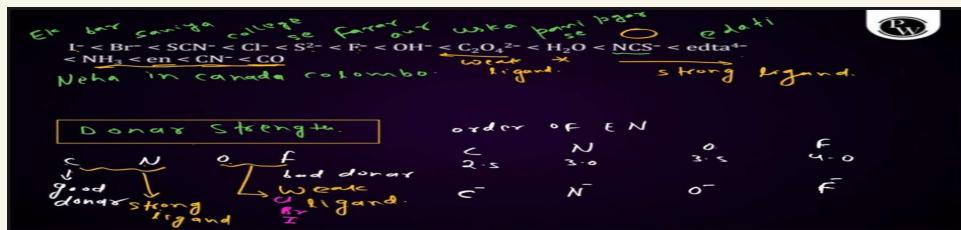
$$\text{EAN} = 24 + 0 + 12 = 36$$

$\text{EAN} = Z - O.N + 2 \times C.N$ $C.N = 6$ $[\text{Co}(\text{en})_3]^{+3} :-$ $Z = 27$ Oxidation Number = 3 Coordination Number = 6 ( en is bidentate ligand ) $\text{EAN} = 27 - 3 + 12 = 36$	$[\text{Pt}(\text{Cl})_6]^{2-} :-$ $Z = 78$ Oxidation Number = 4 Coordination Number = 6 $\text{EAN} = 78 - 4 + 12 = 86$
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## valence bond theory

Number of orbitals in types of hybridisation

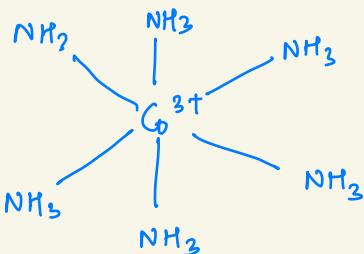
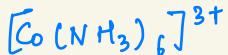
Coordination number	Type of hybridisation	Distribution of hybrid orbitals of space
4	$sp^3$	Tetrahedral
4	$dsp^2$	Square planar
5	$sp^3d$	Trigonal bipyramidal
6	$sp^3d^2$	Octahedral ✓
6	$d^2sp^3$	Octahedral ✓



- \* strong ligand  $\rightarrow$  pairing hoga
- \* weak ligand  $\rightarrow$  pairing nahi hoga

## OCTAHEDRAL COMPLEXES

Inner orbital complexes



Orbitals in  $\text{Co}^{3+}$  ions

$\uparrow\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$

3d

$\square$	$\square$	$\square$

$4s$

$\square$	$\square$	$\square$

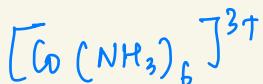
$4p$

$d^2sp^3$  hybridization  
orbitals of  $\text{Co}^{3+}$

$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$

$\square$	$\square$	$\square$	$\square$	$\square$

$d^2sp^3$



(inner orbital or  
low spin complex)

$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$

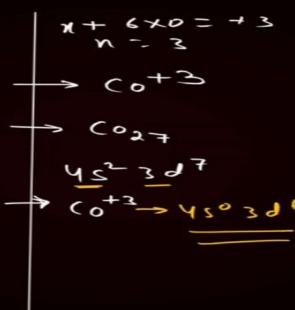
$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$



ligand =  $\text{NH}_3$

→ strong

$\text{CN} = 6$   
 $= \underline{6} \rightarrow$  octahedral.  
 $6 \begin{cases} \text{sp}^3d^2 \\ \text{d}^2\text{sp}^3 \end{cases}$



$\text{C} > \text{N} > \text{O} > \text{F}$   
 $\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$   
 strong      weak

$\text{Co}^{+3} \rightarrow \text{Co}^{+3}$  → low spin complex   inner orbital complex

$\text{CN} = 6$

$\begin{cases} \text{sp}^3d^2 \\ d^2\text{sp}^3 \end{cases}$

$\text{NH}_3$   
strong

pairing  
h.s.

$\uparrow\downarrow$							
$3d^5$	$\times \times$	$4s$	$4p$	$4d$			

$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$
$3d^5$	$\downarrow \downarrow$	$4s$	$4p$	$4d$			

$d + d + s + p + t + p$

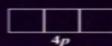
$= d^2\text{sp}^3$

$\chi = 0 \rightarrow \text{D}19$  magnetic.

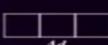
### [CoF<sub>6</sub>]<sup>3-</sup>



Orbitals of Co<sup>3+</sup> ion



*sp<sup>3</sup>d<sup>3</sup>* hybridized orbitals of Co<sup>3+</sup>



[CoF<sub>6</sub>]<sup>3-</sup>  
(outer orbital or  
high spin complex)



→ ligand → F<sup>-</sup>

→ weak ligand.

→ pairing N hi  
hoga.

$$n + 6(-1) = -3$$

$$n - 6 = -3$$

$$n = 3$$

$$\langle N = 6 \times 1 \\ = 6$$

Octahedral.



$$\langle N = 6$$



F<sup>-</sup>  
weak  
ligand



Outer orbital complex  
n = 4.  
paramagnetic.

$$s + p + p + p + d + d$$



### Tetrahedral complexes

In tetrahedral complexes, 1S and 3P orbitals are hybridised to form four equivalent orbitals oriented tetrahedrally

$[\text{NiCl}_4]^{2-}$	Orbitals of $\text{Ni}^{2+}$ ion	
$sp^3$ hybridized orbitals of $\text{Ni}^{2+}$		
$[\text{NiCl}_4]^{2-}$ (high spin complex)		Four pairs of electrons from 4 $\text{Cl}^-$

$[\text{Ni}(\text{CN})_4]^{2-}$	$cN = 4 \rightarrow 5f^3 \rightarrow \text{TS} \checkmark$	
$x - u = -2$	$\rightarrow d\text{s}\text{p}^2$	
$n = 2$	$\text{Ni}^{+2}$	
$\rightarrow \text{weak pairing}$	$\text{Ni}^{+2} \text{ } \underline{\text{4s}} \text{ } 3\text{d}^8 \xrightarrow{-2e} \text{4s}^0 \text{ } 3\text{d}^8$	
$\downarrow$		
$\text{Nhi hog.}$		high spin
	$n = 2$	
	$\text{far} = \text{magnetic.}$	
	$\text{S} + \text{p} + \text{t} + \text{p} = 8\text{f}^3$	

## Square planar complexes

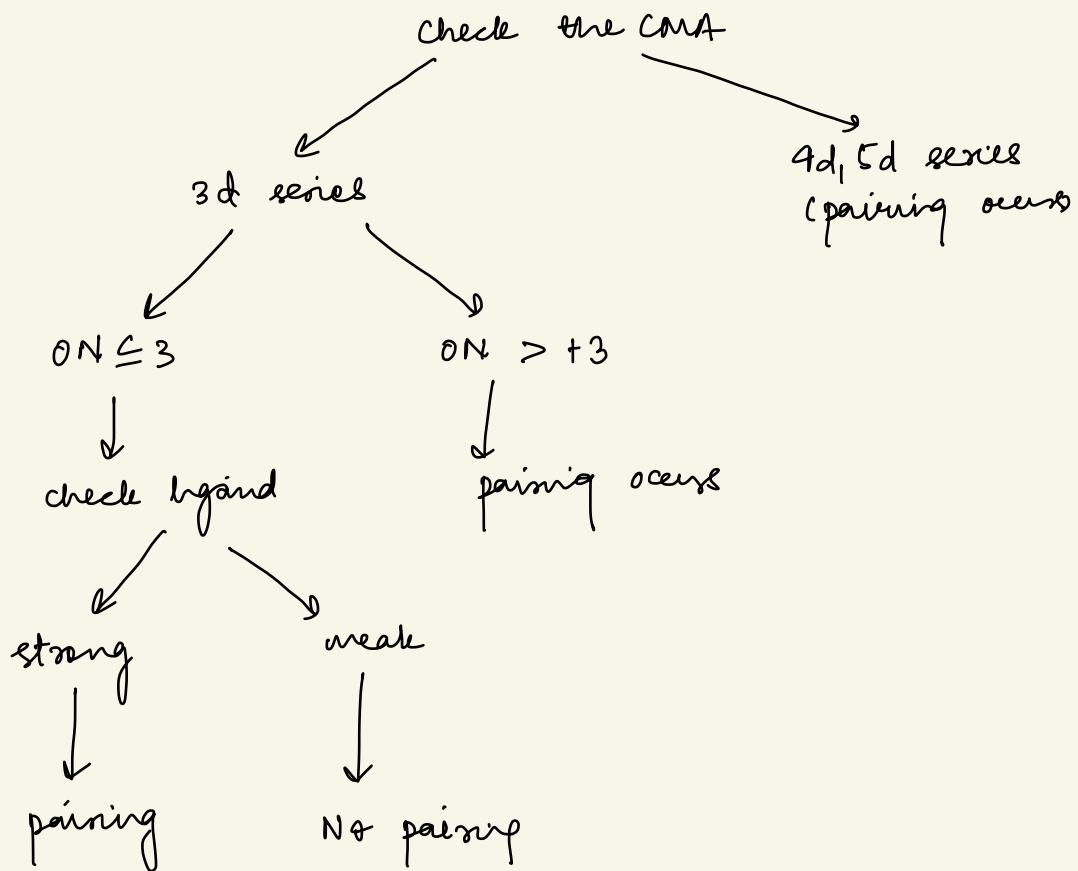
$\checkmark [\text{Ni}(\text{CN})_4]^{2-}$	Orbitals of $\text{Ni}^{2+}$ ion	
$d\text{s}\text{p}^2$ hybridized orbitals of $\text{Ni}^{2+}$		
$[\text{Ni}(\text{CN})_4]^{2-}$ (low spin complex)		Four pairs of electrons from 4 $\text{CN}^-$ groups

$[\text{Ni}(\text{CN})_4]^{2-}$	$cN = 4$	
$x - u = -2$	$\text{Ni}^{+2} \rightarrow \text{4s}^0 \text{ } 3\text{d}^8$	
$n = 2$		
$\downarrow$		
$\text{1g and} \Rightarrow cN =$		
$\downarrow$		
$\text{Strong pairing}$		
$\downarrow$		
$\text{hog.}$		
	$n = 0$	
	$D_{19}$	
	$\text{magnetic.}$	
	$d\text{s}\text{p}^2 \rightarrow \text{1oo S fin.}$	
	$\overline{S} \text{ square planar}$	

$$\text{CN} = 4$$

①  $\text{Zn, Cd, Hg}$  always tetrahedral

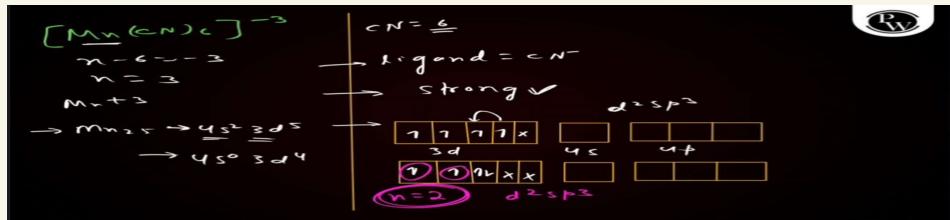
②  $\text{Pt, Pd}$  always square planar.



### Magnetic properties of coordination compound

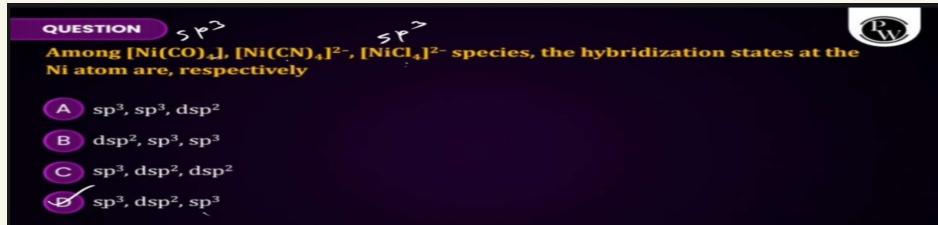
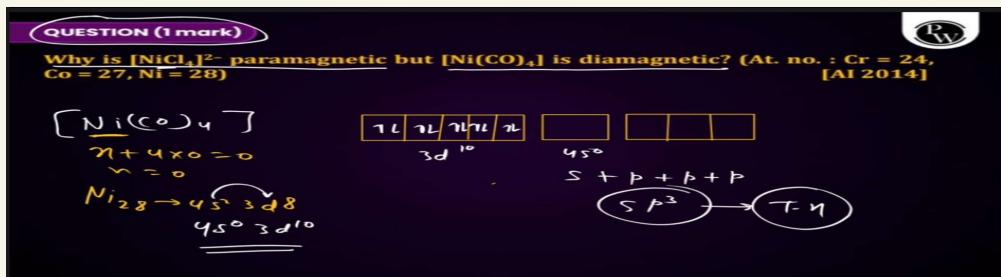
- The magnetic moment of coordination compound can be measured by the magnetic susceptibility experiments
- $\mu = \sqrt{n(n+2)} \text{ B.M.}$
- $n = \text{no. of unpaired e}^-$
- $[\text{Mn(CN)}_6]^{3-}$  has magnetic moment of two unpaired electrons while  $[\text{MnCl}_6]^{3-}$  has a paramagnetic moment of four unpaid electrons
- $[\text{Fe(CN)}_6]^{3-}$  has magnetic moment of a single unpaid electron while

$[\text{FeF}_6]^{3-}$  As a paramagnetic moment of five unpaired electrons



### Limitation of valence bond theory

- it involves a number of assumptions
- it does not give quantitative interpretation of magnetic data
- it does not explain the colour exhibited by the coordination compound
- it does not give a quantitative interpretation of the thermodynamic or kinetic stability of coordination compound
- it does not make exact predictions regarding the tetrahedral or square planar structure of four coordinate complexes
- it does not distinguish between weak and strong ligands



**QUESTION (2 marks)**

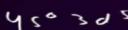
For the complex  $[\text{Fe}(\text{CN})_6]^{3-}$ , write the hybridization type, magnetic character and spin nature of the complex. (At. number : Fe = 26). [Delhi 2016]

**QUESTION**

The hybridization of Fe in  $\text{K}_3[\text{Fe}(\text{CN})_6]$  is:

- A  $\text{sp}^3$
- B  $\text{dsp}^3$
- C  $\text{sp}^3\text{d}^2$
- D  $\text{d}^2\text{sp}^3$

$$3 + n - 6 = 0 \\ n = 3$$

**QUESTION**

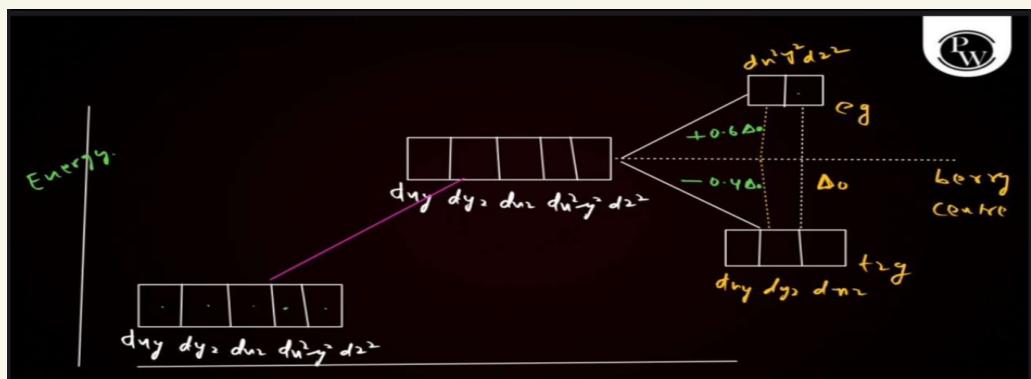
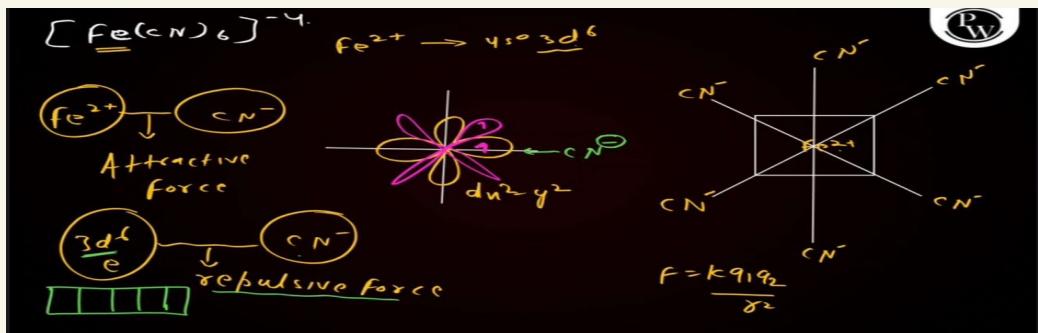
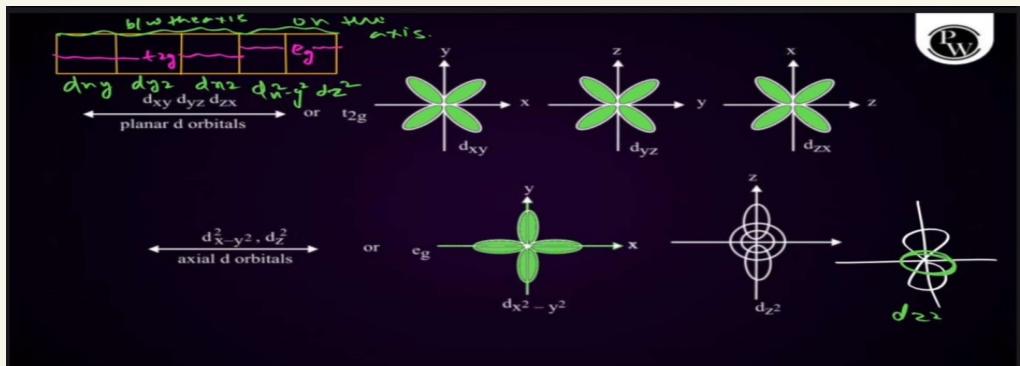
What is the magnetic moment of  $\text{K}_3[\text{FeF}_6]$

- A 5.91 BM
- B 4.89 BM
- C 3.87 BM
- D 6.92 BM

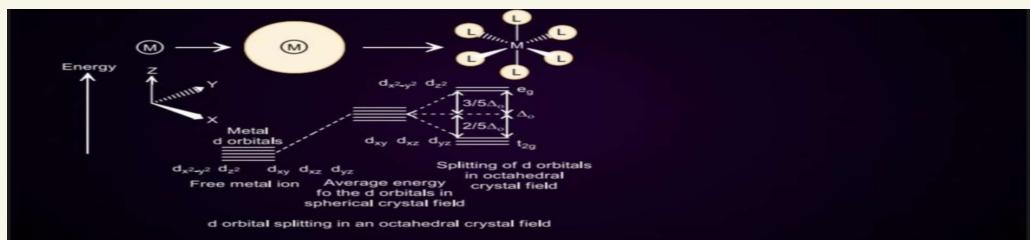


## Crystal field theory

- The Crystal Field theory is an electrostatic model, which considers the metallic bond to be ionic rising, purely from electrostatic interactions between the metal and the ligand
- Ligands are treated as point charges in case of anion or point dipole in case of neutral molecules
- Metal ion is treated as positive charge
- The five d orbital in an isolated gaseous metal atom has same energy that is, they are degenerate
- This degeneracy is maintained if a spherically symmetrical field of negative charges, surrounds the metal atom or ion
- However, when this negative field is due to ligands in a complex. It becomes asymmetrical, and the degeneracy of the d orbitals is lifted. It results in splitting of the d orbitals.



## Crystal Field splitting in octahedral coordination entities



→  $d_{x^2-y^2}$  and  $d_{z^2}$

Orbitals, which point towards the axis along the direction of the ligand, will experience more repulsion and will be raised in energy

→  $d_{xy}$ ,  $d_{yz}$  and  $d_{xz}$

Orbitals which are directed between the axis will be lowered in energy relative to the average energy in the spherical crystal field

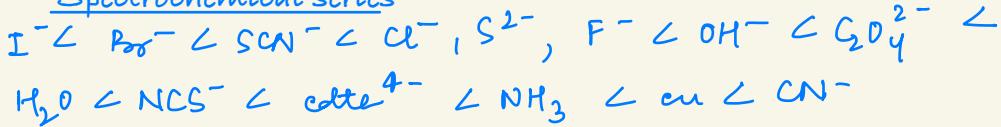
→ This splitting of the degenerate levels due to presence of ligand in a definite geometry is termed as crystal Field splitting, and the energy separation is denoted by  $\Delta_o$

→ The energy of the two  $t_{2g}$  Orbital will increase by  $\frac{3}{5} \Delta_o$  and that of the three  $t_{2g}$  will decrease by  $\frac{2}{5} \Delta_o$

### Factors affecting $\Delta_o$

→ Depends upon the field produced by ligand

#### Spectrochemical series



→ Charge on the metal ion

- $\Delta_o$  is directly proportional to the oxidation number of central metal



### Electron filling in octahedral

→ In  $d^1$ ,  $d^2$  and  $d^3$

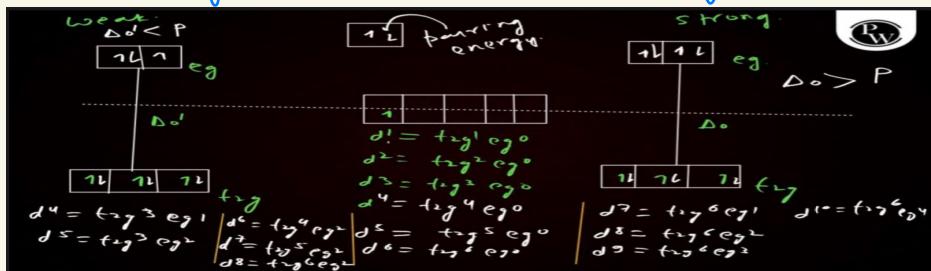
coordination entities, the D electron occupy the  $t_{2g}$  Orbital singly in accordance with the Hund rule.

(i) If  $\Delta_o < P$

The fourth electron enters one of the  $e_g$  Orbitals giving the configuration  $t_{2g}^3 e_g^1$ . Ligands For which  $\Delta_o < P$  Are known as weak fields ligands and form high spin complexes.

(ii) If  $\Delta_o > P$

It becomes more energetically favourable for the fourth electron to occupy a.  $t_{2g}$  Orbital with configuration.  $t_{2g}^4 e_g^0$



## CFSE calculation for octahedral splitting

general formula :  $CFSE = [-0.4(n) t_{2g} + 0.6(n') e_g] \Delta_o + xP$

- where n and n' odd number of electrons in  $t_{2g}$  &  $e_g$  Orbitals respectively
- $\Delta_o$  crystal field splitting energy for octahedral complexes
- X represents the number of extra electron pairs formed because of the ligands and comparison to the normal degenerate configuration

## Electron filling in tetrahedral

The orbital splitting energies are not sufficiently large for forcing pairing and therefore low spin configuration are rarely observed

**QUESTION - Exemplar**

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

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

$$\Delta_{tet} = \frac{4}{5} \Delta_o$$

$$\Delta_{tet} = \frac{4}{5} \times \frac{2 \times 18,000}{3} \text{ cm}^{-1}$$

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

**QUESTION – Exemplar**

**Which of the following systems has maximum number of unpaired electrons?**

- A d<sup>4</sup> (octahedral, low spin)
  - B d<sup>6</sup> (tetrahedral)
  - C d<sup>6</sup> (octahedral, low spin)
  - D d<sup>9</sup> (octahedral)

## QUESTION

**The number of unpaired electrons in  $d^6$ , low spin, octahedral complex is:**

- A 4  
B 2  
C 1  
D ✓ 0

**QUESTION (2 marks)**

- (i) On the basis of crystal field theory, write the electronic configuration of  $d^4$  ion if  $\Delta_0 < P$   
(ii) Write the hybridization and magnetic behaviour of the complex  $[Ni(CO)_4]$ .  
(At. no. of Ni = 28) [CBSE PYQ]

$$e_2 e_3 e_2^{-1}$$

QUESTION- NCERT EXEMPLAR

**Arrange following complex ions in increasing order of crystal field splitting energy ( $\Delta_0$ ):**  
 $[\text{Cr}(\text{Cl}_3)]^{3-}$ ,  $[\text{Cr}(\text{CN})_4]^{3-}$ ,  $[\text{Cr}(\text{NH}_3)_6]^{3+}$

$\Delta\phi$  ligand strength.

## Colour and coordination compounds



## Colour in Coordination Compounds



### Transition of an electron in $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$

$$E = \frac{hc}{d} \quad E_{\text{absorbed}} = \frac{hc}{N_{\text{absorbed}}}$$

White light

$$E = \frac{hc}{n}$$

$$n = \text{wavelength}$$

$$c = \text{speed of light}$$

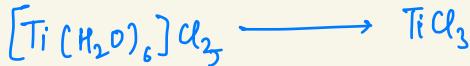
## Relationship between the wavelength of light absorbed and the colour observed in some coordination entities

Coordination entity	Wavelength of light absorbed (nm)	Colour of light absorbed	Colour of coordination entity
$[\text{CoCl}(\text{NH}_3)_5]^{2+}$	535	Yellow	Violet ✓
$[\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+}$	500	Blue Green	Red ✓
$[\text{Co}(\text{NH}_3)_6]^{3+}$	475	Blue	Yellow Orange ✓
$[\text{Co}(\text{CN})_6]^{3-}$	310	Ultraviolet Not in visible region	Pale Yellow ✓
$[\text{Cu}(\text{H}_2\text{O})_4]^{2+}$	600	Red	Blue ✓
$[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$	498	Blue Green	Violet ✓

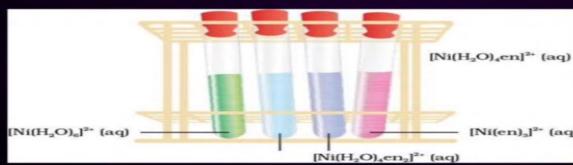
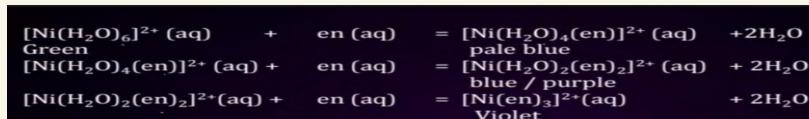
$E_{\text{absorbed}} = \Delta \epsilon$

$\epsilon = \frac{hc}{\lambda_{\text{absorbed}}}$

- the colour of the complex is complimented to that, which is absorbed
- The complimentary colour is the colour generated from the wavelength leftover
- if green light is absorbed by the complex, it appears red
- it is important to note that the absence of Crystal Field splitting does not occur and hence the substance is colourless
- For example, removal of water from  $[\text{Ti}(\text{H}_2\text{O})_6]\text{Cl}_3$  on heating render it colourless.



- Anhydrous  $\text{CuSO}_4$  is white, but  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  is blue in color.



**QUESTION**

**Which of the following compounds is colourless**

- A  $\text{Cu}_2(\text{CH}_3\text{COO})_4 \cdot 2\text{H}_2\text{O}$
- B  $\text{Cu}_2\text{Cl}_2$
- C  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
- D  $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4 \cdot 4\text{H}_2\text{O}$

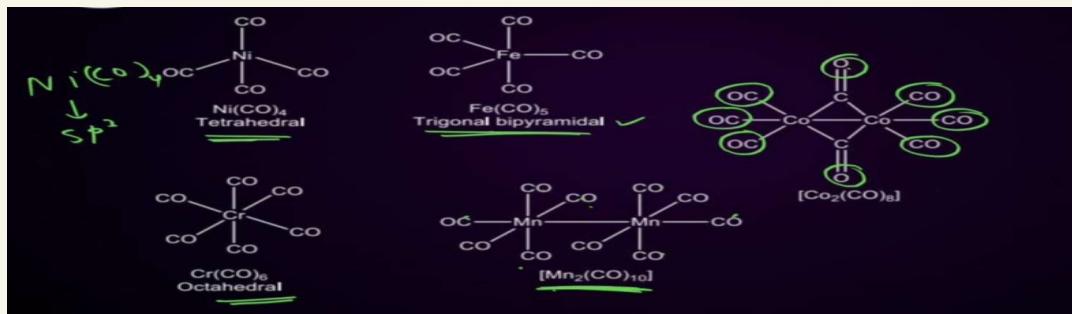
**QUESTION - NCERT EXEMPLAR**

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

$$\lambda \text{ N}^- > \text{NH}_3 > \text{H}_2\text{O}$$

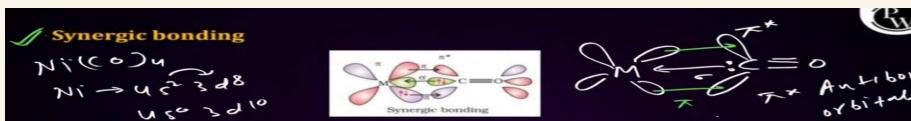
$$E \propto \frac{1}{n}$$

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

Bonding in metal carbonylsSynergic bonding

- the metal carbon bond in metal carbonyls, possess both sigma and pie character
- The M - c sigma bond is formed by the donation of lone pair of electrons on the carbonyl carbon into a vacant orbital of the metal
- The M - c pie bond is formed by the donation of a pair of electrons from a filled D. Orbital of metal into the vacant. Anti bonding pie orbital of carbon monoxide.

- the metal to ligand bonding creates a synergic effect, which strengthens the bond between the CO and the metal



156 of 202

Draw the structure of:

(i)  $\text{Ni}(\text{CO})_4$       (ii)  $\text{Fe}(\text{CO})_5$

[CBSE PYQ]

## Isomerism in coordination compound

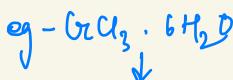
- when complex compounds have same molecular formula, but have different structural or spacial arrangement of ligand around central metal atom or ion called as isomer and this phenomena is known as isomerism
- Coordination compounds exhibit isomerism, the isomerism can be divided into two types
- 1) stereoisomerism
- 2) structural isomerism

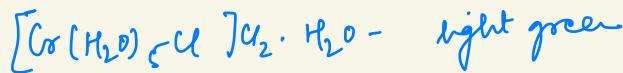
### Structural isomerism

- this form of isomerism arises due to difference in the structure of complexes. It is a four types.
- 1) ionisation isomerism- this form of isomerism arises when the counter in a complex salt is itself a potential ligand can displace a ligand, which can then become the counter ion

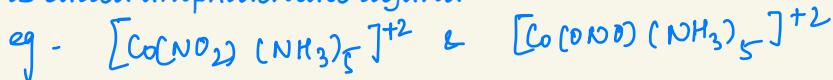


- 2) hydrate/solvate isomerism: hydrate isomerism is a special type of ionisation isomerism. This type of isomerism are due to presence of water molecule in and outside the coordination sphere.





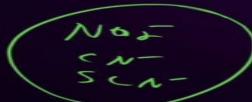
- 3) linkage isomerism: complex consisting amphidentate ligand, give this kind of isomerism. A monodentate ligand with two or more donors atom is called amphidentate ligand



**QUESTION – CBSE PYQ**

Which of the following compounds exhibits linkage isomerism?

- A  $[\text{Co}(\text{en})_3]\text{Cl}_3$  ✗
- B  $[\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{en})_3]$  ✗
- C  $[\text{Co}(\text{en})_2\text{NO}_2\text{Cl}]\text{Br}$
- D  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Br}_2$



- 4) coordination isomerism: it arises due to the mutual exchange of ligand between anionic and cationic spheres of different metal ion in a complex



**QUESTION – CBSE PYQ**

$[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$  and  $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$  are related to each other as:

- A ✗ ionisation isomers
- B linkage isomers
- C coordination isomers
- D geometrical isomers

**QUESTION – NCERT EXEMPLAR**

The compounds  $[\text{Co}(\text{SO}_4)(\text{NH}_3)_5]\text{Br}$  and  $[\text{Co}(\text{SO}_4)_2(\text{NH}_3)_5]\text{Cl}$  represent

- A linkage isomerism
- B ionisation isomerism
- C coordination isomerism
- D no isomerism

N C E R T Exemplar

↓  
Telegram → channel ✓

**QUESTION (1 mark)**

What type of isomerism is shown by the following complex:



[CBSE PYQ]

**QUESTION (1 mark)**

What type of isomerism is exhibited by the following complex:



[CBSE 2014]

**QUESTION (1 mark)**

What type of isomerism is exhibited by the complex  $[\text{Co}(\text{NH}_3)_5\text{NO}_2]^{2+}$ ?

[CBSE PYQ]

Ambidentate  
linkage ✓

**QUESTION (3 marks)**

For the complex  $[\text{NiCl}_4]^{2-}$ , write

- (i) the IUPAC name ✓
- (ii) the hybridization type ✓
- (iii) the shape of the complex. ✓

(Atomic no. of Ni = 28)

[CBSE PYQ]

**Stereo isomerism**

- isomers which have the same position of atoms or groups, but differ in the spatial arrangements around the central atom are called stereoisomer and the phenomena is called stereoisomerism. It is classified into two types.
- 1) geometrical isomerism
- 2) optical isomerism

**Geometrical isomerism**

- compounds have same molecular formula and same connectivity, but have different distances and bond angles between their groups in the structure

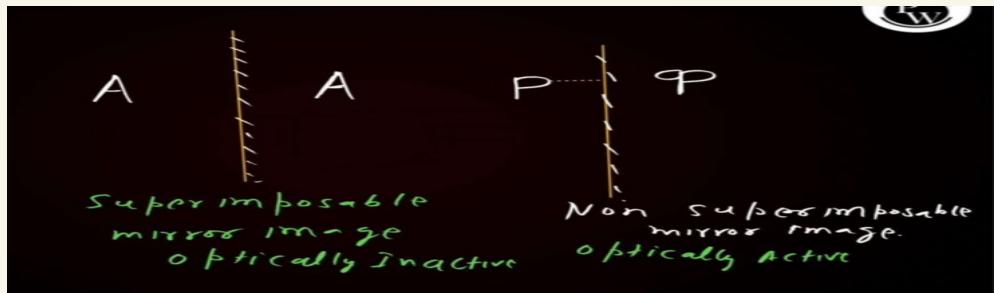
- when two identical ligands occupy adjacent position, the isomer is called cis isomer (bond angle =  $90^\circ$ )
- When two identical ligand occupy opposite position, the isomer is called trans isomer (bond angle =  $180^\circ$ )

## Optical isomerism

- the compounds having same molecular formula, but differ in the rotation of the plane Polarised light are called optical isomers and the phenomenon called optical isomerism.
- The isomer, which rotates the plane polarised light to the right direction is called dextro (d) form while the isomer, which rotates the plane polarised lie to the left direction is called Laevo (l) form
- a pair of optical isomers which are non-superimposable mirror images are called enantiomers
- an equimolar mixture of d and l form is called racemic mixture. They are optically inactive.

### Condition for optical isomerism

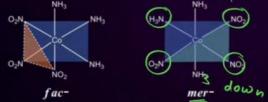
- a pair of optical isomers which are non-superimposable mirror images are optically active and called enantiomers
- an equivalent mixture of D form and L form is called racemic mixture
- racemic mixtures are optically inactive
- if there are any plane of symmetry present in the molecule, then compound will be optically inactive





Total number of geometrical isomers of complex type  $Ma_3b_3$

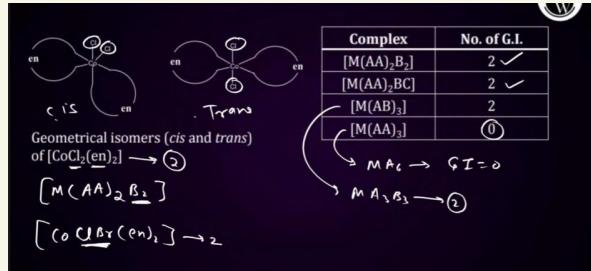
Complex type	Total number of geometrical isomers
$Ma_3b_3$	2



The facial (*fac*) and meridional (*mer*) isomers of  $[Co(NH_3)_3(NO_2)_3]$

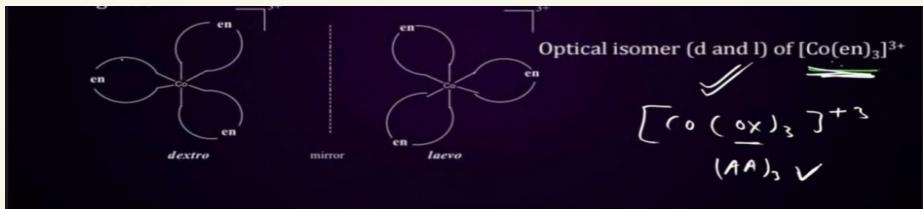
(AA) (AB) (BB)

(AB) (AB) (AB)



## Keynote

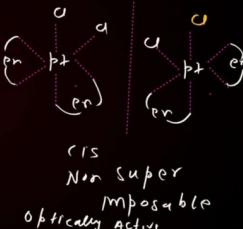
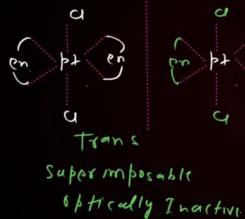
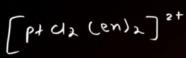
- square planar complexes do not show optical isomerism
- Optical isomerism is common in octahedral complexes involving didentate ligand



✓ In a coordination entity of the type  $\underline{[PtCl_2(en)_2]}^{2+}$ , only the *cis*-isomer shows optical activity



Optical isomer (d and l) of  $cis-[PtCl_2(en)_2]^{2+}$



(2)  
optically  
inactive

Complex	Enantiomer pair
$[\text{MA}_4\text{B}_2]$	0
$[\text{MA}_3\text{BC}]$	0
$[\text{MA}_3\text{B}_3]$	0
$[\text{MA}_2\text{B}_2\text{C}]$	0
$[\text{MA}_3\text{BCD}]$	1
$[\text{MA}_2\text{B}_2\text{C}_2]$	2
$[\text{MA}_2\text{B}_2\text{CD}]$	6
$[\text{MA}_2\text{BCDE}]$	15
$[\text{M}(\text{AA})_2\text{B}_2]$	1
$[\text{M}(\text{AA})_2\text{BC}]$	1
$[\text{M}(\text{AB})_3]$	2

### QUESTION

Which of the following complex will show geometrical as well as optical isomerism?  
(en = ethylene diamine)

- A  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$
  - B  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]$
  - C  $[\text{Pt}(\text{en})_2\text{Cl}_2]^{2+}$
  - D  $[\text{Pt}(\text{en})_3]^{4+}$   ~~X~~
- M(AA)<sub>3</sub>   
or

### QUESTION (1 mark)

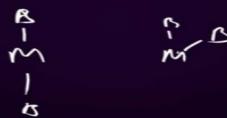
What type of isomerism is exhibited by the complex  $[\text{Co}(\text{en})_3]^{3+}$ ? (en = ethane, 1, 2-diamine) [AI 2014]

M(AA)<sub>3</sub>  
G I X  
or ✓

### QUESTION (3 marks)

Write the IUPAC name of the complex  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$ . What type of isomerism does it exhibit? [CBSE PYQ]

$\frac{\text{M}(\text{NH}_3)_4\text{Cl}_2}{\downarrow \downarrow}$  G I ✓



**QUESTION (3 marks)**

For the complex  $[Fe(en)_2Cl_2]Cl$ , identify the following:

- (i) Oxidation number of iron
- (ii) Hybrid orbitals and shape of the complex
- (iii) Magnetic behaviour of the complex
- (iv) Number of its geometrical isomers
- (v) Whether there may be optical isomer also.
- (vi) Name of the complex.

**QUESTION**

Define Chelate effect. How it affects the stability of complex?

Or

Find the coordination number and oxidation state of chromium in  $Na_3[Cr(C_2O_4)_3]$ .

$$3 + n - 6 = 0$$

$$n = 3$$

$$CN = 3 \times 2 = 6$$

**QUESTION**

Write the electronic configuration of  $d^4$  ion on the basis of crystal field theory when

- (i)  $\Delta_0 < P \rightarrow$  weak  
 (ii)  $\Delta_0 > P \rightarrow$  strong

Or

Find the oxidation state and coordination number of the central metal ion in  $[Co(H_2O)(CN)(en)_2]^{2+}$ .

$$CN = 1 + 1 + 4 \\ = 6$$

$$ON = n + o - l + o = +2 \\ ON = 3$$