

## Coordination Compounds

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### EXERCISE [PAGES 207 - 209]

#### Exercise | Q 1.1 | Page 207

Choose the most correct option.

The oxidation state of cobalt ion in the complex  $[\text{Co}(\text{NH}_3)_5 \text{Br}]\text{SO}_4$  is \_\_\_\_\_.

1. +2
2. +3
3. +1
4. +4

**Solution:** The oxidation state of cobalt ion in the complex  $[\text{Co}(\text{NH}_3)_5 \text{Br}]\text{SO}_4$  is +3.

#### Exercise | Q 1.2 | Page 207

Choose the most correct option.

IUPAC name of the complex  $[\text{Pt}(\text{en})_2(\text{SCN})_2]^{2+}$  is \_\_\_\_\_.

1. bis (ethylenediamine dithiocyanatoplatinum (IV) ion
2. bis (ethylenediamine) dithiocyanatoplatinate (IV) ion
3. dicyanatobis (ethylenediamine) platinate IV ion
4. bis (ethylenediammine)dithiocynato platinate (IV) ion

**Solution:** IUPAC name of the complex  $[\text{Pt}(\text{en})_2(\text{SCN})_2]^{2+}$  is bis (ethylenediamine dithiocyanatoplatinum (IV) ion.

#### Exercise | Q 1.3 | Page 207

Choose the most correct option.

Formula for the compound sodium hexacyanoferrate (III) is \_\_\_\_\_.

1.  $[\text{NaFe}(\text{CN})_6]$
2.  $\text{Na}_2[\text{Fe}(\text{CN})_6]$
3.  $\text{Na}[\text{Fe}(\text{CN})_6]$
4.  $\text{Na}_3[\text{Fe}(\text{CN})_6]$

**Solution:** The formula for the compound sodium hexacyanoferrate (III) is  $\text{Na}_3[\text{Fe}(\text{CN})_6]$

#### Exercise | Q 1.4 | Page 207

**Choose the most correct option.**

Which of the following complexes exist as cis and trans isomers?

1.  $[\text{Cr}(\text{NH}_3)_2\text{Cl}_4]^-$
2.  $[\text{Co}(\text{NH}_3)_5\text{Br}]^{2+}$
3.  $[\text{PtCl}_2\text{Br}_2]^{2-}$  (square planar)
4.  $[\text{FeCl}_2(\text{NCS})_2]^{2-}$  (tetrahedral)

**1. 1 and 3**

2. 2 and 3
3. 1 and 3
4. 4 only

**Solution:** 1 and 3

**Exercise | Q 1.5 | Page 207**

**Choose the most correct option.**

Which of the following complexes is chiral?

1.  $[\text{Co}(\text{en})_2\text{Cl}_2]^+$
2.  $[\text{Pt}(\text{en})\text{Cl}_2]$
3.  $[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$
4.  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$

**1. 1 and 3**

2. 2 and 3
3. 1 and 4
4. 2 and 4

**Solution:** 1 and 3

**Exercise | Q 1.6 | Page 207**

**Choose the most correct option.**

On the basis of CFT predict the number of unpaired electrons in  $[\text{CrF}_6]^{3-}$ .

1. 1
2. 2
- 3. 3**
4. 4

**Solution: 3**

**Exercise | Q 1.7 | Page 207**

**Choose the most correct option.**

When an excess of  $\text{AgNO}_3$  is added to the complex one mole of  $\text{AgCl}$  is precipitated.

The formula of the complex is \_\_\_\_\_.

1.  **$[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$**
2.  $[\text{CoCl}(\text{NH}_3)_4]\text{Cl}_2$
3.  $[\text{CoCl}_3(\text{NH}_3)_3]$
4.  $[\text{Co}(\text{NH}_3)_4]\text{Cl}_3$

**Solution:** When an excess of  $\text{AgNO}_3$  is added to the complex one mole of  $\text{AgCl}$  is precipitated. The formula of the complex is  **$[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$** .

**Exercise | Q 1.8 | Page 207**

**Choose the most correct option.**

The sum of coordination number and oxidation number of M in  $[\text{M}(\text{en})_2\text{C}_2\text{O}_4]\text{Cl}$  is

\_\_\_\_\_.

1. 6
2. 7
3. **9**
4. 8

**Solution:** The sum of coordination number and oxidation number of M in  $[\text{M}(\text{en})_2\text{C}_2\text{O}_4]\text{Cl}$  is **9**.

**Exercise | Q 2.1 | Page 208**

**Answer the following in one or two sentences.**

Write the formula for tetraammineplatinum (II) chloride.

**Solution:**  $[\text{Pt}(\text{NH}_3)_4]\text{Cl}_2$

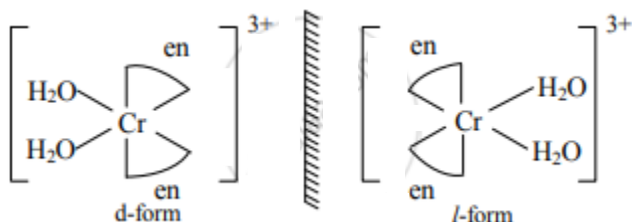
**Exercise | Q 2.2 | Page 208**

**Answer the following in one or two sentences.**

Predict whether the  $[\text{Cr}(\text{en})_2(\text{H}_2\text{O})_2]^{3+}$  complex is chiral. Write the structure of its enantiomer.

**Solution:** i. The complex  $[\text{Cr}(\text{en})_2(\text{H}_2\text{O})_2]^{3+}$  is chiral.

ii. Structures of enantiomers:



### Exercise | Q 2.3 | Page 208

**Answer the following in one or two sentences.**

Name the Lewis acids and bases in the complex  $[\text{PtCl}_2(\text{NH}_3)_2]$ .

**Solution:**

Lewis acid: Platinum (II) ion,  $(\text{Pt}^{2+})$

Lewis bases: Chloride ion  $(\text{Cl}^-)$ , ammonia  $(\text{NH}_3)$

### Exercise | Q 2.4 | Page 208

**Answer the following in one or two sentences.**

What is the shape of a complex in which the coordination number of the central metal ion is 4?

**Solution:**

A complex with coordination number four has a tetrahedral or square planar structure.

### Exercise | Q 2.5 | Page 208

**Answer the following in one or two sentences.**

Is the complex  $[\text{CoF}_6]$  cationic or anionic if the oxidation state of cobalt ion is +3?

**Solution:**

If the oxidation state of Co in  $[\text{CoF}_6]$  is +3, then the charge on complex would be  $-3$ .

Hence, the given complex would be anionic.

### Exercise | Q 2.6 | Page 208

**Answer the following in one or two sentences.**

Consider the complexes  $[\text{Cu}(\text{NH}_3)_4][\text{PtCl}_4]$  and  $[\text{Pt}(\text{NH}_3)_4][\text{CuCl}_4]$ . What type of isomerism these two complexes exhibit?

**Solution:**

The complex  $[\text{Cu}(\text{NH}_3)_4][\text{PtCl}_4]$  and  $[\text{Pt}(\text{NH}_3)_4][\text{CuCl}_4]$  exhibit coordination isomerism.

**Exercise | Q 2.7 | Page 208****Answer the following in one or two sentences.**

Mention two applications of coordination compounds.

**Solution:****Application of coordination compounds are as follows:**

- i. **In biology:** Several biologically important natural compounds are metal complexes. They play important role in a number of processes occurring in plants and animals. For example, chlorophyll present in plants is a complex of Mg. Haemoglobin present in the blood is a complex of iron.
- ii. **In medicines:** a. Pt complex, cisplatin is used in the treatment of cancer. b. EDTA is used for the treatment of lead poisoning.
- iii. **To estimate the hardness of water:** Hardness of water is due to the presence of  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  ions. The ligand, EDTA forms stable complexes with  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ . It can, therefore, be used to estimate hardness.
- iv. **In electroplating:** Usually, stable coordination complexes on dissolution dissociate to a small extent and furnish a controlled supply of metal ions. The metal ions when reduced clump together to form the clusters or nanoparticles. When the coordination complexes have used the ligands in the complex keep the metal atoms well separated from each other. These metal atoms tend to form a protective layer on the surface. Certain cyanide complexes  $\text{K}[\text{Ag}(\text{CN})_2]$  and  $\text{K}[\text{Au}(\text{CN})_2]$  find applications in the electroplating of these noble metals.

**Exercise | Q 3.01 | Page 208****Answer in brief.**

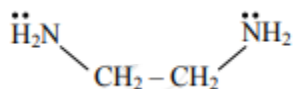
What are bidentate ligands ? Give one example.

**Solution:**

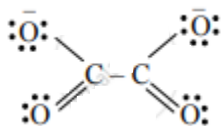
**Bidentate ligands:** The ligands which bind to central metal through two donor atoms are called bidentate ligands.

e.g.

1. Ethylenediamine binds to the central metal atom through two nitrogen atoms.



2. Similarly, Oxalate ligand ( $\text{C}_2\text{O}_4^{2-}$ ) utilizes electron pair on each of its negatively charged oxygen atoms on linking with central metal.



### Exercise | Q 3.02 | Page 208

**Answer in brief.**

What are the coordination number and oxidation state of the metal ion in the complex  $[\text{Pt}(\text{NH}_3)\text{Cl}_5]^-$ ?

**Solution:**

In complex  $[\text{Pt}(\text{NH}_3)\text{Cl}_5]^-$ , the coordination number of the metal ion is 6, and the oxidation state of the metal ion is +4.

### Exercise | Q 3.03 | Page 208

**Answer in brief.**

What is the difference between a double salt and a complex? Give an example.

**Solution:**

A double salt dissociates in water completely into simple ions, whereas a coordination complex dissociates in water with at least one complex ion.

**e.g.** Mohr's salt,  $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$  is a double salt while  $\text{K}_4[\text{Fe}(\text{CN})_6]$  is a complex.

### Exercise | Q 3.04 | Page 208

**Answer in brief.**

Classify the following complexes as homoleptic and heteroleptic  $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$ ,  $[\text{Cu}(\text{en})_2(\text{H}_2\text{O})\text{Cl}]^{2+}$ ,  $[\text{Fe}(\text{H}_2\text{O})_5(\text{NCS})]^{2+}$ , tetraammine zinc (II) nitrate.

**Solution:**

**i. Homoleptic complexes:**  $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$ , tetraamminezinc(II) nitrate.

**ii. Heteroleptic complexes:**  $[\text{Cu}(\text{en})_2(\text{H}_2\text{O})\text{Cl}]^{2+}$ ,  $[\text{Fe}(\text{H}_2\text{O})_5(\text{NCS})]^{2+}$ .

### Exercise | Q 3.05 | Page 208

**Answer in brief.**

Write formulae of the following complexes

- Potassium amminetrichloroplatinate (II)
- Dicyanoaurate (I) ion

**Solution:**

- $\text{K}[\text{Pt}(\text{NH}_3)\text{Cl}_3]$
- $[\text{Au}(\text{CN})_2]^-$

### Exercise | Q 3.06 | Page 208

**Answer in brief.**

What are ionization isomers ? Give an example.

**Solution:**

Isomers that involve the exchange of ligands between coordination and ionization spheres are called ionization isomers.

e.g.  $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$  and  $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$

### Exercise | Q 3.07 | Page 208

**Answer in brief.**

What are the high-spin and low-spin complexes?

**Solution:**

**i. High-spin complexes:** When crystal field splitting energy is greater than electron pairing energy, the complexes formed are high-spin complexes.

**ii. Low-spin complexes:** When crystal field splitting energy is smaller than electron pairing energy, the complexes formed are low-spin complexes.

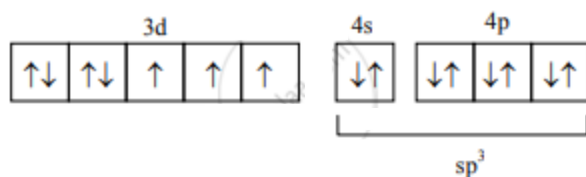
### Exercise | Q 3.08 | Page 208

**Answer in brief.**

$[\text{CoCl}_4]^{2-}$  is a tetrahedral complex. Draw its box orbital diagram. State which orbitals participate in hybridization.

**Solution:**

- Box orbital diagram of  $[\text{CoCl}_4]^{2-}$



ii. One 4s and three 4p orbitals participate in hybridization.

### Exercise | Q 3.09 | Page 208

**Answer in brief.**

What are strong field and weak field ligands ? Give one example of each.

**Solution:**

i. **Strong field ligands:** Those ligands which cause larger splitting of d orbitals and favour pairing of electrons are called strong field ligands. Strong field ligands contain C, N, and P as donor atoms.

e.g.  $\text{CN}^-$ ,  $\text{NCS}^-$ ,  $\text{CO}$ ,  $\text{NH}_3$ , EDTA, en (ethylenediammine).

ii. **Weak field ligands:** Those ligands which cause lower splitting of d orbitals i.e.,  $\Delta^\circ$  parameter is smaller compared to the energy required for the pairing of electrons are called weak field ligands. Weak field ligands contain halogen, O, and S as donor atoms.

e.g.  $\text{F}^-$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ ,  $\text{SCN}^-$ ,  $\text{C}_2\text{O}_4^{2-}$ .

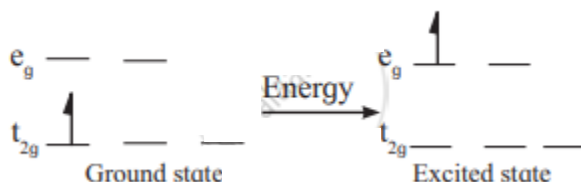
### Exercise | Q 3.1 | Page 208

**Answer in brief.**

With the help of the crystal field, energy-level diagram explain why the complex  $[\text{Cr}(\text{en})_3]^{3+}$  is coloured?

**Solution:**

i. The central metal ion titanium has electronic configuration  $3d^3$  and the electrons occupy one of the  $t_{2g}$  orbitals.



**d - d transition in d' system**

ii. The absorption of the wavelength of light promotes an electron from the  $t_{2g}$  level to  $e_g$  level. Therefore, in the complex  $[\text{Cr}(\text{en})_3]^{3+}$ , d-d transitions are possible. Hence, the complex is coloured.

### Exercise | Q 4.1 | Page 208

#### Answer the following question.

Give valence bond description for the bonding in the complex  $[\text{VCl}_4]^-$ . Draw box diagrams for the free metal ion. Which hybrid orbitals are used by the metal? State the number of unpaired electrons.

#### Solution:

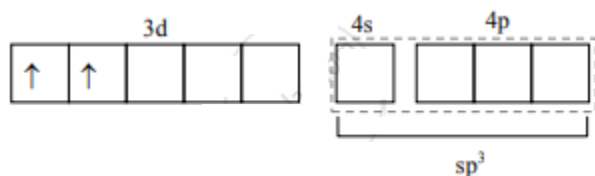
i. The oxidation state of vanadium is +3

ii. Valence shell electronic configuration of free metal ion,  $\text{V}^{3+}$



iii. The number of  $\text{Cl}^-$  ligands is 4. Therefore, the number of vacant metal ion orbitals required for bonding with ligands must be four.

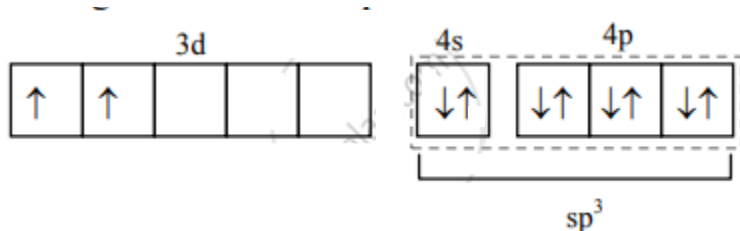
iv. Four orbitals on metal available for hybridisation are one s and three 4p. The complex is tetrahedral.



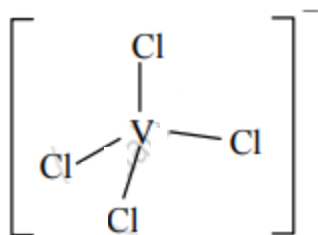
v. The four metal ion orbitals for bonding with  $\text{Cl}^-$  ligands are derived from the  $sp^3$  hybridization.

vi. Four vacant  $sp^3$  hybrid orbitals of  $\text{V}^{3+}$  overlap with four orbitals of  $\text{Cl}^-$  ions.

vii. Configuration after complex formation would be



viii. The complex has two unpaired electrons. The structure of  $[\text{VCl}_4]^-$  is



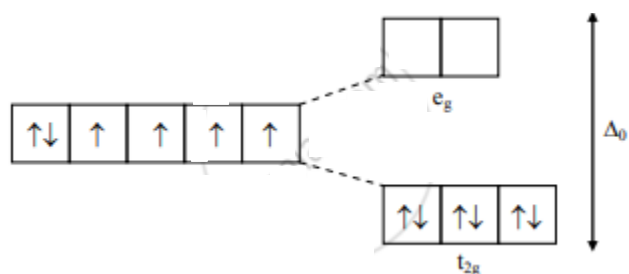
### Exercise | Q 4.2 | Page 208

**Answer the following question.**

Draw a qualitatively energy-level diagram showing d-orbital splitting in the octahedral environment. Predict the number of unpaired electrons in the complex  $[\text{Fe}(\text{CN})_6]^{4-}$ . Is the complex diamagnetic or paramagnetic? Is it coloured? Explain.

**Solution:**

**i. Diagram:**



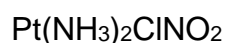
**ii.** There are no unpaired electrons in  $t_{2g}$  orbital; hence, the complex is diamagnetic.

**iii.** In the complex, d-d transitions do not occur and hence, it is colourless.

### Exercise | Q 4.3 | Page 208

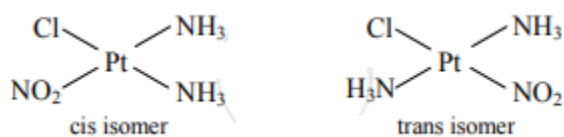
**Answer the following question.**

Draw isomers of the following



**Solution:**

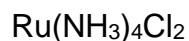
**Cis and trans isomers of  $\text{Pt}(\text{NH}_3)_2\text{ClNO}_2$**



### Exercise | Q 4.3 | Page 208

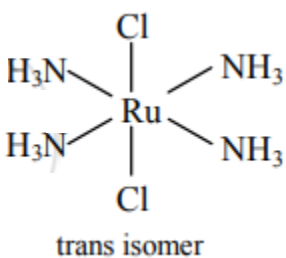
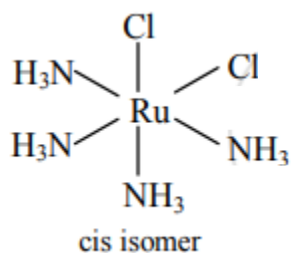
**Answer the following question.**

Draw isomers of the following



**Solution:**

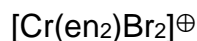
**Cis and trans isomers of  $\text{Ru}(\text{NH}_3)_4\text{Cl}_2$**



**Exercise | Q 4.3 | Page 208**

**Answer the following question.**

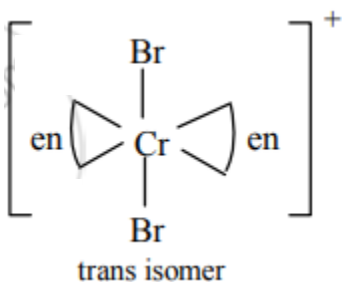
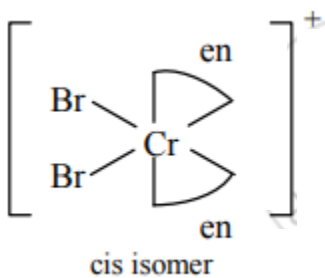
Draw isomers of the following



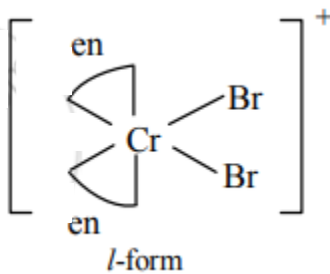
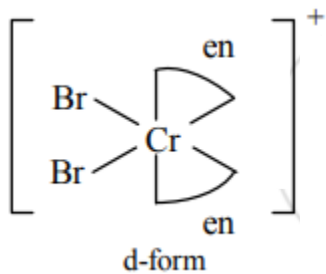
**Solution:**

**Cis and trans isomers of  $[\text{Cr}(\text{en}_2)\text{Br}_2]^{\oplus}$**

a. Cis and trans isomers of  $[\text{Cr}(\text{en}_2)\text{Br}_2]^+$



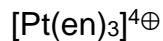
b. Optical isomers of  $[\text{Cr}(\text{en}_2)\text{Br}_2]^+$



**Exercise | Q 4.4 | Page 208**

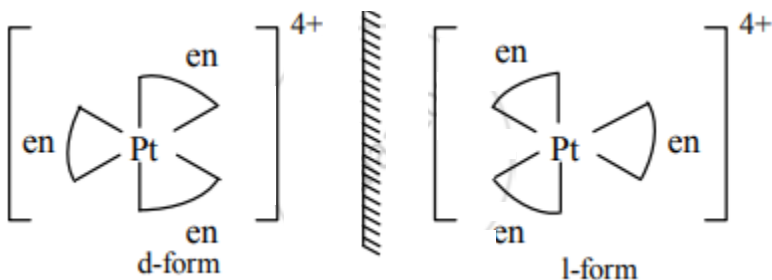
**Answer the following question.**

Draw geometric isomers and enantiomers of the following complex.



**Solution:**

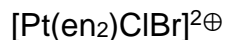
$[\text{Pt}(\text{en})_3]^{4+}$  shows only enantiomers as follows:



**Exercise | Q 4.4 | Page 208**

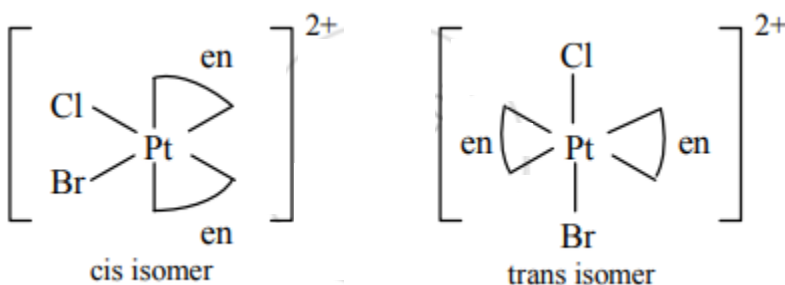
**Answer the following question.**

Draw geometric isomers and enantiomers of the following complex.

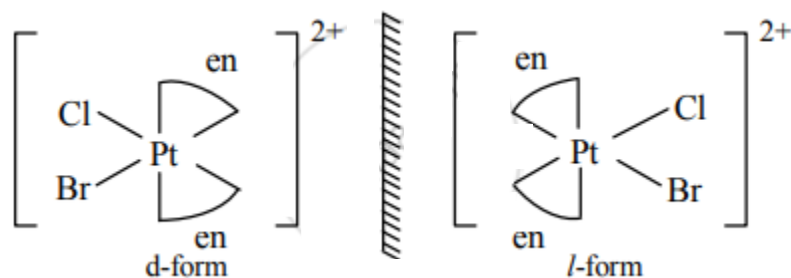


**Solution:**

a. Geometric isomers of  $[\text{Pt}(\text{en})_2\text{ClBr}]^{2+}$



b. Enantiomers of  $[\text{Pt}(\text{en})_2\text{ClBr}]^{2+}$



### Exercise | Q 4.5 | Page 209

#### Answer the following question.

What are ligands? What are their types ? Give one example of each type.

#### Solution:

In the coordination compound, the species surrounding the central metal atom or ion are called ligands. Depending upon the number of electron donor atoms present, ligands are classified as:

**i. Monodentate ligands:** A monodentate ligand is the one where a single donor atom shares an electron pair to form a coordinate bond with the central metal ion.

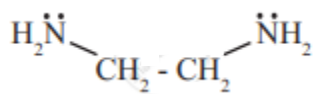
e.g.  $\text{Cl}^-$ ,  $\text{OH}^-$ ,  $\text{CN}^-$ , etc.

**ii. Polydentate ligands:** A polydentate ligand has two or more donor atoms linked to the central metal ion. Based on the number of donor atoms, polydentate ligands are further classified as:

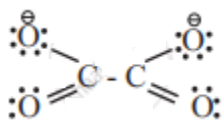
**a. Bidentate ligands:** The ligands which bind to central metal through two donor atoms are called bidentate ligands.

e.g.

1. Ethylenediamine binds to the central metal atom through two nitrogen atoms.

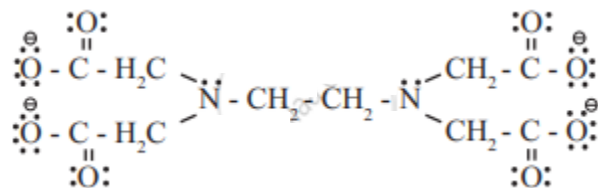


2. Similarly, Oxalate ligand ( $\text{C}_2\text{O}_4^{2-}$ ) utilizes electron pair on each of its negatively charged oxygen atoms on linking with central metal.



**b. Hexadentate ligands:** The ligands which bind to central metal through six donor atoms are called hexadentate ligands.

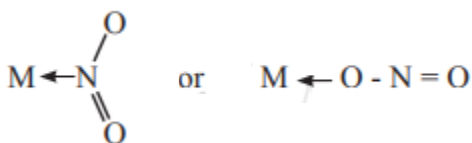
e.g. Ethylenediaminetetraacetate ion ( $\text{EDTA}^{4-}$ ) binds to metal by electron pairs of four oxygen and two nitrogen atoms.



**iii. Ambidentate ligands:** The ligands which have two donor atoms and use the electron pair of either donor atoms to form a coordinate bond with the metal ion are called ambidentate ligands.

e.g.

a. The ligand  $\text{NO}_2^-$  links to the metal ion through nitrogen or oxygen.



b.  $\text{SCN}^-$  has two donor atoms nitrogen and sulphur either of which links to metal  $\text{M} \leftarrow \text{SCN}^-$  or  $\text{M} \leftarrow \text{NCS}^-$ .

### Exercise | Q 4.6 | Page 209

**Answer the following question.**

What are cationic, anionic, and neutral complexes? Give one example of each.

**Solution:**

On the basis of charge on complex ion, coordination complex is classified as:

**i. Cationic complex:** A positively charged coordination sphere or a coordination compound having a positively charged coordination sphere is called the cationic complex or cationic sphere complex.

e.g.  $[\text{Zn}(\text{NH}_3)_4]^{2+}$

**ii. Anionic complex:** A negatively charged coordination sphere or a coordination compound having a negatively charged coordination sphere is called an anionic complex or anionic sphere complex.

e.g.  $[\text{Fe}(\text{CN})_6]^{3-}$

**iii. Neutral sphere complexes:** A coordination complex that does not possess a cationic or anionic sphere are neutral complexes of neutral sphere complexes.

e.g.  $[\text{Ni}(\text{CO})_4]$

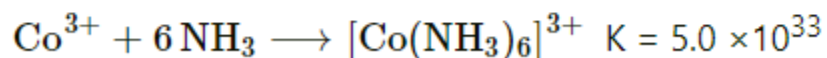
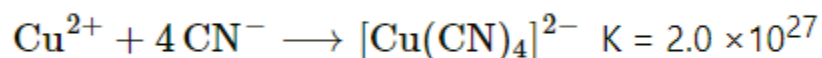
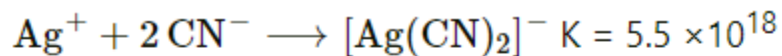
### Exercise | Q 4.7 | Page 209

**Answer the following question.**

How stability of the coordination compounds can be explained in terms of equilibrium constants?

**Solution:**

The stability of the complex can be explained in terms of K. Higher the value of K larger is the thermodynamic stability of the complex. The equilibria for the complex formation with the corresponding K values are given below.



Among the above equilibrium constant data,  $[\text{Co}(\text{NH}_3)_6]^{3+}$  is more stable than  $[\text{Ag}(\text{CN})_2]^-$  and  $[\text{Cu}(\text{CN})_4]^{2-}$  because  $[\text{Co}(\text{NH}_3)_6]^{3+}$  has higher value of equilibrium constant.

#### Exercise | Q 4.8 | Page 209

**Answer the following question.**

Name the factors governing the equilibrium constants of the coordination compounds.

**Solution:**

The stability of a complex or equilibrium constant is governed by

- i. Charge to size ratio of the metal ion
- ii. Nature of the ligand.