

CHAPTER 9

COORDINATION COMPOUNDS

1 mark questions

1. Explain coordination entity with example.

Ans: it constitute a central metal atom or ions bonded to a fixed number of molecules or ions (ligands) .eg. $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$.

2. What do you understand by coordination compounds?

Ans: coordination compounds are the compounds which contains complex ions. These compounds contain a central metal atom or cation which is attached with a fixed number of anions or molecules called ligands through coordinate bonds. eg. $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$

3. What is coordination number?

Ans: the coordination number of a metal ion in a complex may be defined as the total number of ligand donor atoms to which the metal ion is directly bonded. Eg. In the complex ion $[\text{Co}(\text{NH}_3)_6]^{3+}$ has 6 coordination number.

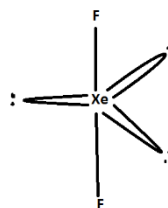
4. Name the different types of isomerisms in coordination compounds.

Ans: structural isomerism and stereoisomerism.

5. Draw the structure of xenon difluoride.

Ans: structure :trigonalbipyramidal

Shape: linear



6. What is spectrochemical series?

Ans: the series in which ligands are arranged in the order of increasing field strength is called spectrochemical series. The order is :



7. What do you understand by denticity of a ligand?

Ans: the number of coordinating groups present in ligand is called denticity of ligand.

Eg. Bidentate ligand ethane-1,2-diamine has 2 donor nitrogen atoms which can link to central metal atom.

8. Why is CO a stronger ligand than Cl^- ?

Ans: because CO has π bonds.

9. Why are low spin tetrahedral complexes not formed?

Ans : because for tetrahedral complexes, the crystal field stabilisation energy is lower than pairing energy.

10. Square planar complexes with coordination number 4 exhibit geometrical isomerism whereas tetrahedral complexes do not. Why?

Ans: tetrahedral complexes do not show geometrical isomerism because the relative positions of the ligands attached to the central metal atom are same with respect to each other.

11. What are crystal fields?

Ans: the ligands has around them negatively charged field because of which they are called crystal fields.

12. What is meant by chelate effect? Give an example .

Ans: when a didentate or polydentate ligand contains donor atoms positioned in such a way that when they coordinate with the central metal atom, a 5 or 6 membered ring is formed , the effect is called chelate effect. Eg. $[\text{PtCl}_2(\text{en})]$

13. What do you understand by ambidentate ligand?

Ans: a ligand which contains two donor atoms but only one of them forms a coordinate bond at a time with central metal atom or ion is called an ambidentate ligand. Eg. nitrito-N and nitrito-O.

14. What is the difference between homoleptic and heteroleptic complexes?

Ans: in homoleptic complexes the central metal atom is bound to only one kind of donor groups whereas in heteroleptic complexes the central metal atom is bound to more than one type of donor atoms.

15. Give one limitation for crystal field theory.

Ans: i) as the ligands are considered as point charges, the anionic ligands should exert greater splitting effect. However the anionic ligands are found at the low end of the spectrochemical series.
ii) it does not take into account the covalent character of metal ligand bond. (any one)

16. How many ions are produced from the complex: $[\text{Co}(\text{NH}_3)_6]\text{Cl}_2$

Ans: 3 ions

17. The oxidation number of cobalt in $\text{K}[\text{Co}(\text{CO})_4]$

Ans: -1

18. Which compound is used to estimate the hardness of water volumetrically?

Ans: EDTA

19. Magnetic moment of $[\text{MnCl}_4]^{2-}$ is 5.92 B.M explain with reason.

Ans: the magnetic moment of 5.9 B.M. corresponds to the presence of 5 unpaired electrons in the d-orbitals of Mn^{2+} ion. As a result the hybridisation involved is sp^3 rather than dsp^2 . Thus tetrahedral structure of $[\text{MnCl}_4]^{2-}$ complex will show 5.92 B.M magnetic moment value.

20. How many donor atoms are present in EDTA ligand?

Ans: 6

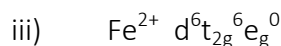
2 marks questions

1. Give the electronic configuration of the following complexes on the basis of crystal field splitting theory.

i) $[\text{CoF}_6]^{3-}$

ii) $[\text{Fe}(\text{CN})_6]^{4-}$

Ans: i) $\text{Co}^{3+} (d^6) t_{2g}^4 e_g^2$



2. Explain the following with examples:

i) Linkage isomerism

ii) Outer orbital complex

Ans: i) this type of isomerism arises due to the presence of ambidentate ligand in a coordination compound. Eg. $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$ and $[\text{Co}(\text{NH}_3)_5\text{ONO}]\text{Cl}_2$

iii) When ns, np and nd orbitals are involved in hybridisation, outer orbital complex is formed. Eg. $[\text{CoF}_6]^{2-}$ in which cobalt is sp^3d^2 hybridised.

3. i) Low spin octahedral complexes of nickel are not found. Explain why?

ii) these complexes are known for transition elements only. explain.

Ans: i) nickel in its atomic or ionic state cannot afford 2 vacant 3d orbitals and hence d^2sp^3 hybridisation is not possible.

ii) transition metals have vacant d orbitals in their atoms or ions into which the electron pairs can be donated by ligands containing π electrons. eg. benzene, ethylene etc. thus $\text{d}\pi\text{-p}\pi$ bonding is possible.

4. How would you account for the following:

i) $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ is coloured while $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$ is colourless.

ii) $[\text{Ni}(\text{CO})_4]$ possess tetrahedral geometry whereas $[\text{Ni}(\text{CN})_4]^{2-}$ is square planar.

Ans: i) due to the presence of 1 electron in 3d subshell in $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ complex d-d transition takes place by the absorption of visible light. Hence the complex appears coloured. On the other hand, $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$ does not possess any unpaired electron. Hence d-d transition is not possible (which is responsible for colour) in this complex is not possible, therefore it is colourless.

ii) Ni in $[\text{Ni}(\text{CO})_4]$ is sp^3 hybridised. Hence it is tetrahedral. Whereas for $[\text{Ni}(\text{CN})_4]^{2-}$ is dsp^2 hybridised hence it has square planar geometry.

5. State reasons for each of the following:

i) All the P—Cl bonds in PCl_5 molecule are not equivalent.

ii) S has greater tendency for catenation than O.

Ans: i) in PCl_5 the 2 axial bonds are longer than 3 equatorial bonds. This is due to the fact that the axial bond pairs suffers more repulsion as compared to equatorial bond pairs.

ii) The property of catenation depends upon the bond strength of the element. As S—S bond is much stronger (213 kJ / mole) than O—O bond (138 kJ/mole), S has greater tendency for catenation than O.

6. Give the stereochemistry and the magnetic behaviour of the following complexes:

i) $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$

ii) $\text{K}_2[\text{Ni}(\text{CN})_4]$

Ans: i) d^2sp^3 hybridisation, structure and shape = octahedral

Magnetic behaviour- diamagnetic

ii) dsp^2 hybridisation, structure and shape = square planar

magnetic behaviour- diamagnetic

7. Draw the structures of isomers if any and write the names of the following complexes:

i) $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$

ii) $[\text{Co}(\text{en})_3]^{3+}$

Ans: i) tetraamminedichloridochromium(III) ion

ii) tris(ethane-1,2-diammine)cobalt(III)ion

8. State reasons for each of the following:

i) The N—O bond in NO_2^- is shorter than the N—O bond in NO_3^-

ii) SF_6 is kinetically an inert substance.

Ans: i) this is because the N—O bone in NO_2^- is an average of a single bond and a double bond whereas N—O bond in NO_3^- is an average of 2 single bonds and a double bond.

iii) In SF_6 the S atom is sterically protected by 6 fluorine atoms and does not allow water molecules to attack the S atom. Further F atoms does not contain d orbitals to accept the electrons denoted by water molecules. Due to these reasons, SF_6 is kinetically an inert substance.

9. Hydrated copper sulphate is blue in colour whereas anhydrous copper sulphate is colourless. Why?

Ans: because water molecules act as ligands which splits the d orbital of the Cu^{2+} metal ion. This result in d-d transition in which $t_{2g}^6 e_g^3$ excited to $t_{2g}^5 e_g^4$ and this impart blue colour to the crystal. Whereas when we talk about anhydrous copper sulphate it does not contain any ligand which could split the d orbital to have CFSE effect.

10. Calculate the magnetic moment of the metal ions present in the following complexes:

i) $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$

ii) $[\text{Ni}(\text{CN})_4]^{2-}$

Ans: i) electronic config. $t_{2g}^6 e_g^3$, $n=1$, $\mu_s = \sqrt{n(n+2)} = 1.732 \text{ B.M}$

ii) electronic config. $t_{2g}^6 e_g^2$, $n=2$, $\mu_s = \sqrt{n(n+2)} = 2.828 \text{ B.M}$

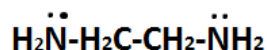
3 marks questions

1. (a) What is a ligand? Give an example of a bidentate ligand.

(b) explain as to how the 2 complexes of nickel, $[\text{Ni}(\text{CN})_4]^{2-}$ and $\text{Ni}(\text{CO})_4$ have different structures but do not differ in their magnetic behaviour. (Ni=28)

Ans: (a) the ion, atom or molecule bound to the central atom or ion in the coordination entity is called ligand. A ligand should have lone pair of electrons in their valence orbital which can be donated to central metal atom or ion.

Eg. Bidentate ligand-



ethylenediammine

(b) dsp^2 , square planar, diamagnetic ($n=0$)

sp^3 hybridisation, tetrahedral geometry, diamagnetic ($n=0$)

2. Nomenclature the following complexes:

i) $[\text{Co}(\text{NH}_3)_5(\text{CO}_3)]\text{Cl}$

ii) $[\text{CoCl}_2(\text{en})_2]\text{Cl}$

iii) $\text{Fe}_4[\text{Fe}(\text{CN})_6]$

Ans: i) pentaamminecarbonatocobalt(III)chloride

ii) dichloridobis(ethane-1,2-diamine)cobalt(III)chloride

iii) iron(III)hexacyanidoferrate(II)

3. (a) why do compounds with similar geometry have different magnetic moment?

(b) what is the relationship between the observed colour and wavelength of light absorbed by the complex?

Ans: (a) it is due to the presence of weak and strong ligands in complexes, if CFSE is high the complex will show low value of magnetic moment and if it is low the value of magnetic moment is high. Eg. $[\text{CoF}_6]^{3-}$ and $[\text{Co}(\text{NH}_3)_6]^{3+}$, the former is paramagnetic and the latter is diamagnetic.

(b) higher the CFS lower will be the wavelength of absorbed light. Colour of the complex is obtained from the wavelength of the leftover light.

4. Explain the following terms giving a suitable example.

(a) ambident ligand

(b) denticity of a ligand

(c) crystal field splitting in an octahedral field

Ans (a) A ligand which contains two donor atoms but only one of them forms a coordinate bond at a time with central metal atom or ion is called an ambidentate ligand. Eg. nitrito-N and nitrito-O.

(b) The number of coordinating groups present in ligand is called denticity of ligand. Eg. Bidentate ligand ethane-1,2-diamine has 2 donor nitrogen atoms which can link to central metal atom.

(c) The splitting of the degenerated d orbital into 3 orbitals of lower energy t_{2g} and 2 orbitals of higher energy e_g due to presence of a ligand in an octahedral crystal field is known as crystal field splitting in an octahedral complex.

5. (a) Copper sulphate pentahydrate is blue in colour while anhydrous copper sulphate is colourless. Why?

(b) Sulphur has greater tendency for catenation than oxygen. Why?

Ans : (a) Because water molecules act as ligands which split the d orbital of the Cu^{2+} metal ion. This results in d-d transition in which $t_{2g}^6 e_g^3$ excited to $t_{2g}^5 e_g^4$ and this imparts blue colour to the crystal. Whereas when we talk about anhydrous copper sulphate it does not contain any ligand which could split the d orbital to have CFSE effect.

(b) The property of catenation depends upon the bond strength of the element. As S—S bond is much stronger (213 kJ / mole) than O—O bond (138 kJ/mole), S has greater tendency for catenation than O.

6. Draw structures of geometrical isomers of the following complexes:

(a) $[Fe(NH_3)_2(CN)_4]^-$ (b) $[CrCl_2(ox)_2]^{3-}$ (c) $[Co(en)_3]Cl_3$

7. Write the state of hybridisation, the shape and the magnetic behaviour of the following complexes:

(i) $[Co(en)_3]Cl_3$

(II) $K_2[Ni(CN)_4]$

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

8. How would you account for the following:

(i) $[Ti(H_2O)_6]^{3+}$ is coloured while $[Sc(H_2O)_6]^{3+}$ is colourless.

(II) $[Fe(CN)_6]^{3-}$ is weakly paramagnetic while $[Fe(CN)_6]^{4-}$ is diamagnetic.

(III) $Ni(CO)_4$ possesses tetrahedral geometry while $[Ni(CN)_4]^{2-}$ is square planar.

Ans (i) Due to the presence of 1 electron in 3d subshell in $[Ti(H_2O)_6]^{3+}$ complex d-d transition takes place by the absorption of visible light. Hence the complex appears coloured. On the other hand, $[Sc(H_2O)_6]^{3+}$ does not possess any unpaired electron. Hence d-d transition is not possible (which is responsible for colour) in this complex is not possible, therefore it is colourless.

(ii) paramagnetism is attributed to the presence of unpaired electrons. Greater the number of unpaired electrons greater is the paramagnetism. Due to the presence of one electron in the 3d subshell in $[\text{Fe}(\text{CN})_6]^{3-}$ it is weakly paramagnetic. On the other hand $[\text{Fe}(\text{CN})_6]^{4-}$ is diamagnetic because all electrons are paired.

(iii) Ni in $[\text{Ni}(\text{CO})_4]$ is sp^3 hybridised. Hence it is tetrahedral. Whereas for $[\text{Ni}(\text{CN})_4]^{2-}$ is dsp^2 hybridised hence it has square planar geometry.

9. Explain the following ::

- (i) low spin octahedral complexes of Ni are not known.
- (ii) The π – complexes are known for the transition elements only.
- (iii) CO is a stronger ligand than NH_3 for many metals

Ans. i) nickel in its atomic or ionic state cannot afford 2 vacant 3d orbitals and hence d^2sp^3 hybridisation is not possible.

ii) transition metals have vacant d orbitals in their atoms or ions into which the electron pairs can be donated by ligands containing π electrons. eg. benzene, ethylene etc. thus $\text{d}\pi\text{-p}\pi$ bonding is possible.

(iii) because in case of CO back bonding takes place in which the central atom uses its filled d orbitals with empty anti bonding π^* molecular orbital of CO.

10. What is meant by stability of a coordination compounds in solutions? State the factors which govern the stability of complexes.

Ans : the stability of a complex in solution refers to the degree of association between the two species involved in the state of equilibrium. The magnitude of the equilibrium constant for the association expresses the stability.

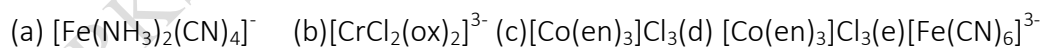


$$K = [\text{ML}_4]/[\text{M}][\text{L}]^4$$

Factors on which stability of complex depends (i) charge on central metal ion (ii) nature of the metal ion (iii) basic nature of the ligand (iv) presence of the chelate ring (v) effect of multidentate cyclic ligand.

5 marks questions

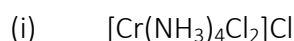
1. Draw the structures of the following molecules:

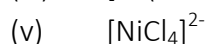
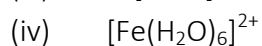
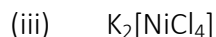


2. What is crystal field theory for octahedral complexes? Also write the limitations of this theory.

Ans :

3. Write the state of hybridisation the shape and the magnetic behaviour of the following complex entities:





4. Using valence bond theory explain the following questions in relation to $[\text{Co}(\text{NH}_3)_6]^{3+}$.

(i) Nomenclature

(ii) Type of hybridisation

(iii) Inner or outer orbital complex

(iv) Magnetic behaviour

(v) Spin only magnetic moment

5. Compare the following complexes with respect to structural shape of units, magnetic behaviour and hybrid orbitals involved in units:

