

CHEMISTRY STUDY MATERIALS FOR CLASS 12

(NCERT BASED QUESTIONS - ANSWERS OF CHAPTER - 09)

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Co-ordination Compounds

Question 8: Predict the number of unpaired electrons in the square planar $[Pt(CN)_4]^{2-}$ ion.

Solution 8: $[Pt(CN)_4]^{2-}$ In this complex, Pt is in the +2 state. It forms a square planar structure. This means that it undergoes dsp^2 hybridization. Now, the electronic configuration $Pd (+2)$ of is $5d^8$.



CN^- being a strong field ligand causes the pairing of unpaired $3d^8$ electrons. Hence, there are no unpaired electrons in $[Pt(CN)_4]^{2-}$.

Question 9: The hexaquo manganese (II) ion contains five unpaired electrons, while the hexacyanoion contains only one unpaired electron. Explain using Crystal Field Theory.

Solution 9:

| $[Mn(H_2O)_6]^{2+}$ | $[Mn(CN)_6]^{4-}$ |
|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mn is in the +2 oxidation state. | Mn is in the +2 oxidation state |
| The electronic configuration is d^5 . | The electronic configuration is d^5 . |
| The crystal field is octahedral. Water is a weak field ligand. Therefore, the arrangement of the electrons in $[Mn(H_2O)_6]^{2+}$ is $t_2g^3e_g^2$. | The crystal field is octahedral. Cyanide is a strong field ligand and hence force pairing occurs. Therefore, the arrangement of the electrons in $[Mn(CN)_6]^{4-}$ is $t_2g^5e_g^0$. |
| Hence, hexaquo manganese (II) ion has five unpaired electrons | while hexacyano ion has only one unpaired electron. |

Question 10: Calculate the overall complex dissociation equilibrium constant for the $[Cu(NH_3)_4]^{2+}$ ion, given that K_f for this complex is 2.1×10^{13} .

Solution 10: The overall complex dissociation equilibrium constant is the reciprocal of the overall stability constant,

$$\frac{1}{\beta_4} = \frac{1}{2.1 \times 10^{13}} = 4.7 \times 10^{-14}$$

NCERT Exercise

Q.1: Explain the bonding in coordination compounds in terms of Werner's postulates.

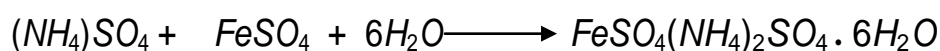
Solution 1: Werner's theory is the first theory to explain the nature of bonding in coordination compounds.

The main postulates of this theory are:

- (i) In coordination compound metals exhibits two types of valencies namely, primary and secondary valencies.
- (ii) Primary valencies are satisfied by negative ions and these ions are ionisable. It is represented by dotted line
- (iii) The primary valency corresponds to the oxidation number of the metal ion.
- (iv) Secondary valencies are non ionisable and satisfied by both negative and neutral ions. It is represented through solid line.
- (v) The secondary valency refers to the coordination number of the metal ion.
- (vi) These valencies project in a specific direction in the space assigned to the definite geometry of the coordination compound.

Q.2: FeSO_4 solution mixed with $(\text{NH}_4)_2\text{SO}_4$ solution in 1:1 molar ratio gives the test of Fe^{2+} ion but CuSO_4 solution mixed with aqueous ammonia in 1:4 molar ratio does not give the test of Cu^{2+} ion. Explain why?

Solution 2:



Mohr's salt



Tetraamminocopper(ii)sulphate

Both the compounds i.e $\text{FeSO}_4(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ and $\text{Cu}(\text{NH}_3)_4\text{SO}_4 \cdot 5\text{H}_2\text{O}$

category of addition compounds with only one major difference i.e., the former is an example of a double salt, while the latter is a coordination compound.

A double salt is an addition compound that is stable in the solid state but that which breaks up into its constituent ions in the dissolved state. These compounds exhibit individual properties of their constituents.

For e.g. $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$ breaks into Fe^{2+} , NH_4^+ and SO_4^{2-} ions.

Hence, it gives a positive test for Fe^{2+} ions.

A coordination compound is an addition compound which retains its identity in the solid as well as in the dissolved state. However, the individual properties of the constituents are lost.

This happens because $Cu(NH_3)_4SO_4 \cdot 5H_2O$ does not show the test for Cu^{2+} . The ions present in the solution of $Cu(NH_3)_4SO_4 \cdot 5H_2O$ are $Cu(NH_3)_4^{2+}$ and SO_4^{2-} .

Q. 3: Explain with two examples each of the following: coordination entity, ligand, coordination number, coordination polyhedron, homoleptic and heteroleptic.

Solution 3:

(i) Coordination entity:

A coordination entity constitutes a central metal atom or ion bonded to a fixed number of ions or molecules called ligands

For example:

$[Ni(NH_3)_6]^{2+}$, $[Fe(CN)_6]^{4-}$ cationic complex

$[PtCl_4]^{2-}$, $[Ag(CN)_2]^-$ anionic complex

$[Ni(CO)_4]$, $[Co(NH_3)_4]Cl_2$ neutral complex

(ii) Ligands

The neutral molecules or negatively charged ions that surround the metal atom in a coordination entity or a coordinational complex are known as ligands.

For example, NH_3 , H_2O , Cl^- , OH^- Ligands are usually polar in nature and possess at least one unshared pair of valence electrons.

(iii) Coordination number:

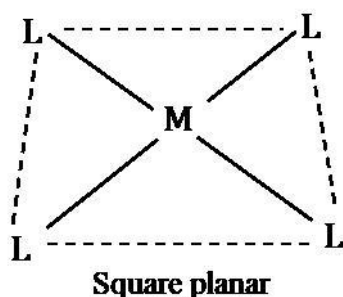
The total number of ligands (either neutral molecules or negative ions) that get attached to the central metal atom in the coordination sphere is called the coordination number of the central metal atom. It is also referred to as its ligancy. **For example:**

- (a) In the complex, $K_2[PtCl_6]$, there are six chloride ions attached to Pt in the coordination sphere. Therefore, the coordination number of Pt is 6.
- (b) Similarly, in the complex $[Ni(NH_3)_4]Cl_2$, the coordination number of the central atom (Ni) is 4.

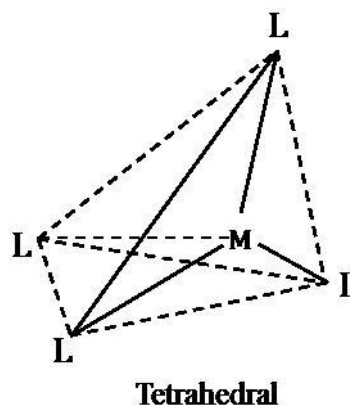
(vi) Coordination polyhedron:

Coordination polyhedrons about the central atom can be defined as the spatial arrangement of the ligands that are directly attached to the central metal ion in the coordination sphere. For example:

(a) Square planar



(b) Tetrahedral



(v) Homoleptic complexes:

These are those complexes in which the metal ion is bound to only one kind of a donor group. For e.g: $[Co(NH_3)_6]^{3+}$, $[PtCl_4]^{2-}$ etc..

(vi) Heteroleptic complexes:

Heteroleptic complexes are those complexes where the central metal ion is bound to more than one type of a donor group.

For e.g.. $[Co(NH_3)_4Cl_2]^+$, $[Co(NH_3)_5Cl]^{2+}$
