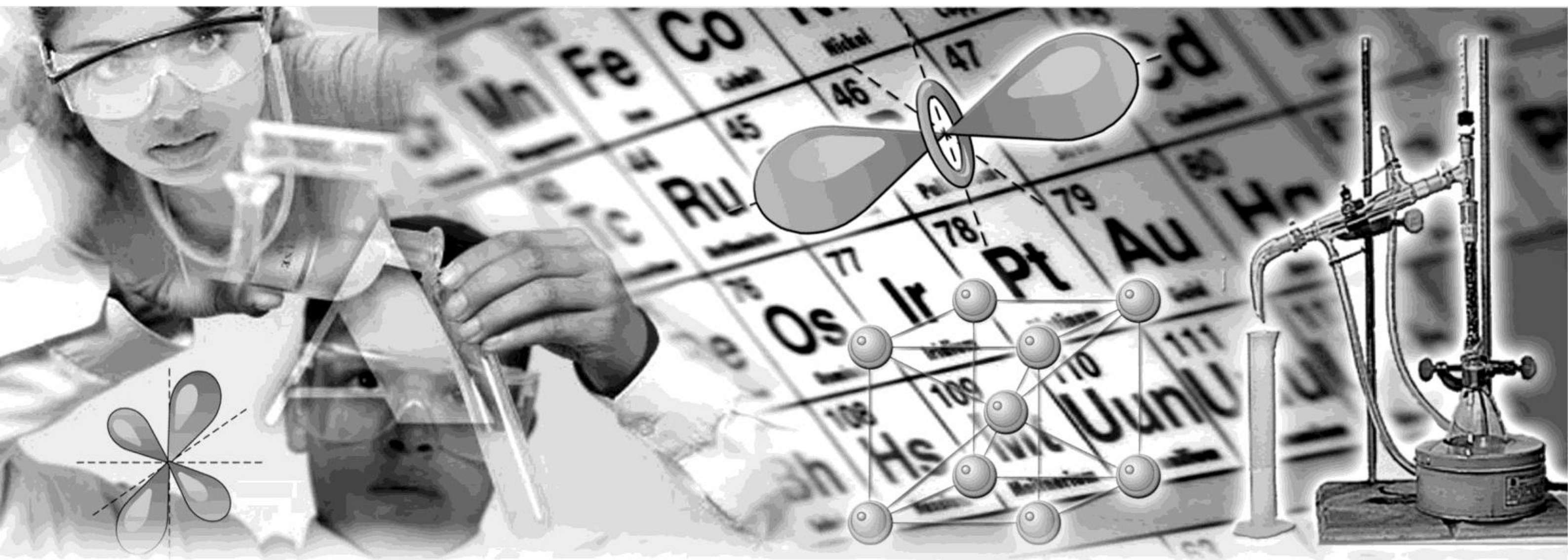


Chapter 20

Co-ordination Chemistry

All transition elements exhibit a characteristic property of complex ion formation. The compounds containing complex ions are called coordination compounds. The branch of chemistry in which coordination compounds are studied that is called co-ordination chemistry.

Double Salts and Co-ordination Compounds

When solutions of two or more stable compounds are mixed in stoichiometric (simple molecular) proportions new crystalline compounds called molecular or addition compounds are formed. These are of two types,

(1) Double salts, (2) Co-ordination or Complex compounds

(1) **Double salts :** Addition compounds, stable in solid state. Dissociate into ions in aqueous solution as such give test for each constituent ion. Examples:

Double Salt	Responds test for the ions
Carnalite : $KCl.\ MgCl_2 6H_2O$	$K^+,\ Mg^{2+}, Cl^-$
Potash alum : $K_2SO_4.Al_2(SO_4)_3\ 24H_2O$	K^+, Al^{3+}, SO_4^{2-}

(2) **Co-ordination or Complex compounds :** Addition compound, stable in solid state. Retain their identity even in solution. Central metal ion form dative or coordinate bond with the species surrounding it (ligands). Examples :

Complex compound	Cation	Anion
$[Cu(NH_3)_4]SO_4$	$[Cu(NH_3)_4]^{+2}$	SO_4^{2-}
$K_2[PtF_6]$	$2K^+$	$[PtF_6]^{2-}$
$[Co(NH_3)_6][Cr(CN_3)_6]$	$[Co(NH_3)_6]^{2+}$	$[Cr(CN)_6]^{3-}$

Terminology of co-ordination compounds

(1) **Central metal atom or ion :** A complex ion contains a metal atom or ion known as the central metal atom or ion. It is sometimes also called a nuclear atom.

(2) **Complex ion :** It is an electrically charged radical which is formed by the combination of a simple cation with one or more neutral molecules or simple anions or in some cases positive groups also.

(3) **Ligands :** Neutral molecules or ions that attach to central metal ion are called ligands. The donor atom associated with the ligands supplies lone pair of electrons to the central metal atom (forming dative bond) may be one or two more. Monodentate (one donor atom), bidentate (two donor atom), tridentate (three donor atom) etc.

Monodentate Ligands (with one donor site)

Table : 20.1 ***Anionic Ligands*** (Negative legands)

Formula	Name	Formula	Name
X^-	Halo	O_2^{2-}	Peroxo

$:OH^-$	Hydroxo	CH_3COO^-	Acetato
CN^-	Cyano	NO_3^-	Nitrato
O^{2-}	Oxo	$S_2O_3^{2-}$	Thiosulphato
NH_2^-	Amido	NO_2^-	Nitrito
S^{2-}	Sulphido	CO_3^{2-}	Carbonato
CNS^-	Thiocyanato	SO_4^{2-}	Sulphato

Table : 20.2 ***Neutral Ligands***

Formula	**Name**	**Formula**	**Name**
CO	Carbonyl	$:NH_3$	Amminato
PH_3	Phosphine	H_2O	Aqua
NO	Nitrosyl	$C_5H_5N:$	Pyridine (py)

Table : 20.3 ***Cationic Ligand*** (Positive)

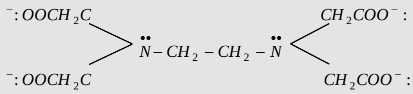
Formula	**Name**	**Formula**	**Name**
NO_2^+	Nitronium	NO^+	Nitrosonium
$H_2NNH_3^+$	Hydrazinium		

Polydentate ligands (with two or more donor site)

Table : 20.4 ***Bidentate*** (Two donor sites)

Formula	**Name**	**Formula**	**Name**
$H_2NCH_2CH_2NH_2$	Ethylenediamine (en)	$\begin{array}{l} Me-C=NO^- \\ \quad\;\; \vert \\ Me-C=NOH \end{array}$	Dimethylglyoximeto (dmg)
$\begin{array}{c} \;\;O\;\;\;O \\ \;\;\Vert\;\;\;\Vert \\ \bar{O}-C-C-O^- \end{array}$	Oxalato (ox)	$NH_2-CH_2-COO^-$	Glycinate ion (gly)

Table : 20.5

	Formula	**Name**
Tridentate	$H_2\ddot{N}(CH_2)_2-\ddot{N}H-(CH_2)_2\ddot{N}H_2$	Diethylenetriaminediamine (dien)
Tetradentate	$H_2\ddot{N}(CH_2)_2-\ddot{N}H-(CH_2)_2\ddot{N}H(CH_2)_2\ddot{N}H_2$	Triethylenetetramine (trien)
Hexadentate		Ethylene-diamine tetra-acetic acid (EDTA)$^{4-}$

Chelating Ligand : When polydentate ligands bind to the central metal ion they form a ring called chelate and the ligand is referred as chelating ligand.

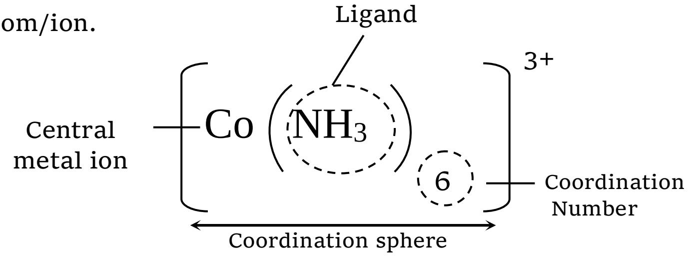
Ambidentate ligands : A ligand which possesses two donor atom but in forming complex it utilizes only one atom depending upon the condition and type of complex.

NO_2 (nitro) , ONO (nitrito), CN (cyano), NC (isocyano), SCN (thiocyanide), NCS (isothiocyanide)

π- acid ligand : Ligands which are capable of accepting an appreciable amount of π- e^- density from the metal atom into emptying π or π^* orbital or their own called $\pi-$ acceptor or $\pi-$ acid ligands eg. CO.

(4) **Co-ordination Sphere :** Ligand with central metal ion is kept in square bracket [ ] retains its identity in the same form is called co-ordination sphere (non-ionisable)

(5) **Co-ordination Number :** Number of monodentate ligands attached to central atom/ion are called coordination number of the central metal atom/ion.



(6) **Ionisation Sphere :** The part present out side of the square bracket is called ionization sphere (ionisable).

IUPAC Nomenclature of complex compounds

In order to name complex compounds certain rules have been framed by IUPAC. These are as follows :

(1) The positive part of a coordination compound is named first and is followed by the name of negative part.

(2) The ligands are named first followed by the central metal. The prefixes *di*-, *tri*-, *tetra*-, etc., are used to indicate the number of each kind of ligand present. The prefixes bis (two ligands), tris (three ligands), etc., are used when the ligands includes a number e.g., dipyridyl, bis (ethylenediamine).

(3) In polynuclear complexes, the bridging group is indicated in the formula of the complex by separating it from the rest of the complex by hyphens. In polynuclear complexes (a complex with two or more metal atoms), bridging ligand (which links two metal atoms) is denoted by the prefix μ before its name.

(4) **Naming of ligands :** The different types of ligands *i.e.* neutral, negative or positive are named differently in a complex compound.

When a complex species has negative charge, the name of the central metal ends in – ate. For some elements, the ion name is based on the Latin name of the metal (for example, argentate for silver). Some such latin names used (with the suffix – ate) are given below :

Fe	Ferrate	Cu	Cuperate
Ag	Argentate	Au	Aurate
Sn	Stannate	Pb	Plumbate

(5) **Point of attachment in case unidentate ligands with more than co-ordinating atoms** (ambidentate ligands) **:** The point of attachment in case of unidentate ligands with more than one co-ordinating atoms is either indicated by using different names for the ligands (*e.g,* thiocyanato and isothiocyanato) or by placing the symbol of the donor atom attached, the name of the ligand separated by a hypen.

$$\underset{\substack{\text{Ammonium hexathioxyanato -S-chromate (III)}\\ \text{or}\\ \text{Ammonium hexathiocyanatochromate (III)}}}{(NH_4)_3[Cr(SCN)_6]} \qquad \underset{\substack{\text{Ammonium hexathiocyanato - N - platinate (IV)}\\ \text{or}\\ \text{Ammonium hexaisothiocyanatoplatinate (IV)}}}{(NH_4)_2[Pt(NCS)_6]}$$

(6) **Name of the bridging groups :** If a complex contains two or more central metal atoms or ions, it is termed as polynuclear. In certain polynuclear complexes. ligands may link the two metal atoms or ions. Such ligands which link the two metal atoms or ions in polynuclear complexes are termed as bridge ligands. These bridge ligands are separated from the rest of the complex by hyphens and denoted by the **prefix** μ**.** If there are two or more bridging groups of the same kind, this is indicated by *di*- μ–, $tri-\mu-$, etc.

$$\underset{\mu\text{-amidobis [pentaamminecobalt (III)] nitrate}}{[(NH_3)]_5Co-NH_2-Co(NH_3)_5](NO_3)_5}$$

$$\underset{\mu\text{- hydroxobis [pentaamminecobalt (III)] chloride}}{[(NH_3)_5Co-OH-Co(NH_3)_5]Cl_5}$$

(7) If any lattice component such as water or solvent of crystallisation are present, these follow the name and are preceded by the number of these groups (molecules of solvent of crystallisation) in Arabic numerals.

For example,

$$\underset{\text{Tetraaquacopper(II)sulphate 1 – water}}{[Cu(H_2O)_4]SO_4.H_2O}$$

$$\underset{\text{tetraaquadichlorochromium (III) chloride 2 - water}}{[Cr(H_2O)_4Cl_2]Cl.2H_2O}$$

(8) Following punctuation rules should also be followed while writing the name of the complex compounds.

(i) The name of the complete compound should not start a capital letter, *e.g.,* $\underset{\substack{\text{tetraamminecopper (II) sulphate (Correct)}\\ \text{Tetraamminecopper (II) sulphate (Incorrect)}}}{[Cu(NH_3)_4]SO_4}$

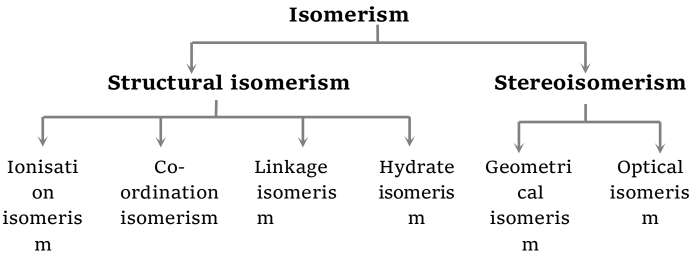
(ii) The full name of the complex ion should be written as one word without any gap.

(iii) There should be a gap between the cation and anion in case of ionic complexes.

(iv) The full name of non-ionic complexes should be written as one word without any gap.

Isomerism in co-ordination compounds

Compounds having the same molecular formula but different structures or spatial arrangements are called isomers and the phenomenon is referred as ***isomerism.***



(1) **Structural isomerism :** Here the isomers have different arrangement of ligands around the central metal atom. It is of the following types :

(*i) **Ionisation isomerism*** : The co-ordination compound having the same composition or molecular formula but gives different ions in solution are called ionization isomers.

There is exchange of anions between the co-ordination sphere and ionization sphere.

Example :

$[Co\,Br(NH_3)_5]SO_4$	$[Co\,SO_4(NH_3)_5]\,Br$
Pentaaminebromo cobalt (III) Sulphate	Pentaaminesulphato cobalt (III) bromide
SO_4^{2-} present in ionisation sphere	Br^- present in ionization sphere
Gives white precipitate with $BaCl_2$	Gives light yellow **precipitate** with $AgNO_3$

(ii) ***Co-ordination isomerism*** : In this case compound is made up of cation and anion and the isomerism arises due to interchange of ligands between complex cation and complex anion.

Example : $[Co(NH_3)_6]\,[Cr(CN)_6]$

$[Cr(NH_3)_6][Co(CN)_6]$

hexaamine cobalt (III) hexacyano chromate (III) hexaamine chromium (III) hexacyanocobalt (III)

complex cation contains $\rightarrow NH_3$ ligand (with cobalt) complex anion contains $\rightarrow NH_3$ ligand (with chromium) complex anion contains $\rightarrow CN^-$ ligand (with chromium) complex anion contains $\rightarrow CN^-$ ligand (with cobalt)

(iii) ***Linkage isomerism*** : In this case isomers differ in the mode of attachment of ligand to central metal ion and the phenomenon is called linkage isomerism.

Example : $[Co\,ONO(NH_3)_5]Cl_2$; $[Co\,NO_2(NH_3)_5]Cl_2$

Pentaamminenitritocobalt (III)

Pentaaminenitrocobalt (III) chloride

$:O-NO^-$ oxygen atom donates lone pair of electrons (nitrito) NO_2^- nitrogen atom donates lone pair of electrons (nitro)

(iv) ***Hydrate isomerism*** : Hydrate isomers have the same composition but differ in the number of water molecules present as ligands and the phenomenon is called hydrate isomerism.

Examples :(a) $[Cr(H_2O)_6]Cl_3$ hexaaquachromium (III) chloride (violet)

(b) $[Cr(H_2O)_5\,Cl]Cl_2.H_2O$

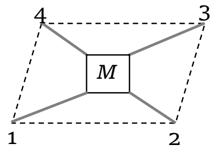
pentaaquachlorochromium (III) chloride monohydrate (blue green)

(c) $[Cr(H_2O)_4Cl]Cl_2.2H_2O$ tetraaquadichloro chromium (III) chloride dihydrate (green)

(2) **Stereo isomerism or space isomerism** : Here the isomers differ only in the spatial arrangement of atoms of groups about the central metal atom. It is of two types :

(i) ***Geometrical or Cis-trans isomerism*** : This isomerism arises due to the difference in geometrical arrangement of the ligands around the central atom. When identical ligands occupy positions near to each other called **cis-isomer**. When identical ligands occupy positions opposite to each other called **trans –isomer**. It is very common in disubstituted complexes with co-ordination number of 4 and 6.

- Complexes of co-ordination number 4

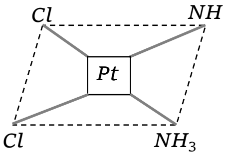


Tetrahedral geometry : In this case all the four ligands are symmetrically arranged with respect to one another as such geometrical isomerism is not possible.

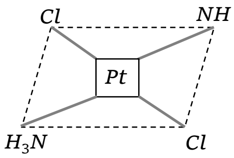
Square planar geometry : The four ligands occupy position at the four corners and the metal atom or ion is at the center and lie in the same plane.

Type : I $[Ma_2b_2]$, $M=Pt, a=Cl, b=NH_3$

Example : $[Pt\,Cl(NH_3)(Py)_2]$



cis –isomer (pale



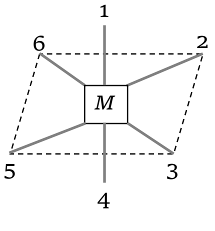
trans –isomer (dark-yellow)

Complexes of co-ordination number 6

Octahedral geometry : Here the metal atom or ion lies at the center and 1 to 6 position are occupied by the ligands.

Cis–Positions : 1–2, 2–3, 3–4, 4–5

Trans – position : 1–4, 2–5, 3–6



Type –I Ma_4b_2, $M=Co, a=NH_3$, and $b=Cl$

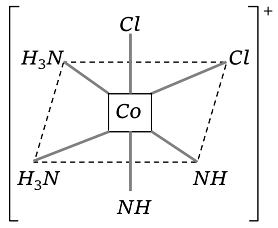
Example : $[CoCl_2(\,NH_3)_4]^+$ ion

Type –II $[Ma_3b_3]$, $M=Rh, a=Cl,$ and $b=Py$

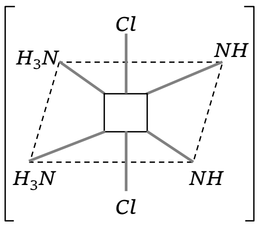
Example : $[Rh\,Cl_3(Py)_3$

Type –III $[M(aa)_2(en)_2]^{++}$, $M=Co, a-a=\begin{array}{c}CH_2NH_2\\|\\CH_2NH_2\end{array}$ (bidentate)

$b=Cl$ (monodentate)



Cis-isomer (blue



Trans-isomer

(ii) ***Optical isomerism***

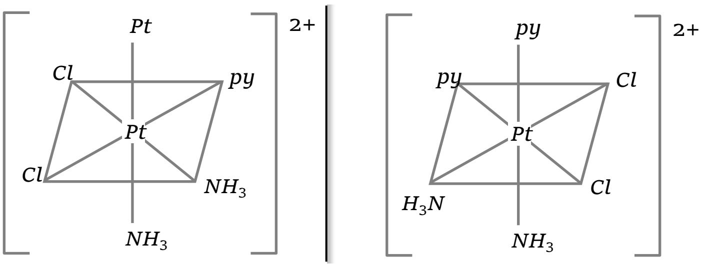
(a) Optical isomers are mirror images of each other and have chiral centers.

(b) Mirror images are not super imposable and do and have the plane of symmetry.

(c) Optical isomers have similar physical and chemical properties but differ in rotating the plane of plane polarized light.

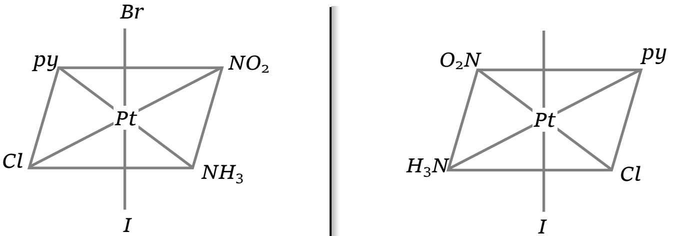
(d) Isomer which rotates the plane polarized light to the right is called dextro rotatory (*d*-form) and the isomer which rotates the plane polarized light to the left is called laevorotatory (*l*–form)

Example : $[Ma_2b_2c_2]^{n\pm}$; $[Pt(Py)_2(NH_3)_2Cl_2]^{2+}$



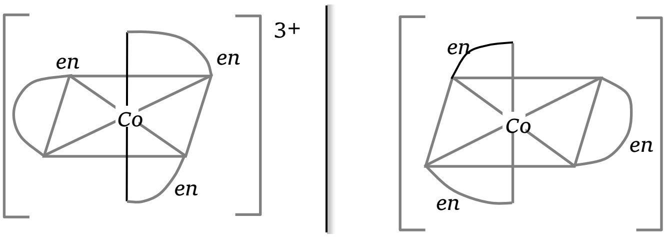
***Cis*-d- isomer** Mirror ***Cis-l*- isomer**

$[M\,a\,b\,c\,d\,e\,f]; Pt\,(py)\,NH_3NO_2Cl\,Br]$

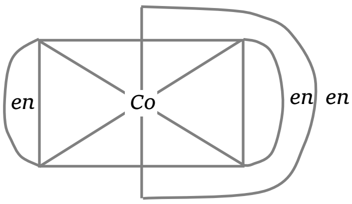


***d*- isomer** Mirror ***l*- isomer**

$[M(AA)_3]^{n\pm};[CO(en)_3]^{3+}$

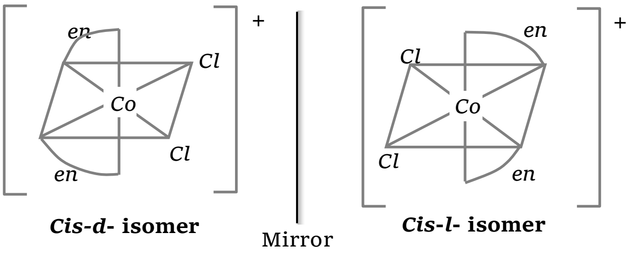


***d*- form** Mirror ***l*- isomer**



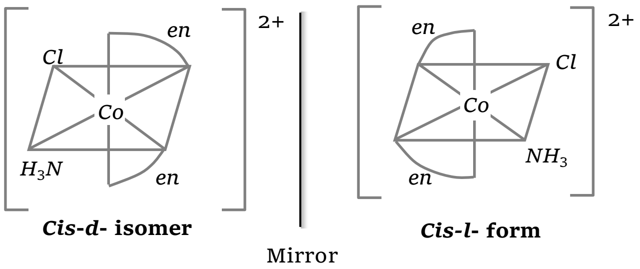
'Meso' or optically inactive

$[M(AA)_2a_2]^{n\pm};[Co(en)_2Cl_2]^{+}$



***Cis-d*- isomer** Mirror ***Cis-l*- isomer**

$[M(AA)_2ab]^{n\pm}$; $[Co(en)_2\,NH_3Cl]^{2+}$



***Cis-d*- isomer** Mirror ***Cis-l*- form**

Bonding in co-ordination compounds (Werner's Coordination theory)

Werner was able to explain the bonding in complex.

Primary valency (Pv) : This is non- directional and ionizable. In fact it is the positive charge on the metal ion.

Secondary valency (Sv) : This is directional and non- ionizable. It is equal to the number of ligand atoms co-ordinated to the metal (co-ordination number). Example :

$[Co\,(NH_3)_6]Cl_3$	or	$Co(NH_3)_6]^{3+}\,3Cl^-$
$Pv \rightarrow 3Cl^-\,[3]$	Sv	$\rightarrow 6NH_3(6)$
$[Co(NH_3)_5\,Cl]Cl_2$	or	$[Co(NH_3)_5\,Cl]^{2+}\,2Cl^-$
$Pv \rightarrow 2Cl^-(2)$	Sv	$\rightarrow 5\,NH_3 + 1Cl^-(6)$
$[Co(NH_3)_4\,Cl_2]\,Cl$	or	$[Co(NH_3)_4\,Cl_2]^+\,Cl^-$

$Pv \rightarrow Cl^-(1)$ Sv $\rightarrow 4NH_3 + 2Cl^-(6)$

Nature of the complex can be understood by treating the above complexes with excess of $AgNO_3$.

$CoCl_3.6NH_3 \rightarrow 3AgCl, [Co(NH_3)_6Cl_3$ (three chloride ion)

$CoCl_3.5NH_3 \rightarrow 2AgCl, [Co(NH_3)_5Cl_2$ (two chloride ion)

$CoCl_3.4NH_3 \rightarrow 1AgCl, [Co(NH_3)_4Cl_2$ (one chloride ion)

$CoCl_3.3NH_3 \rightarrow no\ AgCl, [Co(NH_3)_3Cl_3$ (no chloride ion)

The nature of bonding between central metal atom and ligands in the coordination sphere has been explained by the three well-known theories. These are :

(1) **Valence Bond theory of coordination compounds**

(i) The suitable number of atomic orbitals of central metal ion (*s, p, d*) hybridise to provide empty hybrid orbitals.

(ii) These hybrid orbitals accept lone pair of electrons from the ligands and are directed towards the ligand positions according to the geometry of the complex.

(iii) When inner *d*-orbitals *i.e.* (*n*-1) *d* orbitals are used in hybridization, the complex is called – ***inner orbital*** or ***spin or hyperligated*** complex.

(iv) A substance which do not contain any unpaired electron is not attracted by 2 magnet. It is said to be diamagnetic. On the other hand, a substance which contains one or more unpaired electrons in the electrons in the *d*-orbitals, is attracted by a magnetic field [exception O_2 and *NO*]. It is said to be paramagnetic.

Paramagnetism can be calculated by the expression, $\mu_s = \sqrt{n(n+2)},$ where $\mu =$ magnetic moment.

s= spin only value and *n*= number of unpaired electrons.

Hence, if $n = 1, \mu_s = \sqrt{1(1+2)} = 1.73\ B.M.$, if $n = 3, \mu_s = \sqrt{3(3+2)} = 3.87\ B.M.$ and so on

On the basis of value of magnetic moment, we can predict the number of unpaired electrons present in the complex. If we know the number of unpaired electrons in the metal complex, then it is possible to predict the geometry of the complex species.

(v) There are two types of ligands namely strong field and weak field ligands. A strong field ligand is capable of forcing the electrons of the metal atom/ion to pair up (if required). Pairing is done only to the extent which is required to cause the hybridization possible for that co-ordination number. A weak field ligand is incapable of making the electrons of the metal atom/ ion to pair up.

Strong field ligands : $CN^-, CO, en, NH_3, H_2O, NO^-, Py$.

Weak field ligands :

$I^-, Br^-, Cl^-, F^-, NO_3^-, OH^-, C_2O_4^{2-}, NH_3, H_2O$.

Limitations of valence bond theory

The valence bond theory was fairly successful in explaining qualitatively the geometry and magnetic behaviour of the complexes. But, it could not explain the following :

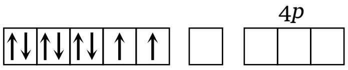
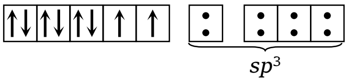
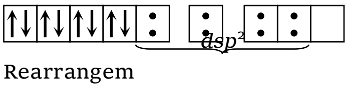
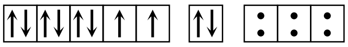
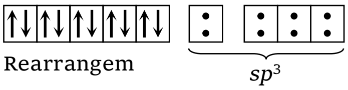
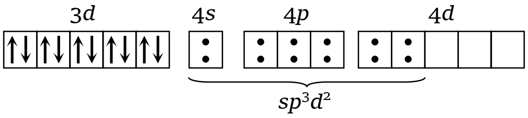
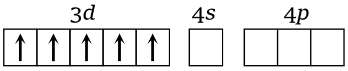
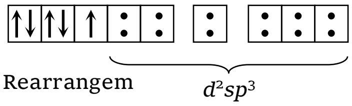
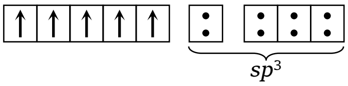
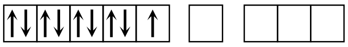
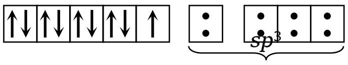
(i) The origin of their absorption spectra could not be explained.

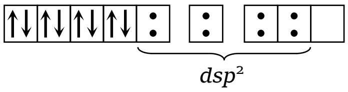
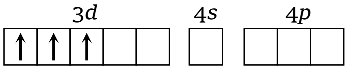
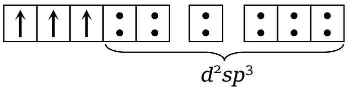
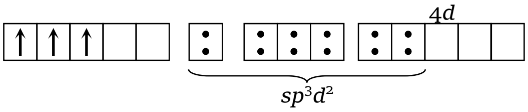
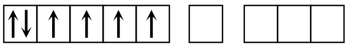
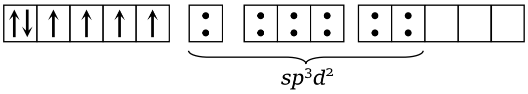
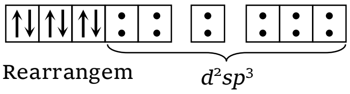
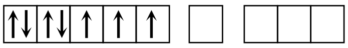
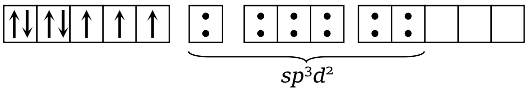
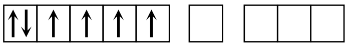
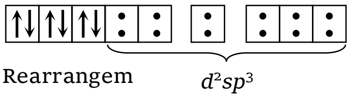
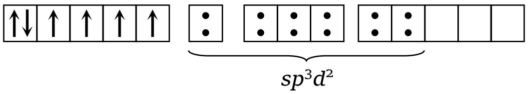
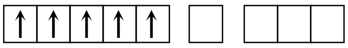
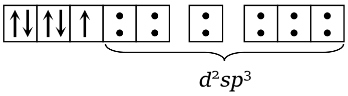
(ii) Why did different complexes of the same metal show different colours.

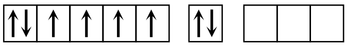
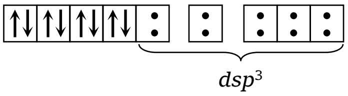
(iii) Relative stabilities of different complexes could not be explained.

(iv) Why should certain ligands form high spin, while others low spin complexes.

Table : 20.6 Geometry and magnetic nature of some complexes

Atom/ion/ complex (1)	Configuration (2)	Oxidation state of metal (3)	Type of hybridization (4)	Geometry shape (5)	No. of unpaired electrons (6)	Magnetic nature (7)
$Ni^{2+}(d^8)$		+2			2	Paramagnetic
$[NiCl_4]^{2-}$		+2	sp^3	Tetrahedral	2	Paramagnetic
$[Ni(CN)_4]^{2+}$		+2	dsp^2	Square planar	0	Diamagnetic
Ni		0			2	Paramagnetic
$Ni(CO)_4$		0	sp^3	Tetrahedral	0	Diamagnetic
$[Ni(NH_3)_6]^{2+}$		+2	sp^3d^2 (outer)	Octahedral	2	Paramagnetic
$Mn^{2+}(d^5)$		+2			5	Paramagnetic
$[Mn(CN)_6]^{4-}$		+2	d^2sp^3 (Inner)	Octahedral	1	Paramagnetic
$[MnCl_4]^2$		+2	sp^3	Tetrahedral	5	Paramagnetic
$Cu^{2+}(d^9)$		+2			1	Paramagnetic
$[CuCl_4]^{2-}$		+2	sp^3	Tetrahedral	1	Paramagnetic

$[Cu(NH_3)_4]^{2+}$	 One electron is shifted from $3d$-to $4p$-orbital	+2	dsp^2	Square planar	1	Paramagnetic
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
$Cr^{3+}(d^3)$		+3			3	Paramagnetic
$[Cr(NH_3)_6]^{3+}$		+3	d^2sp^3 (Inner)	Octahedral	3	Paramagnetic
$[Cr(H_2O)_6]^{3+}$		+3	sp^3d^2 (Outer)	Octahedral	3	Paramagnetic
$CO^{3+}(d^6)$		+3			4	Paramagnetic
$[CoF_6]^{3-}$		+3	sp^3d^2 (Outer)	Octahedral	4	Paramagnetic
$[Co(NH_3)_6]^{3+}$		+3	d^2sp^3 (Inner)	Octahedral	0	Diamagnetic
$CO^{2+}(d^7)$		+2			3	Paramagnetic
$[Co(H_2O)_6]^{2+}$		+2	sp^3d^2 (Outer)	Octahedral	3	Paramagnetic
$Fe^{2+}(d^6)$		+2			4	Paramagnetic
$[Fe(CN)_6]^{4-}$		+2	d^2sp^3 (Inner)	Octahedral	0	Diamagnetic
$[Fe(H_2O)_6]^{2+}$		+2	sp^3d^2 (Outer)	Octahedral	4	Paramagnetic
$[Fe(NH_3)_6]^{2+}$	Same	+2	sp^3d^2 (Outer)	Octahedral	4	Paramagnetic
$Fe^{3+}(d^5)$		+3		Octahedral	5	Paramagnetic
$[Fe(CN)_6{}^{3-}$		+3	d^2sp^3 (Inner)		1	Paramagnetic

Fe		0			4	Paramagnetic
$Fe(CO)_5$		0	dsp^3 (Inner)	Trigonal bipyramidal	0	Diamagnetic

(2) **Ligand field theory :** According to this theory when the ligands come closer to metal atom or ion, a field is created. This field tends to **split** the **degenerate *d*-orbitals** of the metal atom into **different energy levels**. The nature and number of ligands determine the extent of splitting. Energy gap between the splitted energy levels determine the magnetic (paramagnetic or diamagnetic) and spectral properties (colour etc) of the complexes .

Stability of co-ordination in solution and Spectrochemical series

Stronger is the metal-ligand bond, less is the dissociation in the solution and hence greater is the stability of a coordination compounds.

Instability constant for the complex ion $[Cu(NH_3)_4]^{2+}$ *i.e.*

$[Cu(NH_3)_4]^{2+} \rightleftharpoons Cu^{2+} + 4NH_3$, is given by the expression; $K_i = \frac{[Cu^{2+}][NH_3]^4}{[Cu(NH_3)_4]^{2+}}$.

Stability constant of the above complex i.e.

$Cu^{2+} + 4NH_3 \rightleftharpoons [Cu(NH_3)]^{2+}$ is given as under ;

$$K = \frac{[Cu(NH_3)_4^{2+}]}{[Cu^{2+}][NH_3]^4} = \frac{1}{K_i}$$

Greater is the stability constant, stronger is the metal – ligand bond

Factors affecting the stability of complex ion

(1) **Nature of central metal ion :** The higher the charge density on the central metal ion the greater is the stability of the complex

For example, the stability constant of $[Fe(CN)_6]^{3-}$ is much greater than the stability constant of $[Fe(CN)_6]^{4-}$.

$$Fe^{2+} + 6CN^- \rightleftharpoons [Fe(CN)_6]^{4-}; K = 1.8 \times 10^6$$

$$Fe^{3+} + 6CN^- \rightleftharpoons [Fe(CN)_6]^{3-}; K = 1.2 \times 10^{31}$$

Effective atomic number (EAN) or Sidgwick theory : In order to the stability of the complexes sidgwick proposed effective atomic number. EAN generally coincides with the atomic number of next noble gas in some cases. EAN is calculated by the following relation :

EAN = Atomic no. of the metal $-e^-$ lost in ion formation +No. of e^- gained from the donor atom of the ligands.

EAN = Atomic number – Oxidation number + co-ordination no. × 2

Table : 20.7

Complex	**Metal oxidation state**	**At. No. of metal**	**Coordination number**	**Effective atomic number**
$K_4[Fe(CN)_6]$	+ 2	26	6	(26 – 2) + (6 × 2) = 36 [Kr]
$[Cu(NH_3)_4]SO_4$	+ 2	29	4	(29 – 2) + (4 × 2) = 35
$[Co(CH_3)_6]Cl_3$	+ 3	27	6	(27 – 3) + (6 × 2) = 36 [Kr]
$Ni(CO)_4$	0	28	4	(28 – 0) + (4 × 2) = 36 [Kr]
$K_2[Ni(CN)_4]$	+ 2	28	4	(28 – 2) + (4 × 2) = 34
$K_3[Cr(C_2O_4)_3]$	+ 3	24	6	(24 – 3) + (6 × 2) = 33
$K_3[Fe(CN)_6]$	+ 3	26	6	(26 – 3) + (6 × 2) = 35
$[Ag(NH_3)_2]Cl$	+ 1	47	2	(47 – 1) + (2 × 2) = 50

(2) **Nature of ligand :** Greater the base strength is the ease with which it can donate its lone pair of electrons and therefore, greater is the stability of the complex formed by it.

For example : $[Cu(NH_3)_4]^{2+}; K = 4.5 \times 10^{11}$; $[Cu(CN)_4]^{2-}; K = 2.0 \times 10^{27}$

(3) **Presence of chelate ring :** Chelating ligands form more stable complex as compared to monodentate ligands. For example : $Ni^{2+} + 6NH_3 \rightleftharpoons [Ni(NH_3)_6]^{2+}; K = 6\times10^8$; $Ni^{2+} + 3en \rightleftharpoons [Ni(en)_3]^{2+}; K = 4\times10^8$

Spectro chemical series : Ligands can be arranged in increasing order of their strength (ability to cause crystal field splitting) and the series so obtained is called as spectro chemical series.

$$I^- < Br^- < Cl^- < F^- < OH^- < OX^{2-} < H_2O$$

$$< Py < NH_3 < en < NO_2^- < CN^- < CO$$

Ligands arranged left to NH_3 are generally regarded as *weaker ligands which can not cause forcible pairing of electrons within 3d level and thus form outer orbital octahedral complexes*.

On the other hand NH_3 and all ligands lying right to it are *stronger ligands which form inner orbital octahedral complexes after forcible pairing of electrons within 3d level*.

Preparation and Application of coordination compounds

(1) **Preparation :** Coordination compounds are generally prepared by the application of the following methods,

(i) ***Ligand substitution reaction*** **:** A reaction involving the replacement of the ligands attached to the central metal ion in the complex by other ligands is called a ligand substitution reaction.

$$\underset{\text{Light blue}}{[Cu(H_2O)_4]^{2+}{}_{(aq)}} + 3NH_{3(aq))} \rightarrow \underset{\text{Deep blue}}{[Cu(NH_3)_4]^{2+}{}_{(aq)}}$$

$$+4H_2O(l)$$

(ii) ***Direct mixing of reagent*** **:**

$$PtCl_2 + 2\underset{(en)}{H_2N - CH_2 - CH_2 - NH_2} \rightarrow \underset{\substack{\text{(Dichloro bis ethy lene}\\ \text{diam mine platinum (II)}}}{[Pt(en)_2Cl_2]}$$

(iii) ***Redox reactions*** **:** In these reactions, either oxidation or reduction is involved

$$2CO(NO_3)_2 + 8NH_3 + 2NH_4NO_3 + H_2O_2$$

$$\underset{\text{Penta ammine nitrocobalt (II)nitrate.}}{2[CO(NH_3)NO_2](NO_3)_2} + 2H_2O$$

Application

(1) Estimation of hardness in water, as Ca^{++} and Mg^{2+} ions form complexes with EDTA.

(2) Animal and plant world *e.g.* chlorophyll is a complex of Mg^{2+} and haemoglobin is a complex of Fe^{2+} vitamin B_{12} is a complex of Co^{2+}.

(3) Electroplating of metals involves the use of complex salt as electrolytes *e.g.* $K[Ag(CN)_2]$ in silver plating.

(4) Extraction of metals *e.g.* *Ag* and *Au* are extracted from ores by dissolving in *NaCN* to form complexes.

(5) Estimation and detection of metal ions *e.g.* Ni^{2+} ion is estimated using dimethyl glyoxime.

(6) Medicines e.g. cis-platin *i.e.* cis $[PtCl_2(NH_3)_2]$ is used in treatment of cancer.

Organometallic compounds

These are the compounds in which a metal atom or a metalloid (*Ge*, *Sb*) or a non-metal atom like *B*, *Si*, *P*, etc, (less electronegative than *C*) is directly linked to a carbon atom of a hydrocarbon radical or molecule. Organometallic compounds contain at least one.

(1) Metal – Carbon bond, (2) Metalloid – Carbon bond, (3) Non metal – Carbon bond.

Example :

Compounds : C_2H_5MgBr , $(C_2H_5)_2Zn$, $C_6H_5Ti(OC_3H_7)_3$, $(CH_3)_4Si$

Organometallic bond: $Mg-C$, $Zn-C$, $Ti-C$, $Si-C$

Classification of organometallic compounds : Organometallics have been classified as :

(1) **σ–bonded organometallic compounds :** Compounds such as $RMgX, R_2Zn, R_3Pb, R_3Al, R_4Sn$ etc, contains $M-C\ \sigma-$ bond and are called **σ- bonded** organometallic compound.

(2) **π-bonded organometallic compounds :** The transition metals binds to unsaturated hydrocarbons and their derivatives using their d-orbitals. Here metal atom is bonded to ligands in such a way that donations of electrons and back acceptance by the ligand is feassible. These are called **π–orbitals** of the ligand. These are called **π–complexes**.

Examples : (i) $\pi-$ ***cyclopentadienyl – iron complex***

Ferrocene $[Fe(\eta^5 - CH_5)_2]$, Bis (cyclopentadienyl) iron (II)

It is a π bonded sandwitch compound. The number of carbon atoms bonded to the metal ion is indicated by superscript on eta (η^x) i.e. η^5 in this complex.

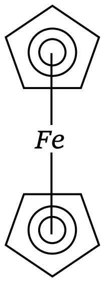
(ii) ***Dibenzene chromium (*** $\pi-$ ***complex)***

It is also a $\pi-$bonded sandwich compound. Its formula is $[Cr(\eta^6-C_6H_6)_2]$

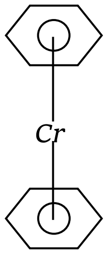
(iii) ***Alkene complex ($\pi-$complex)***

Zeise's salt K $PtCl_3(\eta^2-C_2H_4)]$; Potassium trichloroethylene platinate (IV).

It is a π bonded complex. μ^2 indicates that two carbons of ethylene are bonded to metals.



Ferrocene
$Fe(\eta^5-C_5H_5)_2$



Dibenzene chromium
$Cr(\eta^6-C_6H_6)$

(3) **Complexes containing both $\sigma-$ and $\pi-$ bonding characteristics :** Metal carbonyls, compounds formed between metal and carbon monoxide belong to this class. Metal carbonyls have been included in organometallics.

(i) ***Mononuclear carbonyls*** **:** Contain one metallic atom per molecule. *e.g* $Ni(CO)_4, Fe(CO)_5, Cr(CO)_6$

(ii) ***Polynuclear carbonyls*** **:** Contain two or more metallic atoms per molecule. *e.g.,*

$$Mn_2(CO)_{10}, Fe(CO)_9, Fe(CO)_{12}$$

Applications of organometallics

(1) Grignard reagent $(RMgX)$ has been extensively used for synthesis of various organic compounds.

(2) Wilkinson's catalyst $[(PH_3P)_3RhCl]$ *i.e.* tris (triphenylphosphine) chlororhodium (I) is used as a homogeneous catalyst for the hydrogenation of alkenes.

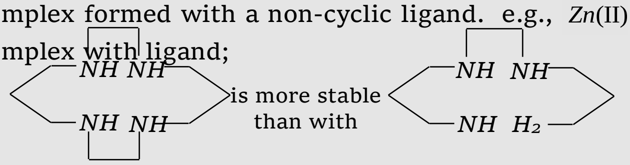
(3) Zeigler Natta catalyst (composed of a transition metal salt, generally $TiCl_4$ and trialkyl aluminium) are used as heterogeneous catalysts in the polymerisation of alkenes.

Tips & Tricks

- **Badecker reaction** : This reaction involves the following chemical change.

$Na_2[Fe(CN)_5NO] + Na_2SO_3 \rightarrow Na_4[Fe(CN)_5(NO.SO_3)]$

- **Everitt's salt :** It is $K_2[Fe(CN)_6]$ obtained by reduction of prussian blue.
- **Masking :** Masking is the process in which a substance without physical separation of it is so transformed that is does not enter into a particular reaction e.g., masking of Cu^{2+} by CN^- ion.
- **Macrocyclic effect :** This term refers to the greater thermodynamic stability of a complex with a cyclic polydentate ligand when compared to the complex formed with a non-cyclic ligand. e.g., Zn(II) complex with ligand;



- ***Prussian blue*** and ***Turnbull's blue*** is pot. ferric ferrocyanide. However colour of Turnbull's blue is less intense than prussian blue. Decrease in colour is due to the presence in it of a white compound of the formula $K_2\{Fe[Fe(CN)_6]\}$ named as potassium ferrous ferrocyanide.
- Crystal field theory explains why certain geometries are more favoured than other by certain metals in terms of crystal field stablization energies.
- The colour of complexes are explained in terms of electronic transitions between the various d orbitals of different energies.
- In octahedral complexes, the energy of the d_{z^2} and $d_{x^2-y^2}$ orbitals increases much more than the energy of the d_{xy}, d_{yz}, d_{xz} orbitals. The potential energy increases as a result of repulsive interactions. The greater the repulsion, greater is the increases in energy.
- Ligands with larger groups from unstable rings than the ligands with smaller groups. This is ascribable to steric hinderance produced by a larger group.
- When Ca^{2+} or Mg^{2+} forms complexes with EDTA, the pH of the solution decreases.
- The copper sulphate solution e.g., turns deep blue when excess of ammonia is added. This is also due to the formation of $[Cu(NH_3)_4]SO_4$
- Co-ordination compound with a general formula MA_4, MA_3B or MABCD do not show any geometric isomerism.
- *Flexidentate character* : polydentate ligand are said to have flexidentate character if they do not use all its donar atoms to get coordinated to the metal ion e.g., EDTA generally act as a hexadentate ligand but it can also act as a pentadentate and tetradentate ligand.
- Octahedral complex of the type [M(ABCDEF)] have 15 different geometrical isomers with a pair of enantiomers. Although a few geometrical isomer have been prepared but none has been resolved e.g., $[Pt\,(Py)(NH_3)(NO_2)(Cl)(Br)I]$.

Ordinary Thinking

Objective Questions

Basic Terms

1. In $K_4Fe(CN)_6$

(a) (CN) are linked with primary valency
(b) (CN) are linked with secondary valency
(c) K are linked with secondary valency
(d) K are linked with non-ionic valency

2. The co-ordination number of copper in cuprammonium sulphate is

(a) 2 (b) 6
(c) 4 (d) – 4

3. Which of the following acts as a bidentate ligand in complex formation

(a) Acetate (b) Oxalate
(c) Thiocyanate (d) EDTA

4. The co-ordination number of cobalt in the complex $[Co(en)_2Br_2]Cl_2$ is

(a) 2 (b) 6
(c) 5 (d) 4

5. Which of the following ligands forms a chelate **[MP PET/PMT 1998]**

(a) Acetate (b) Oxalate
(c) Cyanide (d) Ammonia

6. According to Werner's theory **[MP PMT 2000, 02]**

(a) Primary valency can be ionized
(b) Secondary valency can be ionized
(c) Primary and secondary valencies both cannot be ionized

(d) Only primary valency cannot be ionized

7. Which of the following is not true for ligand-metal complex **[MP PET 1993]**

(a) Larger the ligand, the more stable is the metal-ligand bond

(b) Highly charged ligand forms strong bond

(c) Larger the permanent dipole moment of ligand, the more stable is the bond

(d) Greater the ionization potential of central metal, the stronger is the bond

8. What is the co-ordination number of the metal in $[Co(en)_2Cl_2]^+$

(a) 4 (b) 5

(c) 6 (d) 3

9. Bidentate ligand is

(a) CN^- (b) Ethylene diammine (en)

(c) SCN^- (d) EDTA

10. The coordination number of Pt in $[Pt(NH_3)_4Cl_2]^{++}$ ion is **[MP PET 1995]**

(a) 2 (b) 4

(c) 6 (d) 8

11. Which is the example of hexadentate ligand

(a) 2, 2—dipyridyl

(b) Dimethyl glyoxime

(c) Aminodiacetate ion

(d) Ethylene diammine tetra acetate ion [EDTA]

12. The coordination number of a metal in coordination compounds is **[MP PET 1996; KCET (Engg./Med.) 1999]**

(a) Same as primary valency

(b) Sum of primary and secondary valencies

(c) Same as secondary valency

(d) None of these

13. Ligand in a complex salt are **[KCET 1992]**

(a) Anions linked by coordinate bonds to a central metal atom or ion

(b) Cations linked by coordinate bonds to a central metal atom or ion

(c) Molecules linked by coordinate bonds to a central metal atom or ion

(d) Ions or molecules linked by coordinate bonds to a central metal atom or ion

14. A group of atoms can function as a ligand only when **[KCET 1989; DCE 1999; MP PMT 2000]**

(a) It is a small molecule

(b) It has an unshared electron pair

(c) It is a negatively charged ion

(d) It is a positively charged ion

15. Which of the following complexes show six coordination number **[RPET 2000]**

(a) $[Zn(CN)_4]^{2-}$ (b) $[Cr(H_2O)_6]^{3+}$

(c) $[Cu(CN)_4]^{2-}$ (d) $[Ni(NH_3)_4]^{2+}$

16. The number of ions formed when cuprammonium sulphate is dissolved in water is **[KCET 1993]**

(a) 1 (b) 2

(c) 4 (d) Zero

17. The coordination number of Cu in complex $[Cu(H_2O)_4]^{++}$ is

(a) 4 (b) 3

(c) 2 (d) 1

18. The primary valence of the metal ion in the co-ordination compound $K_2[Ni(CN)_4]$ is

(a) Four (b) Zero

(c) Two (d) Six

19. The metal which does not form a polynuclear carbonyl is

(a) Mn (b) Co

(c) Cr (d) Fe

20. Which one of the following forms with an excess of CN^- (Cyanide) a complex having coordination number two **[AIIMS 2004]**

(a) Cu^+ (b) Ag^+

(c) Ni^{2+} (d) Fe^{2+}

21. According to Lewis the ligands are **[MP PMT 2002]**

(a) Acidic in nature

(b) Basic in nature

(c) Neither acidic nor basic

(d) Some are acidic and others are basic

22. The coordination number of a central metal atom in a complex is determined by

(a) The number of ligands around a metal ion bonded by sigma and pi-bonds both.

(b) The number around a metal ion bonded by pi-bonds

(c) The number of ligands around a metal ion bonded by sigma bonds

(d) The number of only anionic ligands bonded to the metal ion

23. In the extraction of which of the following, complex ion forms **[MP PET 1989]**

(a) Cu (b) Ag

(c) Fe (d) Na

24. Potassium ferrocyanide is a **[AFMC 2000]**

(a) Normal salt (b) Mixed salt

(c) Double salt (d) Complex salt

25. A monodentate ligand has

(a) One co-ordinate site

(b) Two co-ordinate sites

(c) Any number of co-ordinate sites

(d) No capacity to co-ordinate

26. EDTA has coordination number **[AFMC 2004]**

(a) 3 (b) 4

(c) 5 (d) 6

27. Among the properties (a) reducing (b) oxidising (c) complexing, the set of properties shown by CN^- ion towards metal species is

(a) c, a (b) b, c

(c) a, b (d) a, b, c

28. That ion or molecule which forms a complex compound with transitional metal ion is called

(a) Recipient (b) Ligand

(c) Coordinate ion (d) No special name

29. Coordination number of *Zn* in *ZnS* (zinc blende) is **[Orissa JEE 2004]**

(a) 6 (b) 4

(c) 8 (d) 12

30. Wilkinson's catalyst used as a homogeneous catalyst in the hydrogenation of alkenes contains

(a) Iron (b) Aluminium

(c) Rhodium (d) Cobalt

31. Given the molecular formula of the hexa coordinated complexes (A) $CoCl_3.6NH_3$ (B) $CoCl_3.5NH_3$ (C) $CoCl_3.4NH_3$. If the number of co-ordinated NH_3 molecules in *A, B* and *C* respectively are 6, 5 and 4, the primary valency in (*A*), (*B*) and (*C*) are: **[DCE 2003]**

(a) 6, 5, 4 (b) 3, 2, 1

(c) 0, 1, 2 (d) 3, 3, 3

32. Generally, a group of atoms can function as a ligand if **[MP PET 1996]**

(a) They are positively charged ions

(b) They are free radicals

(c) They are either neutral molecules or negatively charged ions

(d) None of these

33. The ligand in potassium ferricyanide is

(a) K^+ (b) CN^-

(c) Fe^{3+} (d) $(CN)_6$

34. Co-ordination number of aluminum is **[MHCET 2004]**

(a) 8 (b) 6

(c) 12 (d) 4

35. In $K_4Fe(CN)_6$, Fe is in the form of

(a) An atom (b) An ion

(c) Cationic complex (d) Anionic complex

36. Which of the following ligands is expected to bidentate **[CBSE PMT 1994]**

(a) Br (b) $C_2O_4^{2-}$

(c) CH_3NH_2 (d) $CH_3C\equiv N$

37. In the compound lithium tetrahydroaluminate, the ligand is **[AIIMS 1997]**

(a) H^+ (b) H^-

(c) H (d) None of these

38. Which of the following is the odd one out **[MP PET 1996]**

(a) Potassium ferrocyanide

[AIEEE 2004]

(b) Ferrous ammonium sulphate

(c) Potassium ferricyanide

(d) Tetrammine copper (II) sulphate

39. The basic ligand is

(a) NH_3 (b) CN^-

(c) F^- (d) All

40. The negative ligand is

(a) Aqua (b) Sulphato

(c) Carboxyl (d) Nitro sodium

41. Which has yellow colour

(a) Potassium cobaltinitrite

(b) Potassium hexanitro cobaltate (III)

(c) Fischer's salt

(d) All the above

42. Ligands, in complex compounds **[MP PMT 2003]**

(a) Accept e^--pair

(b) Donate e^--pair

(c) Neither accept e^--pair nor donate

(d) All of these happen

43. Which of the following is a common donor atom in ligands **[BHU 2001]**

(a) Arsenic (b) Nitrogen

(c) Oxygen (d) Both (b) and (c)

44. Trunbull's blue is a compound **[KCET 1993]**

(a) Ferricyanide (b) Ferrous ferricyanide

(c) Ferrous cyanide (d) Ferriferrocyanide

45. Tollen's reagent is **[KCET 1990]**

(a) $[Ag(NH_3)_2]^+$ (b) Ag_2O

(c) $[Cu(OH)_4]^{2-}$ (d) Cu_2O

46. Finely divided iron combines with *CO* to give **[UPSEAT 2002]**

(a) $Fe(CO)_5$ (b) $Fe_2(CO)_9$

(c) $Fe_2(CO)_{12}$ (d) $Fe(CO)_6$

47. In a complex, the highest possible coordination number is

(a) 6 (b) 12

(c) 4 (d) 8

48. The number of neutral molecules or negative groups attached to the central metal atom in a complex ion is called

(a) Atomic number (b) Effective atomic number

(c) Coordination number (d) Primary valency

49. EDTA combines with cations to form

(a) Ion-exchange resins (b) Chelates
(c) Clathrates (d) Polymers

50. An example of a double salt is **[MP PET 2001]**
(a) Bleaching powder (b) Hypo
(c) $K_4[Fe(CN)_6]$ (d) Potash alum

51. In complex compounds, metal ligand bond is
(a) Coordinate bond (b) Hydrogen bond
(c) Ionic bond (d) Covalent bond

52. Ammonia forms the complex ion $[Cu(NH_3)_4]^{2+}$ with copper ions in alkaline solutions but not in acidic solution. What is the reason for it **[AIEEE 2003]**
(a) In acidic solutions hydration protects copper ions
(b) In acidic solutions protons coordinate with ammonia molecules forming NH_4^+ ions and NH_3 molecules are not available
(c) In alkaline solutions insoluble $Cu(OH)_2$ is precipitated which is soluble in excess of any alkali
(d) Copper hydroxide is an amphoteric substance

53. Zeigler—Natta catalyst is used for which type of reaction
(a) Hydrogenation (b) Polymerization
(c) Oxidation (d) Reduction

54. Which of the following is not considered as an organometallic compound. **[AIIMS 2004]**
(a) Cis-platia (b) Ferrocene
(c) Zeise's salt (d) Gringard reagent

55. Which one is organometallic compound **[MP PMT 2004]**
(a) Lithium methoxide (b) Lithium dimethyl amide
(c) Lithium acetate (d) Methyl lithium

56. An aqueous solution of potash alum gives **[UPSEAT 2004]**
(a) Two types of ions (b) Only one type of ion
(c) Four types of ions (d) Three types of ions

57. Carnallite in solution in H_2O, shows the properties of **[DCE 2003]**
(a) K^+, Mg^{2+}, Cl^- (b) $K^+, Cl^-, SO_4^{2-}, Br^-$
(c) K^+, Mg^{2+}, CO_3^{2-} (d) K^+, Mg^{2+}, Cl^-, Br^-

58. What is the co-ordination number of cobalt in $Co(NH_3)_3Cl_3$ **[MP PET 1994]**
(a) 3 (b) 4
(c) 5 (d) 6

59. The formula of alum is **[Pb. CET 2002]**
(a) $K_2SO_4.Al_2(SO_4)_3.24H_2O$
(b) $K_4[Fe(CN)_6]$
(c) $K_2SO_4.Al_2(SO_4)_3.6H_2O$
(d) $Na_2CO_3.10H_2O$

60. Number of ions present in $K_4[Fe(CN)_6]$ **[Pb. CET 2000]**
(a) 2 (b) 10
(c) 3 (d) 5

61. CH_3MgI is an organometallic compound due to **[DCE 2002]**
(a) $Mg-I$ bond (b) $C-I$ bond
(c) $C-Mg$ bond (d) $C-H$ bond

62. What is the EAN of nickel in $Ni(CO)_4$ **[BVP 2003]**
(a) 34 (b) 35
(c) 32 (d) 36

Nomenclature, Oxidation state and EAN number

1. How many ions are produced in aqueous solution of $[Co(H_2O)_6]Cl_2$ **[RPMT 2002]**
(a) 2 (b) 3
(c) 4 (d) 6

2. IUPAC name of $[Pt(NH_3)_3(Br)(NO_2)Cl]Cl$ is **[CBSE PMT 1998]**
(a) Triamminechlorobromonitroplatinum (IV) chloride
(b) Triamminebromonitrochloroplatinum (IV) chloride
(c) Triamminebromochloronitroplatinum (IV) chloride
(d) Triamminenitrochlorobromoplatinum (IV) chloride

3. Oxidation state of nitrogen is incorrectly given for **[UPSEAT 2000, 01]**

Compound	***Oxidation state***
(a) $[Co(NH_3)_5Cl]Cl_2$	0
(b) NH_2OH	–1
(c) $(N_2H_5)_2SO_4$	+2
(d) Mg_3N_2	–3

4. The formula of dichloro *bis* (urea) copper (II) is **[CBSE PMT 1997]**
(a) $[Cu\{O=C(NH_2)_2\}Cl_2]$
(b) $[CuCl_2\{O=C(NH_2)_2\}_2]$
(c) $[Cu\{O=C(NH_2)_2\}Cl]Cl$
(d) $[CuCl_2]\{O=C(NH_2)_2H_2\}$

5. The IUPAC name of the complex $[Pt(NH_3)_2Cl_2]$ is
(a) Platinum (II) diammino dichloride
(b) Diammino dichloro platinate (IV)
(c) *Bis* (ammino) dichloro platinum (IV)
(d) Dichloro diammine platinum (II)

6. Correct formula of diammine silver (I) chloride is

(a) $Ag(NH_3)Cl$ (b) $Ag(NH_2)Cl$
(c) $[Ag(NH_3)_2]Cl$ (d) $[Ag(NH_2)_2]Cl$

7. The formula of sodium nitroprusside is **[AIIMS 1992]**
(a) $Na_4[Fe(CN)_5 NOS]$ (b) $Na_2[Fe(CN)_5 NO]$
(c) $NaFe[Fe(CN)_6]$ (d) $Na_2[Fe(CN)_6 NO_2]$

8. The correct name of $[Pt(NH_3)_4Cl_2][PtCl_4]$ is

[MP PET 2003]

(a) Tetraammine dichloro platinum (iv) tetrachloro platinate (ii)
(b) Dichloro tetra ammine platinium (iv) tetrachloro platinate (ii)
(c) Tetrachloro platinum (ii) tetraammine platinate (iv)
(d) Tetrachloro platinum (ii) dichloro tetraammine platinate (iv)

9. Correct formula of potassium ferrocyanide is

[CBSE PMT 1988]

(a) $K_4[Fe(CN)_6]$ (b) $K_2[Fe(CN)_6]H_2O$
(c) $K_3[Fe(CN)_6]$ (d) None of these

10. The IUPAC name of $[Co(NH_3)_3(NO_2)_3]$ is
(a) Trinitrotriammine cobalt (III)
(b) Trinitrotriammine cobalt (II)
(c) Trinitrotriammine cobalt (III) ion
(d) Trinitritriammine cobaltate (III)

11. In $K_4[Fe(CN)_6]$, the E.A.N. of Fe is **[DCE 2000]**
(a) 33 (b) 35
(c) 36 (d) 26

12. Which of the following pairs is not correctly matched

[MP PET 1993]

(a) Effective atomic number of Pt in $[PtCl_6]^{2-} = 84$
(b) Absorption peak for $[Cr^{III}(NH_3)_6]^{+3} = 21680\ cm^{-1}$
(c) Crystal field stabilization energy of d^2 in weak ligand field $= (-)0.8\Delta_0$
(d) Example of weak ligand field for d^5 configuration $= [Mn^{II}F_6]^{-4}$

13. The oxidation number of chromium in sodium tetrafluoro oxochromate complex is
(a) II (b) IV
(c) VI (d) III

14. The IUPAC name of $K_4[Fe(CN)_6]$ is

[CBSE PMT 1990; MP PET 1992;
MP PMT 1995, 97; Kurukshetra CET 2002]

(a) Potassium hexacyanoferrate (II)
(b) Potassium ferrocyanide
(c) Tetrapotassium hexacyanoferrate (II)
(d) Tetrapotassium ferroushexacyanide (II)

15. The IUPAC name of $[Ni(CO)_4]$ is **[RPET 1999]**
(a) Tetra carbonyl nickel (II)
(b) Tetra carbonyl nickel (0)
(c) Tetra carbonyl nickelate (II)
(d) Tetra carbonyl nickelate (0)

16. The correct nomenclature for $Fe_4[Fe(CN)_6]_3$ is

[MP PMT 1994]

(a) Ferroso-ferric cyanide
(b) Ferric-ferrous hexacyanate
(c) Iron (III) hexacyanoferrate (II)
(d) Hexacynoferrate (III-II)

17. The IUPAC name of compound $Na_3[Co(ONO)_6]$ will be

[MP PMT 2000]

(a) Hexanitritocobalt (III) sodium
(b) Sodium cobalt nitrite
(c) Sodium hexanitrocobaltate (III)
(d) Sodium hexanitritocobaltate (III)

18. In which of the following complexes oxidation state of metal is zero **[MP PET 1997]**
(a) $[Pt(NH_3)_2Cl_2]$ (b) $[Cr(CO)_6]$
(c) $[Cr(NH_3)_3Cl_3]$ (d) $[Cr(en)_2Cl_2]$

19. The oxidation number of Cr in $[Cr(NH_3)_6]Cl_3$ is

[CBSE PMT 2001]

(a) 8 (b) 6
(c) 4 (d) 3

20. In $[Ni(NH_3)_4]SO_4$, the E.A.N. of Ni is
(a) 34 (b) 35
(c) 36 (d) 37

21. IUPAC name of $[Co(ONO)(NH_3)_5Cl_2]$ is

[AMU 2002]

(a) Pentaammine nitro cobalt (III) chloride
(b) Pentaammine nitrito cobalt (III) chloride
(c) Pentaammine nitroso cobalt (III) chloride
(d) Pentaammine oxo-nitro cobalt (III) chloride

22. The oxidation number of Pt in $[Pt(C_2H_4)Cl_3]^-$ is

[MNR 1993]

(a) + 1 (b) + 2
(c) + 3 (d) + 4

23. The oxidation state of cobalt in the complex compound $[Co(NH_3)_6]Cl_3$ is
(a) + 3 (b) + 6
(c) + 5 (d) + 2

24. The correct IUPAC name of potassium cuprochloride is
(a) Potassium copper (I) tetrachloride
(b) Potassium tetrachlorocuprate (I)
(c) Tetrachloropotassium cuprate (I)

(d) Tetrachlorocopper (I) potassiate

25. The effective atomic number of cobalt in the complex $[Co(NH_3)_6]^{3+}$ is **[MP PET 2003]**

(a) 36
(b) 33
(c) 24
(d) 30

26. IUPAC name of $K_3Fe(CN)_6$ is

[MP PMT 1993; MP PET 1997]

(a) Potassium ferrocyanide (II)
(b) Potassium hexaferrocyanate (III)
(c) Potassium ferrohexacyanate (II)
(d) Potassium hexacyanoferrate (III)

27. The EAN of iron in potassium ferricyanide is

[Pb. CET 2000]

(a) 18
(b) 54
(c) 35
(d) 23

28. In the coordination compound, $K_4[Ni(CN)_4]$ oxidation state of nickel is

(a) -1
(b) 0
(c) $+1$
(d) $+2$

29. According to IUPAC nomenclature sodium nitroprussied is named is

[CBSE PMT 2003]

(a) Sodium pentacyanonitrosyl ferrate (III)
(b) Sodium nitroferricyanide
(c) Sodium nitroferrocyanide
(d) Sodium pentacyanonitrosyl ferrate (II)

30. Pick out the complex compound in which the central metal atom obeys EAN rule strictly **[KCET 2003]**

(a) $K_4[Fe(CN)_6]$
(b) $K_3[Fe(CN)_6]$
(c) $[Cr(H_2O)_6]Cl_3$
(d) $[Cu(NH_3)_4]SO_4$

31. Which of the following is wrong statement **[BHU 2003]**

(a) $Ni(CO)_4$ has oxidation number + 4 for Ni
(b) $Ni(CO)_4$ has zero oxidation number for Ni
(c) Ni is metal
(d) CO is gas

32. Oxidation state of Fe in $K_3[Fe(CN)_6]$ **[RPMT 2002]**

(a) 2
(b) 3
(c) 0
(d) None of these

33. Which complexes have zero oxidation state

(a) Carbonyl
(b) Ferrocyanide
(c) Amine
(d) Cyanide

34. The proper name for $K_2[PtCl]_6$ is **[MH CET 2002]**

(a) Potassium platinum hexachloride
(b) Potassium hexachloro platinum IV
(c) Potassium hexachloro platinate IV
(d) Potassium hexachloro platinum

35. IUPAC name of $K_3[Al(C_2O_4)_3]$ is called

[MP PMT 1993, 02, 03]

(a) Potassium alumino oxalato
(b) Potassium aluminium (III) trioxalate
(c) Potassium trioxalato aluminate (III)
(d) Potassium trioxalato aluminate (IV)

36. The I.U.P.A.C. name of $K_3[Ir(C_2O_4)_3]$ is

[MP PMT 2001]

(a) Potassium tri oxalato iridium (III)
(b) Potassium tri oxalato iridate (III)
(c) Potassium tris (oxalato) iridium (III)
(d) Potassium tris (oxalato) iridate (III)

37. The charge on $[Ag(CN)_2]^-$ complex is **[AIIMS 2001]**

(a) -1
(b) $+1$
(c) $+2$
(d) $+3$

38. The IUPAC name of $[Co(NH_3)_6]Cl_3$ is **[IIT-JEE 1994]**

(a) Hexammine cobalt (III) chloride
(b) Hexammine cobalt (II) chloride
(c) Triammine cobalt (III) trichloride
(d) None of these

39. IUPAC name of $[Co(NH_3)_3(H_2O)_2Cl]\ Cl_2$ is

[AIEEE 2003] **[MP PET 1994]**

(a) Diaquachlorodiammine cobalt (III) chloride
(b) Triamminediaquachloro cobalt (III) chloride
(c) Chlorodiamminediaqua cobalt (III) chloride
(d) Diamminediaquachloro cobalt (II) chloride

40. Dichloro diammine platinum (II) complex has the formula

[MP PMT 1997]

(a) $Pt[Cl_2(NH_3)_2]$
(b) $Pt[R.(NH_2)_2]Cl_2$
(c) $[PtCl_2(NH_3)_2]$
(d) $[Pt.R.(NH_2)_2]Cl_2$

41. The formula of potassiumdicyano *bis* (oxalato) nickelate (II) is

(a) $K_4[Ni(CN)_2(Ox)_2]$
(b) $K_3[Ni_2[Ni_2(CN)_2(Ox)_2]$
(c) $K[Ni(CN)(Ox)_2]$
(d) $K_2[Ni(CN)_2(Ox)_2]$

42. The value of x which appears in the complex $[Ni(CN)_4]^x$ is

(a) + 2
(b) – 2
(c) 0
(d) 4

43. Pick the correct name of $[Co(NH_3)_5Cl]Cl_2$ **[AMU 2001]**

(a) Chloropentammine cobalt (III)
(b) Pentammine cobalt (III) chloride
(c) Chloropentammine cobalt (III) chloride
(d) Chloropentammine cobalt (II) chloride

44. The valency of cuprammonium ion is

(a) + 4
(b) + 2
(c) – 2
(d) – 4

45. In which of the following compounds transition metal has zero oxidation state

(a) CrO_5
(b) $NH_2.NH_2$
(c) $NOClO_4$
(d) $[Fe(CO)_5]$

46. The complex chlorocompound diaquatriammine cobalt (III) chloride is represented as **[CBSE PMT 2002]**

(a) $[Co(NH_3)_3(H_2O)_3]Cl_2$

(b) $[Co(NH_2)_3\,(H_2O)_2]Cl_2$

(c) $[CoCl(NH_3)_3\,(H_2O)_2]Cl_3$

(d) $[CoCl(NH_3)_3\,(H_2O)_2]Cl_2$

47. The complex compound $\left[Co(NH_3)_3NO_2ClCN\right]$ is named as

(a) Chlorocyanonitrotriammine cobalt (III)
(b) Nitrochlorocyanotriammine cobalt (III)
(c) Cyanonitrochlorotriammine cobalt (III)
(d) Triamminenitrochlorocyano cobalt (III)

48. The oxidation number of Pt in $[Pt(C_2H_4)Cl_3]^-$ is **[UPSEAT 1999, 01]**

(a) $+1$ (b) $+2$
(c) $+3$ (d) $+4$

49. What is the structural formula of lithium tetrahydridoaluminate **[MP PMT 2003]**

(a) $Al[LiH_4]$ (b) $Al_2[LiH_4]_3$
(c) $Li[AlH_4]$ (d) $Li[AlH_4]_2$

50. IUPAC name for $K\left[Ag(CN)_2\right]$ is

(a) Potassium argentocyanide
(b) Potassium silver cyanide
(c) Potassium dicyanoargentate (I)
(d) Potassium dicyanosilver (II)

51. The oxidation state of Co in $\left[Co(H_2O)_5Cl\right]^{2+}$ is

(a) + 2 (b) + 3
(c) + 1 (d) + 4

52. The chemical formula of diammine silver (I) chloride is **[BHU 2004]**

(a) $[Ag(NH_3)]Cl$ (b) $[Ag(NH_3)_2]Cl$
(c) $[Ag(NH_3)_2]Cl$ (d) $[Ag(NH_4)_2]Cl$

53. IUPAC name of $[Co(NH_3)_5NO_2]Cl_2$ **[Pb. CET 2000]**

(a) Pentamminenitrocobalt (III) chloride
(b) Pentamminenitrosocobalt (III) chloride
(c) Pentamminenitrocobalt (II) chloride
(d) None of these

54. The pair of the compounds in which both the metals are in the highest possible oxidation state is **[IIT-JEE (Screening) 2004]**

(a) $[Fe(CN)_6]^{3-}, [Co(CN)_6]^{3-}$

(b) CrO_2Cl_2, MnO_4^-

(c) TiO_3, MnO_2

(d) $[Co(CN)_6]^{3-}, MnO_3$

55. The IUPAC name of $[Cr(NH_3)_6]^{3+}$ is **[Pb. CET 2001]**

(a) Hexamminechromium (VI) ion
(b) Hexamminechromium (III) ion
(c) Hexamminechromium (II) ion
(d) Hexamminechloride

56. The IUPAC name of $K_2[Cr(CN)_2O_2(O)_2(NH_3)]$ is **[DCE 2003]**

(a) Potassium ammine dicyano dioxoperoxochromate (VI)
(b) Potassium ammine cyano peroxo dioxo chromium (VI)
[MP PMT 1996]
(c) Potassium ammine cyano peroxo dioxo chromiun (VI)
(d) Potassium ammine cyano peroxo dioxo chromatic (IV)

57. The IUPAC name of the coordination compound $K_3[Fe(CN)_6]$ is **[AIEEE 2005]**

(a) Potassium hexacyanoferrate (II)
(b) Potassium hexacyanoferrate (III)
(c) Potassium hexacyanoiron (II)
(d) Tripotassium hexacyanoiron (II)

58. Which compound is zero valent metal complex **[KCET 200**

(a) $[Cu(NH_3)_4]SO_4$ (b) $[Pt(NH_3)_2Cl_2]$
(c) $[Ni(CO)_4]$ (d) $K_3[Fe(CN)_6]$

Isomerism and magnetic properties

1. Which one of the following octahedral complexes will not show geometric isomerism (A and B are monodentate ligands) **[CBSE PMT 2003]**

(a) $[MA_5B]$ (b) $[MA_2B_4]$
(c) $[MA_3B_3]$ (d) $[MA_4B_2]$

2. The number of unpaired electrons in the complex ion $[CoF_6]^{3-}$ is (Atomic no. of $Co = 27$) **[CBSE PMT 2003]**

(a) Zero (b) 2
(c) 3 (d) 4

3. Which would exhibit co-ordination isomerism

(a) $\left[Cr(NH_3)_6\right]\left[Co(CN)_6\right]$ (b) $\left[Co(en)_2Cl_2\right]$
(c) $\left[Cr(NH_3)_6\right]Cl_3$ (d) $\left[Cr(en)_2Cl_2\right]^+$

4. $\left[Co(NH_3)_5NO_2\right]Cl_2$ and $\left[Co(NH_3)_5(ONO)\right]Cl_2$ are related to each other as

(a) Geometrical isomers (b) Optical isomers
(c) Linkage isomers (d) Coordination isomers

5. $\left[Co(NH_3)_5Br\right]SO_4$ and $\left[Co(NH_3)_5SO_4\right]Br$ are examples of which type of isomerism **[MP PMT 1993, 94, 95; MP PET 1997; MP PET/PMT 1998]**

(a) Linkage (b) Geometrical
(c) Ionization (d) Optical

6. $\left[Co(NH_3)_4Cl_2\right]NO_2$ and $\left[Co(NH_3)_4Cl.NO_2\right]Cl$ are .... isomers **[MP PMT 1993; MP PET 1995, 2001]**

(a) Geometrical (b) Optical
(c) Linkage (d) Ionization

7. Which would exhibit ionisation isomerism **[MP PET 1997]**

(a) $\left[Cr(NH_3)_6\right]Cl_3$ (b) $\left[Co(NH_3)_5Br\right]SO_4$

(c) $[Cr(en)_2Cl_2]$ (d) $[Cr(en)_3Cl_3]$

8. $[Ti(H_2O)_6]^{+3}$ is paramagnetic in nature due to **[RPMT 2002]**

(a) One unpaired e^- (b) Two unpaired e^-

(c) Three unpaired e^- (d) No unpaired e^-

9. Coordination isomerism is caused by the interchange of ligands between the **[UPSEAT 2002]**

(a) *Cis* and *Trans* structure

(b) Complex cation and complex anion

(c) Inner sphere and outer sphere

(d) Low oxidation and higher oxidation states

10. Which one of the following will not show geometrical isomerism **[MP PMT 2002]**

(a) $[Cr(NH_3)_4Cl_2]Cl$ (b) $[Co(en)_2Cl_2]Cl$

(c) $[Co(NH_3)_5NO_2]Cl_2$ (d) $[Pt(NH_3)_2Cl_2]$

11. Paramagnetic co-ordination compounds contain .... electrons

(a) No

(b) Both paired and unpaired

(c) Paired

(d) Unpaired

12. Which of the following isomeric pairs shows ionization isomerism **[MP PET 1993]**

(a) $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$

(b) $[Cr(H_2O)_6]Cl_3$ and $[Cr(H_2O)_5Cl]Cl_2.H_2O$

(c) $[Pt(NH_3)_2Cl_2]$ and $[Pt(NH_3)_4][PtCl_4]$

(d) $[Co(NH_3)_5Br]SO_4$ and $[Co(NH_3)_5SO_4]Br$

13. Among the following ions which one has the highest paramagnetism **[IIT 1993; UPSEAT 2002]**

(a) $[Cr(H_2O)_6]^{3+}$ (b) $[Fe(H_2O)_6]^{2+}$

(c) $[Cu(H_2O)_6]^{2+}$ (d) $[Zn(H_2O)_6]^{2+}$

14. Amongst $Ni(CO)_4$, $[Ni(CN)_4]^{2-}$ and $[NiCl_4]^{2-}$ **[IIT 1991]**

(a) $Ni(CO)_4$ and $[NiCl_4]^{2-}$ are diamagnetic and $[Ni(CN)_4]^{2-}$ is paramagnetic

(b) $[NiCl_4]^{2-}$ and $[Ni(CN)_4]^{2-}$ are diamagnetic and $Ni(CO)_4$ is paramagnetic

(c) $Ni(CO)_4$ and $[Ni(CN)_4]^{2-}$ are diamagnetic and $[NiCl_4]^{2-}$ is paramagnetic

(d) $Ni(CO)_4$ is diamagnetic and $[NiCl_4]^{2-}$ and $[Ni(CN)_4]^{2-}$ are paramagnetic

15. $[Co(NH_3)_4Cl_2]^+$ exhibits

(a) Geometrical isomerism (b) Optical isomerism

(c) Bonding isomerism (d) Ionisation isomerism

16. The compound which does not show paramagnetism is **[IIT 1992]**

(a) $[Cu(NH_3)_4]Cl_2$ (b) $[Ag(NH_3)_2]Cl$

(c) NO (d) NO_2

17. The number of geometrical isomers for $[Pt(NH_3)_2Cl_2]$ is **[CBSE PMT 1995]**

(a) Two (b) One

(c) Three (d) Four

18. The pair of complex compounds $[Cr(H_2O)_6Cl_3]$ and $[Cr(H_2O)_5Cl]Cl_2H_2O$ are an example of **[MP PMT 1997]**

(a) Linkage isomerism (b) Ionisation isomerism

(c) Coordination isomerism (d) Hydrate isomerism

19. The number of geometrical isomers of the complex $[Co(NO_2)_2(NH_3)_2]$ is **[CBSE PMT 1997]**

(a) 2 (b) 3

(c) 4 (d) 0

20. The type of isomerism present in nitropentamine chromium (III) chloride is

(a) Optical (b) Linkage

(c) Ionization (d) Polymerisation

21. Which of the following compounds exhibits linkage isomerism **[MP PMT 2001]**

(a) $[Co(en)_3]Cl_3$ (b) $[Co(NH_3)_6][Cr(CN)_6]$

(c) $[Co(en)_2NO_2Cl]Br$ (d) $[Co(NH_3)_5Cl]Br_2$

22. Pick out from the following complex compounds, a poor electrolytic conductor in solution **[MP PMT 1994]**

(a) $K_2[PtCl_6]$ (b) $[Co(NH_3)_3(NO_2)_3]$

(c) $K_4[Fe(CN)_6]$ (d) $[Cu(NH_3)_4]SO_4$

23. The possible number of optical isomers in $[Co(en)_2Cl_2]^+$ are

(a) 2 (b) 3

(c) 4 (d) 6

24. Magnetic moment of $[Cu(NH_3)_4]^{2+}$ ion is **[RPET 2003]**

(a) 1.414 (b) 1.73

(c) 2.23 (d) 2.38

25. What is true for $[Fe(CN)_6]^{3-}$ and $[FeF_6]^{3-}$ **[RPET 1999]**

(a) Both are paramagnetic

(b) Only $[Fe(CN)_6]^{3-}$ is paramagnetic

(c) Only $[FeF_6]^{3-}$ is paramagnetic

(d) Both are diamagnetic

26. Which of the following is paramagnetic **[AFMC 1997]**

(a) $[Ni(CO)_4]$ (b) $[Co(NH_3)_6]^{3+}$

(c) $[Ni(CN)_4]^{2-}$ (d) $[NiCl_4]^{2-}$

27. The total number of possible isomers for the complex compound $[Cu^{II}(NH_3)_4][Pt^{II}Cl_4]$ are **[CBSE PMT 1998; DPMT 2004; J & K CET 2005]**

(a) 3 (b) 4

(c) 5 (d) 6

28. Which one of the following shows maximum paramagnetic character **[AIIMS 1998]**

(a) $[Cr(H_2O)_6]^{3+}$ (b) $[Fe(CN)_6]^{4-}$

(c) $[Fe(CN)_6]^{3-}$ (d) $[Cu(H_2O)_6]^{2+}$

29. The complexes $[Co(NH_3)_6][Cr(C_2O_4)_3]$ and $[Cr(NH_3)_6][Co(C_2O_4)_3]$ **[AMU 2002]**

(a) Linkage isomerism (b) Geometrical isomerism

(c) Coordination isomerism (d)Ionisation isomerism

30. Which of the following exhibits highest molar conductivity **[MP PET 1994]**

(a) $[Co(NH_3)_6]Cl_3$ (b) $[Co(NH_3)_5Cl]Cl_2$

(c) $[Co(NH_3)_4Cl_2]Cl$ (d) $[Co(NH_3)_3Cl_3]$

31. Which of the following compounds is colourless **[MP PET 1994]**

(a) $Cu_2(CH_3COO)_4.2H_2O$ (b) Cu_2Cl_2

(c) $CuSO_4.5H_2O$ (d) $[Cu(NH_3)_4]SO_4.4H_2O$

32. The type of magnetism exhibited by $[Mn(H_2O)_6]^{2+}$ ion is **[IIT 1994]**

(a) Paramagnetism (b) Diamagnetism

(c) Both (a) and (b) (d) None of these

33. The number of isomers possible for square planar complex $K_2[PdClBr_2(SCN)]$ is **[MP PET 1994]**

(a) 2 (b) 3

(c) 4 (d) 6

34. The number of unpaired electrons in $Ni(CO)_4$ is **[AIIMS 1997]**

(a) Zero (b) One

(c) Three (d) Five

35. If the magnetic moment of $[Ag(CN)_2]^{-1}$ is zero, then the number of unpaired electrons will be**[MP PET 1995]**

(a) 1 (b) 2

(c) 3 (d) Zero

36. $[Pt(NH_3)_4Cl_2]Br_2$ and $[Pt(NH_3)_4Br_2]Cl_2$ are related to each other as **[MP PET 1996; AFMC 2000; CBSE PMT 2001]**

(a) Optical isomers (b) Coordinate isomers

(c) Ionization isomers (d) Linkage isomers

37. Which of the following complex will show geometrical as well as optical isomerism (*en* = ethylene diamine) **[KCET 1996]**

(a) $Pt(NH_3)_2Cl_2$ (b) $[Pt(NH_3)Cl_4]$

(c) $[Pt(en)_3]^{4+}$ (d) $[Pt(en)_2]Cl_2$

38. Which of the following complexes is diamagnetic **[RPMT 1997]**

(a) $Ni(CO)_4$ (b) $Ni(Cl_4)^{2-}$

(c) $Ni(Br)_4^{2-}$ (d) $NiCl_2.4H_2O$

39. Which one has the highest paramagnetism **[AMU 2001]**

(a) $Ni(CO)_4$ (b) $[Ni(NH_3)_4]Cl_2$

(c) $[Ni(NH_3)_6]Cl_2$ (d) $[Cu(NH_3)_4]Cl_2$

40. Which of the following coordiantion compounds would exhibit optical isomerism

(a) *trans*-dicyanobis (ethylenediamine) chromium (III) chloride

(b) *tris*-(ethylenediamine) cobalt (III) bromide

(c) pentaamminenitrocobalt (III) iodide

(d) diamminedichloroplatinum (II)

41. Which of the following does not have optical isomer **[AIIMS 2004]**

(a) $[Co(NH_3)_3Cl_3]$ (b) $[Co(en)_3]Cl_3$

(c) $[Co(en)_2Cl_2]Cl$ (d) $[Co(en)(NH_3)_2Cl_2]Cl$

42. Change in composition of co-ordination sphere yields which types of isomers

(a) Optical (b) Geometrical

(c) Ionisation (d) None of these

43. Types of isomerism shown by $[Cr(NH_3)_5NO_2]Cl_2$ is

(a) Optical (b) Ionisation

(c) Geometrical (d) Linkage

44. Which of the following will not give a precipitate with $AgNO_3$ **[MP PET 2003]**

(a) $[Co(NH_3)_3Cl_3]$ (b) $[Co(NH_3)_4Cl_2]Cl$

(c) $[Co(NH_3)_5Cl]Cl_2$ (d) $[Co(NH_3)_6]Cl_3$

45. How many ions are produced from $[Co(NH_3)_6]Cl_3$ in solution **[RPET 1999]**

(a) 6 (b) 4

(c) 3 (d) 2

46. The colour of $CoCl_3.5NH_3.H_2O$ is**[Kerala (Med.) 2002]**

(a) Orange yellow (b) Orange

(c) Green (d) Violet

(e) Pink

47. Which one of the following is expected to be a paramagnetic complex **[MP PMT 1991, 2000]**

(a) $[Ni(H_2O)_6]^{2+}$ (b) $[Ni(CO)_4]$

(c) $[Zn(NH_3)_4]^{2+}$ (d) $[Co(NH_3)_6]^{+3}$

48. Which one of the following will give a white precipitate with $AgNO_3$ in aqueous mediun**[MP PMT 1994]**

(a) $[Co(NH_3)_5Cl](NO_2)_2$ (b) $[Pt(NH_3)_2Cl_2]$

(c) $[Pt(en)Cl_2]$ (d) $[Pt(NH_3)_4]Cl_2$

49. How many ions will be produced in solution from one molecule of chloropentammine cobalt (III) chloride

(a) 1 (b) 2

(c) 3 (d) 4

50. Which of the following complex will give white precipitate with $BaCl_2$ $(aq.)$

(a) $[Co(NH_3)_4SO_4]NO_2$ (b) $[Cr(NH_3)_5SO_4]Cl$

(c) $[Cr(NH_3)_5Cl]SO_4$ (d) Both (b) and (c)

51. The number of precipitable halide ions in the sample $[Pt(NH_3)Cl_2Br]Cl$ will be

(a) 2 (b) 3

(c) 4 (d) 1

52. The colour of tetrammine copper (II) sulphate is

(a) Blue (b) Red

(c) Violet (d) Green

53. The number of ions per mole of a complex $[CoCl_2.5NH_3]Cl_2$ in aqueous solution will be

[MP PMT 2001]

(a) Nine (b) Four

(c) Three (d) Two

54. How many unpaired electrons are present in the central metal ion of $[CoCl_4]^{2-}$ **[Orissa JEE 2005]**

(a) 3 (b) 4

(c) 5 (d) 2

55. What is the magnetic moment of $K_3[FeF_6]$

[Orissa JEE 2005]

(a) 5.91 BM (b) 4.89 BM

(c) 3.87 BM (d) 6.92 BM

56. (i) $K_4[Fe(CN)_6]$ (ii) $K_3[Cr(CN)_6]$ (iii) $K_3[Fe(CN)_6]$ (iv) $K_2[Ni(CN)_4]$

Choose the complex which is paramagnetic

[Kerala CET 2005]

(a) (i), (ii) and (iii) (b) (i), (iii)and (iv)

(c) (i), (iii) and (iv) (d) (i), (ii) and (iv)

(e) (ii) and (iv)

57. In coordination compound $[Co(en)_2Cl_2]Cl$ which is false

[Kerala CET 2005]

(a) Show geometrical Isomerism

(b) Show optical Isomerism

(c) Show ionic Isomerism

(d) A octahedral complex

(e) A cationic complex

Hybridisation and Geometry

1. The correct structural formula of *zeise's salt* is

(a) $K^+\left[PtCl_3-\eta^2-(C_2H_4)\right]^-$

(b) $K_2\left[PtCl_3-\eta^2-C_2H_4\right]$

(c) $K^+\left[PtCl_2-\eta^2-(C_2H_4)\right]Cl^-$

(d) $K^+\left[PtCl_3(C_2H_4)\right]^-$

2. The correct order of hybridisations of central atom in $NH_3, [PtCl_4]^{2-}, PCl_5$ and BCl_3 is **[MP PMT 2003]**

(a) dsp^2, dsp^3, sp^2 and sp^3

(b) sp^3, sp^3, sp^3d and sp^2

[JIPMER 1997]

(c) dsp^2, sp^2, sp^3 and dsp^3

(d) dsp^2, sp^3, sp^2 and dsp^3

3. One mole of the complex compound $Co(NH_3)_5Cl_3$, gives 3 moles of ions on dissolution in water. One mole of the same complex reacts with two moles of $AgNO_3$ solution to yield two moles of $AgCl(s)$. The structure of the complex is

[AIEEE 2003]

(a) $[Co(NH_3)_5Cl]Cl_2$

(b) $[Co(NH_3)_3Cl_3].2NH_3$

(c) $[Co(NH_3)_4Cl_2]Cl.NH_3$

(d) $[Co(NH_3)_4Cl]Cl_2.NH_3$

4. Cuprammonium ion $\left[Cu(NH_3)_4\right]^{2+}$ is

[MP PMT 1997; KCET 2002]

(a) Tetrahedral (b) Square planar

(c) Triangular bipyramid (d) Octahedral

5. In the complex $[SbF_5]^{2-}, sp^3d$ hydridisation is present. Geometry of the complex is **[Pb. PMT 2000]**

(a) Square pyramidal (b) Square bipyramidal

(c) Tetrahedral (d) Square

6. The type of hybridization involved in the metal ion of $[Ni(H_2O)_6]^{2+}$ complex is

(a) d^3sp^2 (b) sp^3d^2

(c) sp^3 (d) dsp^2

7. In the formation of $K_4Fe(CN)_6$, the hybridisation involved is

(a) sp^2 (b) d^2sp^3

(c) d^3sp^2 (d) d^4p

8. Which of the following is not true for metal carbonyls

[MP PET 1993]

(a) The oxidation state of the metal in the carbonyls is zero

(b) The secondary carbonyls are obtained from photo-decomposition

(c) Metal carbonyls are single bonded species

(d) $d\pi - p\pi$ overlap is observed in metal carbonyls

9. An octahedral complex is formed, when hybrid orbitals of the following type are involved **[DCE 2003]**

(a) sp^3 (b) dsp^2

(c) sp^3d^2 (d) sp^2d

10. Which one is an example of octahedral complex

[MP PET 2000]

(a) FeF_6^{3-} (b) $Zn(NH_3)_4^{2+}$

(c) $Ni(CN)_4^{2-}$ (d) $Cu(NH_3)_4^{2+}$

11. Which of the following complexes has a square planar geometry

(a) $Ag(NH_3)_2^+$
(b) $Cu(en)_2^{2+}$
(c) $[MnCl_4]^{2-}$
(d) $Ni(CO)_4$

12. The shape of $[Fe(CN)_6]^{4-}$ ion is
(a) Hexagonal
(b) Pyrimidal
(c) Octahedral
(d) Octagonal

13. What is the shape of $Fe(CO)_5$ **[CBSE PMT 2000]**
(a) Linear
(b) Tetrahedral
(c) Square planar
(d) Trigonal bipyramidal

14. What type of hybridization is involved in $[Fe(CN)_6]^{3-}$ **[AMU 1999]**
(a) d^2sp^3
(b) dsp^2
(c) sp^3d^2
(d) dsp^3

15. The example of dsp^2 hybridisation is **[MP PET 1999; AIIMS 2001]**
(a) $Fe(CN)_6^{3-}$
(b) $Ni(CN)_4^{2-}$
(c) $Zn(NH_3)_4^{2+}$
(d) FeF_6^{3-}

16. The shape of $[Cu(NH_3)_4]^{2+}$ is square planar, Cu^{2+} in this complex is **[NCERT 1989; RPET 1999]**
(a) sp^3 hybridised
(b) dsp^2 hybridised
(c) sp^3d hybridised
(d) sp^3d^2 hybridised

17. The geometry of $Ni(CO)_4$ and $Ni(PPh_3)_2Cl_2$ are **[IIT-JEE 1999; DCE 2002]**
(a) Both square planar
(b) Tetrahedral and square planar respectively
(c) Both tetrahedral
(d) Square planar and tetrahedral respectively

18. Which complex has square planar structure **[JIPMER 2002]**
(a) $Ni(CO)_4$
(b) $[NiCl_4)^{2-}$
(c) $[Ni(H_2O)_6]^{2+}$
(d) $[Cu(NH_3)_4]^{2+}$

19. $[Pt(NH_3)_4]Cl_2$ is **[DCE 2001]**
(a) Square planar
(b) Tetrahedral
(c) Pyramidal
(d) Pentagonal

20. A complex involving dsp^2 hybridization has
(a) A square planar geometry
(b) A tetrahedral geometry
(c) An octahedral geometry
(d) Trigonal planar geometry

21. A tetrahedral complex ion is formed due to .... hybridization
(a) sp^2
(b) sp^3
(c) dsp^2
(d) d^2sp^3

22. Back bonding is involved in which of the organometallic compounds
(a) $[(CH_3)_3Al]_2$
(b) $Mg^{2+}(C_5H_5^-)_2$
(c) $R-Mg-X$
(d) $[(C_5H_5)_2Fe]$

23. d^2sp^3 hybridisation leads to
(a) Hexagonal shape
(b) Trigonal bipyrimidal
(c) Octahedral shape
(d) Tetrahedral shape

24. Chromium hexacarbonyl is an octahedral compound involving
(a) sp^3d^2
(b) dsp^2
(c) d^2sp^3
(d) d^3sp^2 orbitals

25. $[CoF_6]^{-3}$ is formed by ..... hybridization
(a) d^2sp^3
(b) d^3sp^2
(c) d^2sp^3
(d) sp^3d^2

26. The species havoing tetrahedral shape is **[IIT-JEE (Screening) 2004]**
(a) $[PdCl_4]^{2-}$
(b) $[Ni(CN)_4]^{2-}$
(c) $[Pd(CN)_4]^{2-}$
(d) $[NiCl_4]^{2-}$

27. Among $[Ni(CO)_4], [Ni(CN)_4]^{2-}, [NiCl_4]^{2-}$ species, the hybridization states at the Ni atom are, respectively
[CBSE PMT 2004; MP PMT 1992; BHU 1995; AFMC 1997]
(a) sp^3, sp^3, dsp^2
(d) dsp^2, sp^3, sp^3
(c) sp^3, dsp^2, dsp^2
(d) sp^3, dsp^2, sp^3
(At. no. of Ni = 28)

28. The bond in $K_4[Fe(CN)_6]$ are: **[MP PET 2004]**
(a) All ionic
(b) All covalent
(c) Ionic and covalent
(d) Ionic, covalent and co-ordiante covalent

29. Hybridization of Fe in $K_3Fe(CN)_6$ is **[DCE 2002]**
(a) sp^3
(b) dsp^3
(c) sp^3d^2
(d) d^2sp^3

30. The complex ion which has no 'd' electrons in the central metal atom is **[IIT-JEE Screening 2001]**
(a) $[MnO_4]^-$
(b) $[Co(NH_3)_6]^{3+}$
(c) $[Fe(CN)_6]^{3-}$
(d) $[Cr(H_2O)_6]^{3+}$

31. Which of the following statement is correct
(a) $[Cu(NH_3)_6]^{2+}$ is a colourless ion
(b) $[Zn(H_2O)_6]^{2+}$ ion is blue coloured
(c) $[Ni(CN)_4]^{2-}$ ion has a tetrahedral shape
(d) Nickel dimethyl glyoxides is red in colour

32. Which of the following shall form an octahedral complex **[DCE 2001]**
(a) d^4 (low spin)
(b) d^8 (high spin)
(c) d^6 (low spin)
(d) None of these

33. Which one of the following is a strong field ligand
(a) CN^-
(b) NO_2^-
(c) en
(d) NH_3

34. The strongest ligand in the following is **[MP PET 1995]**
(a) CN^-
(b) Br^-
(c) HO^-
(d) F^-

35. The neutral ligand is

(a) Chloro (b) Hydroxo

(c) Ammine (d) Oxalato

36. The ligands which can get attached to the central metal ion through more than one atom are called

(a) Ambident ligands (b) Polydentate ligands

(c) Chelate ligands (d) Neutral ligands

37. A strong ligand gives a complex which is generally called

(a) High spin (b) High energy

(c) Low spin (d) Stable

38. CN^- is a strong field ligand. This is due to the fact that **[CBSE PMT 2004]**

(a) It can accept electron from metal species

(b) It forms high spin complexes with metal species

(c) It carries negative charge.

(d) It is a pseudohalide

39. Considering H_2O as a weak field ligand, the number of unpaired electrons in $[Mn(H_2O)_6]^{2+}$ will be (At. No. of *Mn* = 25) **[CBSE PMT 2004]**

(a) Two (b) Four

(c) Three (d) Five

40. Which of the following is a π - complex

(a) Trimethyl aluminium (b) Ferrocene

(c) Diethyl zinc (d) Nickel carbonyl

41. Which of the following is a π – acid ligand **[KCET 1996; AIIMS 2003]**

(a) NH_3 (b) CO

(c) F^- (d) Ethylene diamine

42. The value of the 'spin only' magnetic moment for one of the following configurations is 2.84 BM. the correct one **[AIEEE 2005]**

(a) d^4 (in strong ligand field)

(b) d^4 (in weak ligand field)

(c) d^3 (in weak as well as in strong fields)

(d) d^5 (in strong ligand field)

43. The geometry of $Ni(CO)_4$ and $Ni(PPh_3)_2Cl_2$ are **[BHU 2005]**

(a) Both square planer

(b) Tetrahedral and square planar respectively

(c) Both tetrahedral

(d) Square planar and tetrahedral respectively

Complexes and complex stability

1. Which of the following complexes has the highest stability constant at 298 K

(a) $[CdCl_4]^{2-}$ (b) $[CdBr_4]^{2-}$

(c) $[CdI_4]^{2-}$ (d) $[Cd(CN)_4]^{2-}$

2. The most stable ion is **[AIEEE 2002]**

(a) $[Fe(OH)_3]^{3-}$ (b) $[Fe(Cl)_6]^{3-}$

(c) $[Fe(CN)_6]^{3-}$ (d) $[Fe(H_2O)_6]^{3+}$

3. The most stable complex among the following is **[MP PMT 2002]**

(a) $K_3[Al(C_2O_4)_3]$ (b) $[Pt(en)_2]Cl_2$

(c) $Ag(NH_3)_2Cl$ (d) $K_2(Ni(EDTA))$

4. Which of the following factors tends to increase the stability of metal ion complexes

(a) Higher ionic radius of the metal ion

(b) Higher charge/size ratio of the metal ion

(c) Lower ionisation potential of the metal ion

(d) Lower basicity of the ligand

5. $CuSO_4$ reacts with *KCN* solution and forms: **[DPMT 2004]**

(a) $K_3[Cu(CN)_4]$ (b) $Cu(CN)$

(c) $Cu(CN)_2$ (d) $K_4[Cu(CN)_6]$

6. A co-ordination complex compound of cobalt has the molecular formulae containing five ammonia molecules, one nitro group and two chlorine atoms for one cobalt atom. One mole of this compound produces three mole ions in an aqueous solution on reacting with excess of $AgNO_3$, $AgCl$ precipitate. The ionic formula for this complex would be: **[DPMT 2004; Kerala PMT 2004]**

(a) $[Co(NH_3)_5(NO_2)]Cl_2$

(b) $[Co(NH_3)_5Cl][Cl(NO_2)]$

(c) $[Co(NH_3)_4(No_2)Cl][(NH_3)Cl]$

(d) $[Co(NH_3)_5][(NO_2)_2Cl_2]$

7. In any ferric salt, on adding potassium ferrocyanide, a prussian blue colour is obtained, which is **[BIT 1992; BHU 2002]**

(a) $K_3Fe(CN)_6$ (b) $KFe[Fe(CN)_6]$

(d) $FeSO_4.Fe(CN)_6$ (d) $Fe_4[Fe(CN)_6]_3$

8. Prussian blue is formed when **[CBSE PMT 1990]**

(a) Ferrous sulphate reacts with $FeCl_3$

(b) Ferric sulphate reacts with $K_4[Fe(CN)_6]$

(c) Ferrous ammonium sulphate reacts with $FeCl_3$

(d) Ammonium sulphate reacts with $FeCl_3$

9. Complex salt can be made by the combination of $[Co^{III}(NH_3)_5Cl]^X$ with **[RPMT 2000, AFMC 2002]**

(a) PO_4^{3-} (b) Cl^-

(c) $2Cl^-$ (d) $2K^+$

10. Which reagent can be used to identify nickel ion

(a) Resorcinol

(b) Dimethyl glyoxime [DMG]

(c) Diphenyl benzidine

(d) Potassium ferrocyanide

11. Dimethyl glyoxime forms a coloured complex with

(a) Ag (b) Ni

(c) Cr (d) Zn

12. Silver chloride dissolves in excess of NH_4OH. The cation present in this solution is **[EAMCET 1998]**

(a) Ag^+ (b) $\left[Ag(NH_3)_2\right]^+$

(c) $\left[Ag(NH_3)_4\right]^+$ (d) $\left[Ag(NH_3)_6\right]^+$

13. Silver sulphide dissolved in a solution of sodium cynamide to form the complex **[AMU 1999]**

(a) $Na[Ag(CN)_2]$ (b) $Na_3[Ag(CN)_4]$

(c) $Na_5[Ag(CN)_6]$ (d) $Na_2[Ag(CN)_2]$

14. Which one will give Fe^{3+} ions in solution

(a) $\left[Fe(CN)_6\right]^{3-}$

(b) $Fe_2(SO_4)_3$

(c) $\left[Fe(CN)_6\right]^{4-}$

(d) $NH_4(SO_4)_2.FeSO_4.6H_2O$

15. The cation that does not form an amine complex with excess of ammonia is

(a) Cd^{2+} (b) Al^{3+}

(c) Cu^{2+} (d) Ag^+

Application of organometallics

1. Ziegler-Natta catalyst is an organometallic compound of which metal

(a) Iron (b) Zirconium

(c) Rhodium (d) Titanium

2. In the case of small cuts, bleeding is stopped by applying potash alum. Here alum acts as **[KCET (Med.) 2001]**

(a) Fungicide (b) Disinfectant

(c) Germicide (d) Coagulating agent

3. The formula of ferrocene is

(a) $\left[Fe(CN)_6\right]^{4-}$ (b) $\left[Fe(CN)_6\right]^{3-}$

(c) $\left[Fe(CO)_5\right]$ (d) $\left[(C_5H_5)_2Fe\right]$

4. Which of the following is formed when *n*-butyl lithium reacts with tin (II) chloride **[AFMC 2001]**

(a) $LiBr$ (b) Et_4Pb

(c) $(C_4H_9)_4Sn$ (d) $(C_2H_5)_4Pb$

5. Which of the following organo-silicon compound on hydrolysis will give a three dimensional silicone **[Orissa JEE 2003]**

(a) R_3SiCl (b) $RSiCl_3$

(c) $SiCl_4$ (d) R_2SiCl_2

6. Which one is not an organometallic compound **[J & K CET 2005; Pb. CET 2003]**

(a) $RMgX$ (b) C_2H_5ONa

(c) $(CH_3)_4Sn$ (d) KC_4H_9

7. The complex used as an anticancer agent is **[AIIMS 2003]**

(a) trans $-[Co(NH_3)_3Cl_3]$ (b) cis $-[PtCl_2(NH_3)_2]$

(c) cis $-K_2[PtCl_2Br_2]$ (d) Na_2CO_3

8. The compound that is not olefinic organometallic is

(a) $K[C_2H_4PtCl_3]3H_2O$ (b) $Be(CH_2)_2$

(c) $(C_2H_4PtCl_3)_2$ (d) $C_4H_4Fe(CO)_3$

9. Among the following, which is not the π-bonded organometallic compound **[CBSE PMT 2003]**

(a) $(CH_3)_4Sn$ (b) $K[PtCl_3(\eta^2-C_2H_4)]$

(c) $Fe(\eta^5-C_5H_5)_2$ (d) $Cr(\eta^6-C_6H_6)_2$

10. Wilkinson's catalyst is used in

(a) Polymerization (b) Condensation

(c) Halogenation (d) Hydrogenation

11. What is the use of tetraethyl lead

(a) As a catalyst in addition reaction of alkenes

(b) As a catalyst in polymerization reaction of alkenes

(c) For reducing knocking

(d) For creating knocking

12. Which of the following is an organo-metallic compound **[MP PMT 2001]**

(a) Lithium ethoxide (b) Ethyl lithium

(c) Lithium acetate (d) Lithium carbide

13. Which of the following is an organometallic compound **[J & K CET 2005]** **[AIIMS 1997]**

(a) $Ti(C_2H_5)_4$ (b) $Ti(OC_2H_5)_4$

(c) $Ti(OCOCH_3)_4$ (d) $Ti(OC_6H_5)_4$

14. Which of the following is not an organometallic compound **[MP PET 1996; BHU 2002]**

(a) Ethyl magnesium bromide

(b) Tetraethyl lead

(c) Sodium ethoxide

(d) Trimethyl aluminium

15. An organometallic compound amongst the following is

(a) Ferrocene (b) CaC_2

(c) Tetraethyl lead (TEL) (d) All of these

16. Which of the following does not have a metal carbon bond **[CBSE PMT 2004]**

(a) $K[Pt(C_2H_4)Cl_3]$ (b) $Ni(CO)_4$

(c) $Al(OC_2H_5)_3$ (d) C_2H_5MgBr

17. Coordination compounds have great importance in biological systems. In this context which of the following statements is incorrect

(a) Cyanocobalamin is B_{12} and contains cobalt.

(b) Haemoglobin is the red pigment of blood and contains iron.

(c) Chlorophylls are green pigments in plants and contains calcium.

(d) Carboxypepticase-*A* is an enzyme and contains zinc.

18. Ziegler-Natta catalyst is **[Pb. CET 2004]**

(a) $(Ph_3P)_3RhCl$ (b) $K[PtCl_3(C_2H_4)]$

(c) $[Al_2(C_2H_6)_6]+TiCl_4$ (d) $[Fe(C_2H_5)_2]$

19. Dimethyl glyoxime gives a red precipitate with Ni^{2+}, which is used for its detection. To get this precipitate readily the best pH range is **[AIIMS 2004]**

(a) < 1 (b) 2-3

(c) 3-4 (d) 9-11

20. The $\pi-$bonded organo metallic compound which has ethene as one of its component is **[J & K CET 2005]**

(a) Zeise's salt (b) Ferrocene

(c) Dibenzene chromium (d) Tetraethyl tin.

Critical Thinking

Objective Questions

1. The coordination number and oxidation state of Cr in $K_3[Cr(C_2O_4)_3]$ are, respectively **[CBSE PMT 1995]**

(a) 4 and +2 (b) 6 and +3

(c) 3 and +3 (d) 3 and 0

2. The complex compounds which result from the coordination of carbon monoxide are known as

(a) Electronic (b) Carbonyls

(c) Carbonates (d) Carbon permono

3. Mixture $X = 0.02\,mol$ of $[Co(NH_3)_5SO_4]Br$ and 0.02 *mol* of $[Co(NH_3)_5Br]SO_4$ was prepared in 2 *litre* of solution

1 *litre* of mixture *X* + excess $AgNO_3 \rightarrow Y$.

1 *litre* of mixture *X* + excess $BaCl_2 \rightarrow Z$

Number of moles of *Y* and *Z* are

(a) 0.01, 0.01 (b) 0.02, 0.01

(c) 0.01, 0.02 (d) 0.02, 0.02

4. Which of the following organometallic compound is σ and π bonded **[MH CET 2001; PCET 2002]**

(a) $Fe(CH_3)_3$

(b) $[Fe(\eta^5-C_5H_5)_2]$

(c) $[Co(CO)_5NH_3]^{2+}$

(d) $K[PtCl_3(n^2-C_2H_4)]$

5. In $[Ni(NH_3)_4]SO_4$, the valency and coordination number of Ni will be respectively

(a) 3 and 6 (b) 2 and 4

(c) 4 and 2 (d) 4 and 4

6. Co-ordination number of Fe in the complexes $[Fe(CN)_6]^{4-}$, $[Fe(CN)_6]^{3-}$ and $[FeCl_4]^-$ would be respectively **[MP PET 2003]**

(a) 2, 3, 3 (b) 6, 6, 4

(c) 6, 3,3 (d) 6, 4, 6

7. On hydrolysis $(Me)_2SiCl_2$ will produce **[IIT-JEE 2003]**

(a) $(Me)_2Si(OH)_2$

(b) $(Me)_2Si=O$

(c) $-[-O-(Me)_2Si-O-]_n-$

(d) $Me_2SiCl(OH)$

8. Which of the following represents a chelating ligand **[JIPMER 2002]**

(a) H_2O (b) OH^-

(c) DMG (d) Cl^-

9. $CuSO_4$ reacts with KCN solution and forms **[MP PMT 1992; IIT 1996; UPSEAT 2001, 02]**

(a) $Cu(CN)_2$ (b) $Cu(CN)$

(c) $K_2[Cu(CN)_4]$ (d) $K_3[Cu(CN)_4]$

10. In the process of extraction of gold,

Roasted gold ore $+CN^- + H_2O \xrightarrow{O_2} [X] + OH^-$

$[X] + Zn \rightarrow [Y] + Au$

Identify the complexes $[X]$ and $[Y]$ **[BHU 1999]**

(a) $X=[Au(CN)_2]^-, Y=[Zn(CN)_4]^{2-}$

(b) $X=[Au(CN)_4]^{3-}, Y=[Zn(CN)_4]^{2-}$

(c) $X=[Au(CN)_2]^-, Y=Zn(CN)_6]^{4-}$

(d) $X=[Au(CN)_4]^-, Y=[Zn(CN)_4]^{2-}$

11. A solution of potassium ferrocyanide would contains ...... ions

(a) 2 (b) 3

(c) 4 (d) 5

12. Which one of the following complexes is an outer orbital complex **[AIEEE 2004]** **[IIT JEE 2003]**

(a) $[Co(NH_3)_6]^{3+}$ (b) $[Mn(CN)_6]^{4-}$

(c) $[Fe(CN)_6]^{4-}$ (d) $[Ni(NH_3)_6]^{2+}$

Atomic nos : $Mn=25, Fe=26, Co=27, Ni=28$

13. Which one of the following has largest number of isomers ? **[AIEEE 2004]**

(a) $[Ir(PP_3)_2H(CO)]^{2+}$ (b) $[Co(NH_3)_5Cl]^{2+}$

(c) $[Ru(NH_3)_4Cl_2]^+$ (d) $[Co(en)_2Cl_2]^+$

(*R* = alkyl group; *en* = ethylenediamine)

14. Which kind of isomerism is exhibited by octahedral $Co(NH_3)_4Br_2Cl$?

(a) Geometrical and Ionization

(b) Geometrical and Optical

(c) Optical and Ionization

(d) Geometrical only

15. Which one of the following is expected to exhibit optical isomerism (*en* = ethylenediamine)

(a) *cis* – $[Pt(NH_3)_2Cl_2]$ (b) *trans* – $[Co(en)_2Cl_2]$

(c) *trans* – $[Pt(NH_3)_2Cl_2]$ (d) *cis* – $[Co(en)_2Cl_2]$

16. $[\text{EDTA}]^{4-}$ is a: **[UPSEAT 2004]**

(a) Monodentate ligand (b) Bidentate ligand

(c) Quadridentate ligand (d) Hexadentate ligand

17. Which of the following statements is incorrect ? **[KCET 2004]**

(a) In $K_3[Fe(CN)_6]$, the ligand has satisfied only the secondary valency of ferric ion.

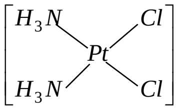
(b) In $K_3[Fe(CN)_6]$, the ligand has satisfied both primary and secondary valencies of ferric ion.

(c) In $K_4[Fe(CN)_6]$, the ligand has satisfied both primary and secondary valencies of ferrous ion.

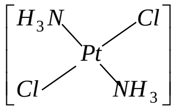
(d) In $[Cu(NH_3)_4]SO_4$, the ligand has satisfied only the secondary valency of copper.

18. Which of the following is considered as an anticancer species. **[CBSE PMT 2004]**

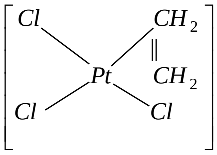
(a)



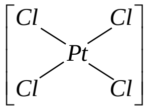
(b)



(c)



(d)



19. An aqueous solution of $CoCl_2$ on addition of excess of concentrated HCl turns blue due to formation of **[AIIMS 2005]**

(a) $[Co(H_2O)_4Cl_2]$

(b) $[Co(H_2O)2Cl_4]^{2-}$

(c) $[CoCl_4]^{2-}$

(d) $[Co(H_2O)2Cl_2]$

20. The correct order for the wavelength of absorption in the visible region is

(a) $[Ni(NO_2)_6]^{4-} < [Ni(NH_3)_6]^{2+} < [Ni(H_2O)_6]^{2+}$

(b) $[Ni(NO_2)_6]^{4-} < [Ni(H_2O)_6]^{2+} < [Ni(NH_3)_6]^{2+}$

(c) $[Ni(H_2O)_6]^{2+} < [Ni(NH_3)_6]^{2+} < [Ni(NO_2)_6]^{4-}$

(d) $[Ni(NH_3)_6]^{2+} < [Ni(H_2O)_6]^{2+} < [Ni(NO_2)_6]^{4-}$

21. In which of the following pairs both the complexes show optical isomerism

(a) *cis*-$[Cr(C_2O_4)_2Cl_2]^{3-}$, *cis*-$[Co(NH_3)_4Cl_2]$

(b) $[Co(en)_3]Cl_3$, *cis*-$[Co(en)_2Cl_2]Cl$

(c) $[PtCl(dien)]Cl$, $[NiCl_2Br_2]^{2-}$

(d) $[Co(NO_3)_3(NH_3)_3]$, *cis*-$[Pt(en)_2Cl_2]$

22. Which of the following compounds shows optical isomerism **[AIEEE 2005; CBSE PMT 2005]**

(a) $[Cu(NH_3)_4]^{2+}$ (b) $[ZnCl_4]^{2-}$

(c) $[Cr(C_2O_4)_3]^{3-}$ (d) $[Co(CN)_6]^{3-}$

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Potassium ferrocyanide and potassium ferricyanite both are diamagnetic.
Reason : Both have unpaired electrons.

2. Assertion : NF_3 is a weaker ligand than $N(CH_3)_3$
Reason : NF_3 ionizes to give F^- ions in aqueous solution.

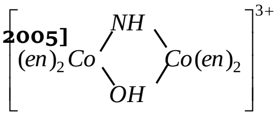
3. Assertion : The $[Ni(en)_3]Cl_2$ (en = ethylene diamine) has lower stability than $[Ni(NH_3)_6]Cl_2$
Reason : In $[Ni(en)_3]Cl_2$ the geometry of Ni is trigonal bipyramidal

4. Assertion : The ligands nitro and nitrito are called ambidentate ligands.
Reason : These ligands give linkage isomers.

5. Assertion : Geometrical isomerism is also called *cis-trans* isomerism.
Reason : Tetrahedral complexes show geometrical isomerism.

[AIIMS 2005]

6. Assertion :



is named as tetrakis (ethylene diamine) μ-hydroxo-imido dicobalt (III) ion.
Reason : In naming polynuclear complexes *i.e.*, containing two or more metal atoms joined by bridging ligands, the word μ is added with hyphen before the name of such ligands.

[AIIMS 2005]

7. Assertion : $[Fe(CN)_6]^{3-}$ is weakly paramagnetic while $[Fe(CN)_6]^{4-}$ is diamagnetic.
Reason : $[Fe(CN)_6]^{3-}$ has +3 oxidation state while $[Fe(CN)_6]^{4-}$ has +2 oxidation state.

8. Assertion : H_2N-NH_2 is a chelating ligand.
Reason : A chelating ligand must possess two or more lone pairs at such a distance

that it may form suitable strain free rings at the metal ion.

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

Reason : *d*-*d* transition is not possible in $[Sc(H_2O)_6]^{3+}$.

10. Assertion : All the octahedral complexes of Ni^{2+} must be outer orbital complexes.

Reason : Outer orbital octahedral complexes are given by weak ligands.

11. Assertion : Potassium ferrocyanide is diamagnetic whereas potassium fericyanide is paramagnetic.

Reason : Crystal field splitting in ferrocyanide ion is greater than that of ferricyanide ion.

[AIIMS 2005]

Answers

Basic Terms

1	b	2	c	3	b	4	b	5	d
6	a	7	b	8	c	9	b	10	c
11	d	12	c	13	d	14	b	15	b
16	b	17	a	18	c	19	c	20	b
21	b	22	c	23	b	24	d	25	a
26	d	27	a	28	b	29	b	30	c
31	b	32	c	33	b	34	b	35	d
36	d	37	b	38	b	39	d	40	b
41	d	42	b	43	d	44	b	45	a
46	a	47	d	48	c	49	b	50	d
51	a	52	b	53	d	54	a	55	d
56	d	57	a	58	d	59	a	60	d
61	c	62	d						

Nomenclature, oxidation State and EAN number

1	b	2	c	3	c	4	b	5	d
6	c	7	b	8	a	9	a	10	a
11	c	12	a	13	b	14	a	15	b
16	c	17	d	18	b	19	d	20	a
21	b	22	b	23	a	24	b	25	a
26	d	27	c	28	b	29	a	30	a
31	a	32	b	33	a	34	b	35	c
36	b	37	a	38	a	39	b	40	c
41	a	42	b	43	c	44	b	45	b
46	d	47	a	48	b	49	c	50	c
51	b	52	b	53	c	54	d	55	b
56	a	57	b	58	c				

Isomerism and Magnetic properties

1	a	2	d	3	a	4	c	5	c
6	d	7	b	8	a	9	a	10	c
11	d	12	d	13	b	14	c	15	a
16	b	17	a	18	d	19	a	20	b
21	c	22	b	23	b	24	a	25	a
26	d	27	d	28	a	29	c	30	a
31	b	32	a	33	c	34	a	35	d
36	c	37	d	38	a	39	d	40	b
41	a	42	c	43	d	44	a	45	b
46	e	47	a	48	d	49	c	50	c
51	d	52	a	53	c	54	a	55	a
56	c	57	c						

Hybridisation and Geometry

1	a	2	b	3	a	4	b	5	a
6	b	7	b	8	d	9	c	10	a
11	b	12	c	13	d	14	a	15	b
16	b	17	d	18	d	19	a	20	a
21	b	22	d	23	c	24	c	25	c
26	d	27	d	28	d	29	d	30	a
31	d	32	c	33	a	34	a	35	c
36	a	37	c	38	d	39	d	40	b
41	b	42	a	43	c				

Complexes and complex stability

1	d	2	d	3	d	4	b	5	a
6	a	7	d	8	b	9	c	10	b
11	b	12	b	13	a	14	b	15	b

Application of organometallics

1	d	2	d	3	d	4	c	5	b
6	b	7	b	8	a	9	a	10	d
11	c	12	b	13	a	14	c	15	d
16	c	17	c	18	c	19	d	20	a

Critical Thinking Questions

1	b	2	b	3	a	4	b	5	b
6	b	7	c	8	c	9	d	10	a
11	d	12	d	13	d	14	a	15	d
16	d	17	ad	18	a	19	c	20	a
21	b	22	c						

Assertion & Reason

1	d	2	c	3	d	4	a	5	c
6	e	7	b	8	e	9	a	10	b
11	c								

Answers and Solutions

Basic terms

1. (b) (CN) are linked with secondary valency.

2. (c) In Cuprammonium sulphate $[Cu(NH_3)_4]SO_4$

co-ordination no. of Cu is 4.

3. (b) As it makes use of its two atoms to form two co-ordinate covalent bonds with the central metal ion.

4. (b) $[Co\,(en)_2Br_2]Cl_2$

$C.N.$of Co = 2 × number of bidentate ligand

+1×number of monodentate ligand =2× 2 + 1× 2 = 6.

7. (b) The charge does not decide the formation of bond but availability of lone pair decide the formation of Co-ordinate bond.

8. (c) In $[Co(en)_2Cl_2]^+$

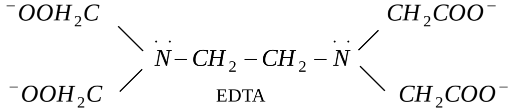
No. of monodentate ligand = 2

No. of bidentate ligand = 2

Co-ordination no. of the metal = 2 + 2(2)= 6.

10. (c)

11. (d)



EDTA

12. (c) According to modern view primary valency of complex compound is its oxidation number while secondary valency is the co-ordination number.

15. (b) Co-ordination number is equal to total number of ligands in a complex.

16. (b) Cuprammonium salt-$[Cu\,(NH_3)_4]SO_4$

$[Cu\,(NH_3)_4]SO_4 \rightleftharpoons [Cu\,(NH_3)_4]^{2+} + SO_4^{2-}$

So, it will give two ions in water.

17. (a) The co-ordination no. = no. of ligands attached.

18. (c) Primary valencies are also known as oxidation state.

$K_2[\,Ni(CN)_4]$, $2 + x - 4 = 0 \Rightarrow x = +2$

20. (b) Ag^+ has two coordination number forms complex with excess of CN^- $Ag(CN)_2$.

21. (b) According to Lewis the ligands are basic in nature.

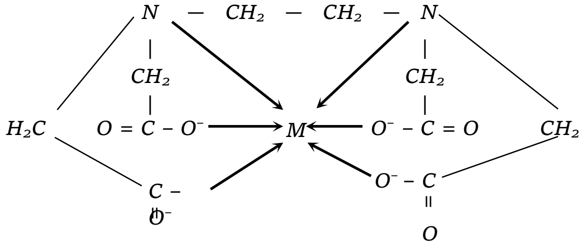
22. (c) The number of atoms of the ligand that are directly bounded to the central metal atom or ion by coordinate bond is known as the coordination number of the metal atom or ion coordination number of metal = number of σ bonds formed by metal with ligand .

23. (b) $Ag_2S + 4NaCN \rightleftharpoons \underset{\text{Sodium dicyno argentate}}{2Na\left[Ag(CN)_2\right]} + Na_2S$

$$2Na[Ag(CN)_2] + Zn \rightarrow \underset{\text{Sodium tetracyno zincate (ppt)}}{Na_2[Zn(CN)_4]} + 2Ag\downarrow$$

24. (d) In $K_4Fe(CN)_6$, the species retains its identity in solid as well as in solution state.

26. (d) The number of atom of the ligand that are directly bound to the central metal atom or ion by coordinate bonds is known as the coordinate number of the metal or ion. It is actually the number of chemical bonds which the ligand form with the central metal atom or ion.



27. (a) CN^- ions acts both as reducing agent as well as good complexing agent.

29. (b) ZnS structure shows the coordination number of Zn is 4.

30. (c) Wilkinson’s catalyst is $Rh(P.Ph_3)_3Cl]$.

31. (b) The complexes can be written as follows

$$\underset{(A)}{[Co(NH_3)_6]Cl_3}\ \underset{(B)}{[Co(NH_3)_5Cl]Cl_2}\ \underset{(C)}{[Co(NH_3)_4Cl_4]Cl}$$

Hence, number of primary valencies are 3, 2 and 1 respectively.

32. (c) Ligand must have capacity to donate lone pair of electrons to form co-ordinate bond.

33. (b) $K_3[Fe(CN)_6]$ because in it CN^- donats a lone pair of electron.

34. (b) Al has 6 co-ordination number.

35. (d) $K_4[Fe\,(CN)_6] \rightarrow 4K^+ + [Fe\,(CN)_6]^{4-}$

Complex has negative charge so it is anionic complex.

36. (d) Co-ordination number is equal to total number of ligands in a complex.

37. (b) Lithium tetrahydroaluminate is $Li[Al(H)_4]$.

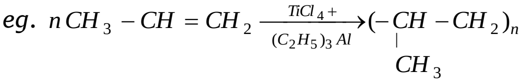
40. (b) Negative ligands end in $-O$ *eg.* SO_4^{2-} (sulphato).

44. (b) Turnbull’s blue is $K\{Fe^{\text{II}}[Fe^{\text{III}}(CN)_6]\}$.

46. (a) $Fe + 5CO \xrightarrow[\text{Pressure}]{\text{Heat}} \underset{\text{Iron pentacarbonyl.}}{[Fe\,(CO)_5]}$

48. (c) When a ligand attaches to the central metal atom through two or more atoms to form a ring like structure is known as chelats and the ligand is called chelating ligand.

53. (b) *eg.*



$n CH_3 - CH = CH_2 \xrightarrow[(C_2H_5)_3 Al]{TiCl_4 +} (-\underset{\underset{CH_3}{|}}{CH} - CH_2)_n$

55. (d) CH_3Li is the organometallic compound in which lithium bonded with carbon and organometallic are those in which metal-carbon bond found.

56. (d) Potash alum is a mixed salt of K_2SO_4 and $Al_2(SO_4)_3$ and on dissolving, it gives all three ion Al^{3+}, K^+ and SO_4^{2-} of which it is made.

57. (a) Carnallite is a double salt with molecular formula $KCl \,.\, MgCl_2.6H_2O$. It gives K^+, Mg^{2+} and Cl^- ions in solution.

59. (a) General formula for alum is

$M_2SO_4.R_2(SO_4)_3.24H_2O$

$M =$ mono valent cation $(K^+, Na^+ ....)$

$R =$ Trivalent cation (Al^{+3}, Fe^{+3})

Hence, $K_2SO_4Al_2(SO_4)_2.24H_2O$ represent an alum.

60. (d) $K_4[Fe(CN)_6]$ is a complex salt. On ionisation it will dissociate in $4K^+$ and $[Fe(CN)_6]^{4-}$ ion. Hence, in $K_4[Fe(CN)_6]$ five ions are present.

61. (c) Due to $C - Mg$ bond.

62. (d) EAN = (At. number $-0.S + 2 \times C.N.$)

Hence, EAN of Ni in $Ni(CO)_4$ is

$= 28 - 0 + 2 \times 4 = 36$

Nomenclature, Oxidation State & EAN number

1. (b) $[Co\,(H_2O)_6]Cl_2 \rightleftharpoons [Co\,(H_2O)_6]^+ + 2Cl^-$.

5. (d) Follow IUPAC rule.

7. (b) Follow IUPAC rule.

9. (a) Follow IUPAC rule.

10. (a) Follow IUPAC rule.

11. (c) EAN =Atomic number – Oxidation state + 2 × number of Ligands = 26 – 2 + 2 (6) = 36.

12. (a) EAN of *Pt* in $[PtCl_6]^{2-} = 80$

13. (b) $Na_2[Cr\,F_4O]$

$x + 4(-1) + (-2) = -2$

$x - 6 = -2 \Rightarrow x = +4$.

14. (a) Follow IUPAC rule.

16. (c) Follow IUPAC rule.

17. (d) Follow IUPAC rule.

18. (b) The oxidation state of metal in metal carbonyl is zero.

19. (d) $x + 6 \times (0) + 3 \times (-1) = 0$

$x - 3 = 0$, $x = +3$, Oxidation number of Cr is $= +3$.

20. (a) EAN = (atomic no)- (oxidation state) + (2 × number of Ligands) = 28 - 2 + 2 × 4 = 34

21. (b) Follow IUPAC rule.

22. (b) $[\underset{x}{Pt}(\underset{0}{C_2\,H_4})\underset{-1}{Cl_3}]^-$

$x + 0 + 3x(-1) = -1$, $x - 3 = -1$, $x = +2$.

23. (a) $[Co\,(NH_3)_6]Cl_3 \rightarrow [Co(NH_3)_6]^{3+} + 3Cl^-$

$x + 6(0) = +3 \Rightarrow x = +3$.

24. (b) Follow IUPAC rule.

25. (a) EAN = at. no. of central atom - oxidation state + $2 \times$ (no. of ligands) $= 27 - 3 + 2 \times 6 = 36$.

26. (d) Follow IUPAC rules for nomenclature.

27. (c) EAN of a central metal ion=(atomic no. of central atom) – oxidation state + no. of ligands × 2 $= 26 - 3 + (6 \times 2) = 23 + 12 = 35$

28. (b) $+1 \times 4 + x - 1 \times 4 = 0$

$4 + x - 4 = 0 \Rightarrow x = 0$ for Ni.

29. (a) Follow IUPAC rule.

30. (a) In complex $K_4[Fe(CN)_6]$ the Fe obey EAN rule strictly.

31. (a) $Ni(CO)_4$ has O.N. zero for Ni.

32. (b) $3 \times (+1) + x + 6 \times (-1) = 0$ or $x = 6 - 3 = +3$ Oxidation state of $Fe = +3$.

33. (a) Complexes containing carbonyl ligand (CO) have zero oxidation state.

34. (b) Follow IUPAC rule.

35. (c) Follow IUPAC rule.

36. (b) Follow IUPAC rule.

38. (a) Follow IUPAC rule.

39. (b) Follow IUPAC rule.

41. (a) Follow IUPAC rule.

42. (b) $[Ni(CN)_4]^x$, $(Ni = +2)$ $(CN = -1)$

$x = 2 + 4(-1) \Rightarrow x = -2$.

44. (b) $[Cu(NH_3)_4]^{2+}$ so, copper has + 2 valency.

47. (a) Follow IUPAC rule.

50. (c) Follow IUPAC rule.

51. (b) $[\underset{x}{Co}\,(\underset{0}{H_2O})_5\,\underset{-1}{Cl}]^{+2}$

$x - 1 = 2 \Rightarrow x = +3$.

52. (b) It is clear from the chemical formulae that Ag is central metal atom and ligands are 2 ammonia molecule.

Hence, compound is $[Ag(NH_3)_2]Cl$.

53. (a) In the compounds $[Co(NH_3)_5NO_2]Cl_2$, the oxidation state of cobalt is +3 and here 5 NH_3 ligand, a NO_2 ligand are attached to the central atom. therefore its name is pentaamminecobalt (III) chloride.

54. (b) $\overset{+6}{Cr}O_2\,Cl_2,\ \overset{+7}{Mn}O_4$.

55. (b) In the given ion $[Cr(NH_3)_6]^{3+}$, the oxidation state of chromium is +3 and here $6NH_3$ ligand are attached to the central metal atom. Therefore its IUPAC name is hexamminechromium (III) ion.

56. (a) It is potassium ammine dicyano dioxo peroxo-chromate (VI)

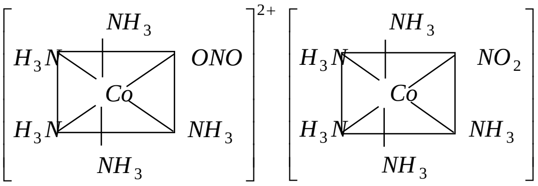
57. (b) Potassium hexa cyanoferrate (III).

Isomerism and Magnetic Properties

1. (a) Octahedral complexes of the type $[MA_4B_2],[MA_2B_4],[MA_3B_3]$ exhibit geometrical isomerism.

2. (d) The number of unpaired electrons in the Complex ion $[CoF_6]^{3-}$ is 4.

4. (c)



Here more than one atom function as donor, as oxygen in first one and nitrogen in second, so they show linkage isomerism

5. (c) The two given compounds have same composition but in solution both will give different ions. The isomerism is known as ionisation isomerism.

6. (d) Both produce different ions in solution state-

$$[Co(NH_3)_4Cl_2]NO_2 \rightleftharpoons [Co(NH_3)_4Cl_2]^+NO_2^-$$

$$[Co(NH_3)_4Cl.NO_2]Cl \rightleftharpoons [Co(NH_3)_4Cl.NO_2]^+ + Cl^-$$

7. (b) The compound which has same composition but give different ions in solution, show ionization. So $[Co(NH_3)_5Br]\,SO_4$ is ionization isomer.

$$[Co(NH_3)_5Br]SO_4 \rightleftharpoons [Co(NH_3)_5Br]^{2+} + SO_4^{2-}$$

$$[Co(NH_3)_5SO_4]Br \rightleftharpoons [Co(NH_3)SO_4]^+ + Br^-.$$

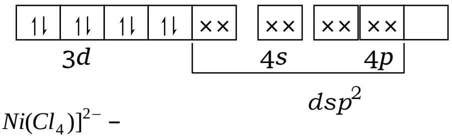
9. (a) Co-ordination isomerism is caused by the interchange of ligands between cis and trans structure.

10. (c) $[Co(NH_3)_5NO_2]Cl_2$ will not show geometrical isomerism because this complex showed 4 and 6 co-ordination number.

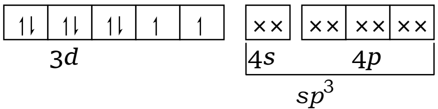
13. (b) $[Fe(H_2O)_6]^{2+}$ has four unpaired electrons, $[Cr(H_2O)_6]^{3+}$, $[Cu(H_2O)_6]^{2+}$ and $[Zn(H_2O)_6]^{2+}$ have 3, 1, 0 unpaired electrons respectively.

14. (c) The electronic configuration of Ni in $[Ni(CN)_4]^{2-},[Ni(Cl_4)]^{2-}$ and $Ni(CO)_4$ are as following

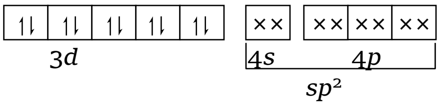
Ni^+ in $[Ni(CN)_4]^{2-}$ –



Ni^{2+} in $[Ni(Cl_4)]^{2-}$ –

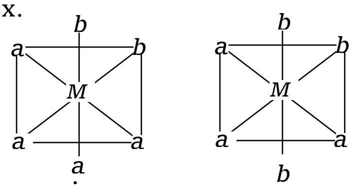


Ni in $[Ni(CO)_4]$ –



CO and CN^- are strong ligands so they induces pairing of electrons so their complexes are diamagnetic while Cl^- is a weak ligand so it does not induce the pairing of electrons so its complex is paramagnetic.

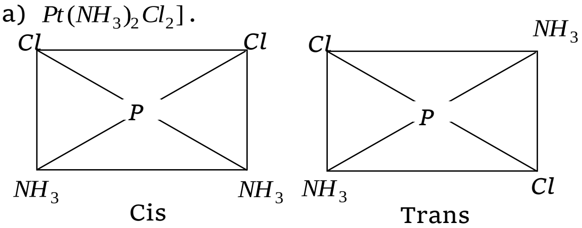
15. (a) $[Co\,(NH_3)_4\,Cl_2]^+$ is the Ma_4b_2 and Ma_2b_3 type complex.



cis trans

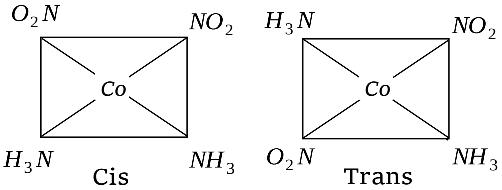
16. (b) In $[Ag(NH_3)_2]Cl, Ag^+$ contains d^{10} configuration. All others contain unpaired electrons.

17. (a) $Pt(NH_3)_2Cl_2]$.



Cis Trans

19. (a)

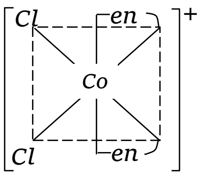


Cis Trans

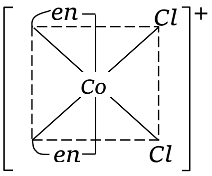
21. (c) $[Co(en)_2NO_2Cl]Br$; $[Co(en)_2ONOCl]Br$

22. (b) Because it will not give any ions in solution.

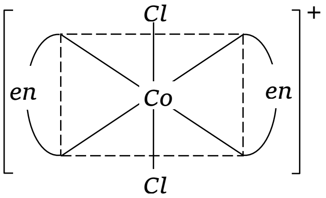
23. (b) $[Co(en)_2Cl_2]^+$ have three optical isomers which are.



d-cis form



l -cis forms



Trans-meso form.

24. (a) Magnetic moment of $[Cu(NH_3)_4]^{2+}$ ion is 1.414 due to the presence of one unpaired electron.

25. (a) Due to the presence of one unpaired electron, both are slightly paramagnetic.

27. (d) 1. $[Cu(NH_3)_4].[PtCl_4]$

2. $[Cu(NH_3)_3Cl].[PtCl_3(NH_3)]$

3. $[Cu(NH_3)_2Cl_2].[PtCl_2(NH_3)_2]$cis

4. $[Cu(NH_3)_2Cl_2].[PtCl_2(NH_3)_2]$Trans

5. $[Cu(NH_3)Cl_3].[Pt(Cl)(NH_3)_3]$

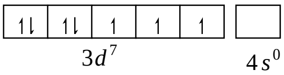
6. $[Pt(NH_3)_4Cl].[CuCl_4]$

29. (c) Co-ordination isomerism is possible when both *+ve* and *-ve* ions of a salt are complex ions and the two isomers differ in the distribution of ligands in the cation and the anion.

30. (a) On ionisation it gives maximum number of (four) ions.

31. (b) The anhydrous complex of Cu^+ do not involve *d–d* transition and are thus colourless.

32. (a) Mn^{2+}



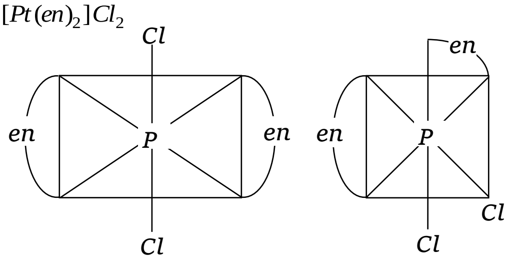
In presence of H_2O which is a weak ligand no pairing occurs which results in unpaired electrons left in the compound, due to which it shows paramagnetism.

33. (c) Geometrical isomers (cis and trans) and linkage isomers (–SCN and –NCS).

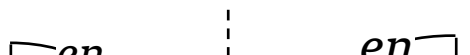
34. (a) Due to presence of strong ligand all the e^- get paired. So no. of unpaired electrons are 0.

36. (c) Both have same composition but give different ions in the solution.

37. (d) $[Pt(en)_2]Cl_2$

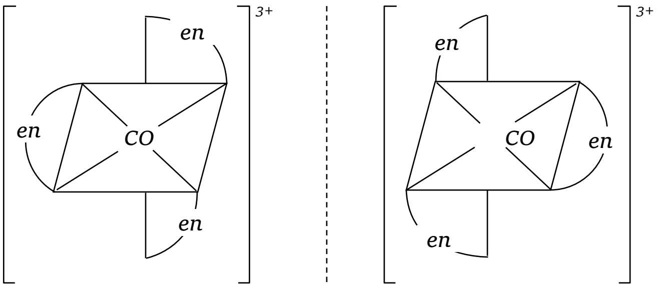


Geometrical isomers



38. (a) CO is a strong ligand so induce pairing of electrons and hence $Ni(CO)_4$ is diamagnetic.

40. (b) $[Co(en)_3]^{3+}$



d-form Mirror *l*-form

41. (a) $[Co(NH_3)_3Cl_3]$ does not have optical isomers because it is of formula MA_3B_3 which does not show optical isomerism.

42. (c) Change in composition of co-ordination sphere yield ionization isomers.

$[Cr(H_2O)_6]Cl_3$ and $[CrCl_3(H_2O)_3].3H_2O$

43. (d) NO_2 is ambident and can be linked either to N -side as $(-NO_2)$ or to O -side as $(-ONO)$.

44. (a) As $[Co(NH_3)_3Cl_3]$ does not losses any Cl^-ions in the solution so it will not give ppt. with $AgNO_3$.

45. (b) $[Co(NH_3)_6]Cl_3 \rightleftharpoons [Co(NH_3)_6]^{3+} + 3Cl^-$.

46. (e) $CoCl_3.5NH_3.H_2O$ is pink in colour.

47. (a) The configuration of Ni^{2+} has two unpaired electron so it is paramagnetic.

48. (d) $[Pt(NH_3)_4]Cl_2 \rightarrow [Pt(NH_3)_4]^{+2} + 2Cl^-$

As it gives Cl^- ions in solution so it will give white ppt. of $AgCl$ with $AgNO_3$.

49. (c) $[Co(NH_3)_5Cl]Cl_2 \rightleftharpoons [Co(NH_2)_5Cl]^{2+} + 2Cl^-$

50. (c) $[Cr(NH_3)_5Cl]SO_4 \rightarrow [Cr(NH_3)_5Cl]^{2+} + SO_4^{2-}$

$(Cr(NH_3)_5Cl]^{2+} + SO_4^{2-} + BaCl_2 \rightarrow$

$[Cr(NH_3)_5Cl]Cl_2 + BaSO_4 + HCl$.

51. (d) $[Pt(NH_3)Cl_2Br]Cl \rightleftharpoons \underbrace{[Pt(NH_3)Cl_2Br]^+ + Cl^-}$

Cl^- ion is precipitable.

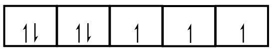
52. (a) $Cu(II)$ complexes are blue.

53. (c) It will ionize in the following manner.

$[Co(NH_3)_5]Cl_2 \rightleftharpoons [Co(NH_3)_5]^{2+} + 2Cl^-$ (3 ions).

54. (a) $_{27}Co \rightarrow [Ar]3d^7 4s^2$

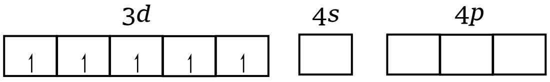
$Co^{2+} \rightarrow 3d^7 4s^0$



Number of unpaired electrons = 3.

55. (a) $K_3[FeF_6]$

$Fe^{3+} = [Ar]3d^5 4s^0$

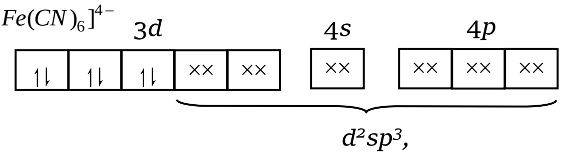


Number of unpaired electrons = 5

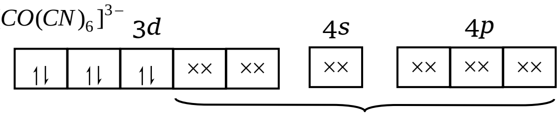
Magnetic moment $= \sqrt{n(n+2)} = \sqrt{5(5+2)}$

$= \sqrt{35}$ = 5.91 BM.

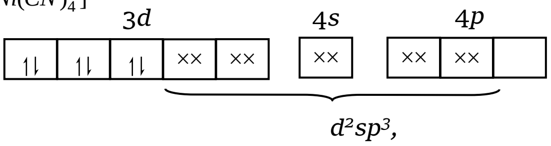
56. (c) $[Fe(CN)_6]^{4-}$



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



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



57. (c) When coordinate compounds gives different ions in solution then it produces ionic isomerism while this situation is not present in $[Co(en)_2Cl_2]Cl$.

Hybridisation and Geometry

3. (a) $2Cl^-$ ions are ionizable

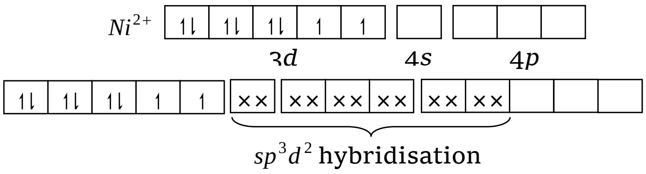
$\therefore [Co(NH_3)_5Cl]Cl_2 \rightleftharpoons \underbrace{[Co(NH_3)_5Cl]^{2+} + 2Cl^-}_{\text{3 ions}}$

$2Cl^- + 2AgNO_3 \rightarrow 2AgCl + 2NO_3^-$.

4. (b) Copper complexes usually involve with four co-ordination number and have square planar in shape.

5. (a) Complex with sp^3d – hybridisation show square pyramidal geometry.

6. (b) sp^3d^2

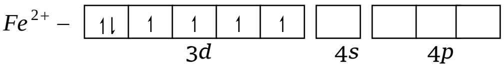


8. (d) Metal carbonyls does not show overlapping.

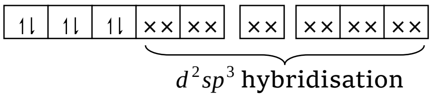
9. (c) sp^3d^2 – hybridisation gives octahedral complex.

11. (b) Copper complexes usually involve co-ordination number of four and are thus square planar in shape.

12. (c) $[Fe(CN)_6]^{4-}$



In presence of CN^-



Hence, Octahedral geometry.

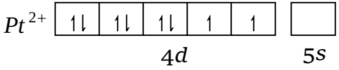
13. (d) $Fe(CO)_5$ has dsp^3-hybridisation so it show trigonal bipyramidal geometry.

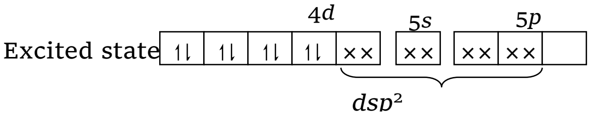
16. (b) Due to formation of inner orbital complex.

17. (d) $Ni(CO)_4$ and $Ni(PPh_3)_2Cl_2$ have sp^3 and dsp^2-hybridisation respectively.

18. (d) $[Cu(NH_3)_4]^{2+}$ has square planer structure.

19. (a) Since hybridisation is dsp^2 so it is square planar,

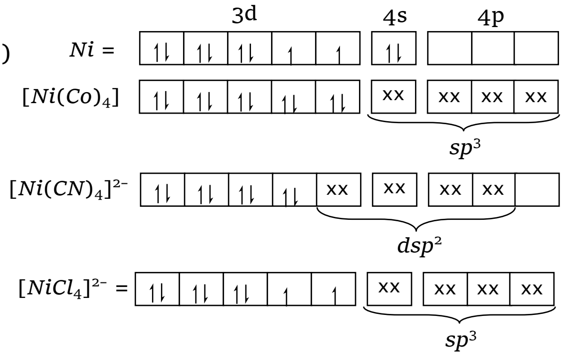




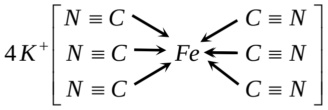
23. (c) d^2sp^3-hybridisation leads to octahedral geometry

25. (c) $[CoF_6]^{3-}$ is an outer complex having d^2sp^3 hybridisation.

27. (d)



28. (d)



$4K^+\left[\begin{array}{ccc} N\equiv C & \searrow & \swarrow\, C\equiv N\\ N\equiv C & \rightarrow Fe \leftarrow & C\equiv N\\ N\equiv C & \nearrow & \nwarrow\, C\equiv N\end{array}\right]$

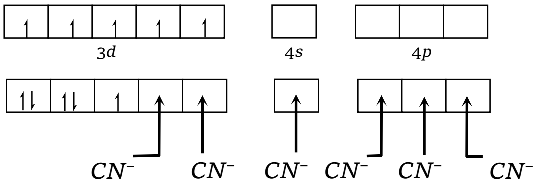
29. (d) $K_3[Fe(CN)_6]$

Electronic configuration of $Fe=[Ar]4s^2\,3d^6$

Electronic configuration of $Fe^{+3}=[Ar]3d^5$

Number of ligand (coordination numbr)=6

Nature of ligand is strong field.



Hybridization of Fe is d^2sp^3.

32. (c) The compounds which show d^6-configuration are octahedral complexes.

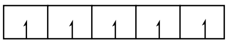
33. (a) CN^- ligand has strong field ligand because of higher value of Δ.

35. (c) Ammine (NH_2) is neutral ligand.

37. (c) A strong field ligand produces low spin complexes.

38. (d) Cyanide ion is strong field ligand because it is a pseudohalide ion pseudohalide ions are stronger coordinating ligand & they have the ability to form σ bond (from the pseudohalide to the metal) and π bond (from the metal to pseudohalide).

39. (d) $Mn^{25}\longrightarrow 3d^5+4s^2$

$Mn^{2+}\longrightarrow 3d^5$ 

In presence of weak ligand field, there will be no pairing of electrons. So it will form a high spin complex. i.e. the number of unpaired electrons = 5.

40. (b) The complexes, in which, the metal and ligand form a bond that involves the $\pi-$electrons of the ligand are know as $\pi-$complexes *e.g.* Ferrocene

$Fe\ (\eta^5-C_5H_5)_2$, zeise's salt $K[PtCl_3(\eta^2-C_2H_4)]$.

41. (b) CO has strong $M\rightarrow L$ $\pi-$bonding ability so it can accept electron pairs from metal ion so it is a π -acid ligand.

42. (a) d^4 (in strong ligand field).

43. (c) Both $Ni(CO)_4$ and $Ni(PPh_3)_2Cl_2$ are tetrahedral.

Complexes and complex stability

1. (d) The cyano and ammine complexes are far more stable than those formed by halide ions. This is due to the fact that NH_3 and CN^- are strong lewis bases.

4. (b) Greater the charge on central metal ion greater is the stability of complex.

5. (a) $CuSO_4$ on reaction with KCN gives $K_3[Cu(CN)_4]$

$$2CuSO_4+10KCN\rightarrow 2K_3[Cu(CN)_4]+2K_2SO_4+(CN)_2$$

6. (a) The most probable complex which gives three moles ions in aqueous solution may be $[Co(NH_3)_5NO_2]Cl_2$ because it gives two chlorine atoms on ionisation.

$$[Co(NH_3)_5NO_2]Cl_2\rightarrow[Co(NH_3)_5NO_2]^{2+}+2Cl^-$$

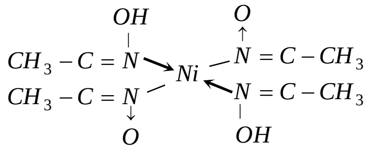
7. (d) $\underset{\text{pot. ferrocyanide}}{3K_4[Fe(CN)_6]}+4FeCl_3\rightarrow\underset{\substack{\text{(Ferri ferrocynide)}\\ \text{(Prussion blue)}}}{Fe_4[Fe(CN)_6]_3}+12KCl$

8. (b) $Fe_2(SO_4)_3\rightarrow 2Fe^{3+}+3SO_4^{2-}$

$$K_4[Fe(CN)_6]+2Fe^{3+}\rightarrow\underset{\text{Prussion blue}}{Fe_4[Fe(CN)_6]_3}\ .$$

9. (c) $[Co\,(NH_3)_5Cl]^x+2Cl^-\rightarrow[Co\,(NH_3)_5Cl]Cl_2$.

10. (b) Ni reacts with dimethylglyoxime to give red *ppt.* of nickel-dimethyl glyoxime complex.



12. (b) $AgCl+2NH_4OH\rightarrow[Ag\,(NH_3)_2]\ Cl+2H_2O$

$$\uparrow\downarrow$$

$$[Ag(NH_3)_2]^+Cl^-$$

13. (a) $Ag_2S+NaCN\rightleftharpoons\ Na\,[Ag\,(CN)_2]+Na_2S$.

14. (b) $Fe_2(SO_4)_3\rightarrow 2Fe^{3+}+3SO_4^{-2}$.

15. (b) Aluminum is a *p*-block element and does not form complex compounds.

Application of Organometallics

1. (d) $(CH_3CH_2)_3Al+TiCl_4$ is the Ziegler-Natta catalyst.

2. (d) Alum acts as coagulating agent.

4. (c) $4CH_3CH_2CH_2CH_2-Li+SnCl_2\rightarrow(C_4H_9)_4Sn$.

6. (b) As there is no direct bonding between the metal atom and the carbon atom.

9. (a) $(CH_3)_4Sn$ is a $\sigma-$bonded organometallic compound.

10. (d) Wilkinson's catalyst is used as homogeneous catalyst in the hydrogenation of alkenes as –

$H-H+\,\rangle C=C\langle \;\longrightarrow H-C-C-H.$

12. (b) $C_2H_5\ Li$ is an organo-metallic compound.

13. (a) Because there is direct bonding of metal ion with carbon.

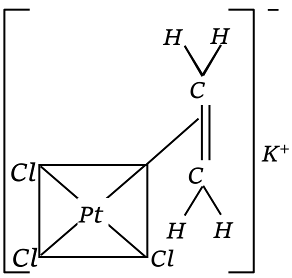
14. (c) Organometallic compounds are those compounds in which carbon atom is directly linked to metal. But in sodium ethoxide as oxygen is attached to sodium metal so it is not a organometallic compound.

16. (c) $Al(OC_2H_5)_3$ contains bonding through O and thus it does not have metal-carbon bond.

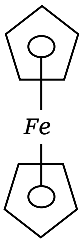
17. (c) Chlorophyll are green pigment in plant & contain magnesium instead of calcium.

19. (d) This reaction carried out in alkaline *pH i.e.*, 9–11

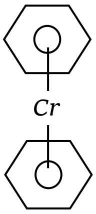
20. (a)



Zeise's salt



Ferrocene



dibenzene chromium

$(C_2H_5)_4Sn$
tetraethyl

Critical Thinking Questions

1. (b) Its coordination number will be 6 because it is bonded with three bidentale ligands.

Oxi. No. of Cr in $K_3[Cr(C_2O_4)_3]$ is
$\underset{-1}{K_3}[Cr(\underset{-2}{C_2O_4})_3]$

$x+3(-2)+3(+1)=0 \;\Rightarrow x=+3$

2. (b) *e.g.* $Fe(CO)_5, Ni(CO)_4$ *etc.*

3. (a) $\underset{0.02\,\text{mole}}{[Co\,(NH_3)_5SO_4]Br}+AgNO_3 \rightarrow$

$$\underset{0.02\,\text{mole}\,(y)}{[Co\,(NH_3)_5.SO_4]NO_3}+AgBr$$

$\underset{0.02\,\text{mole}}{[Co\,(NH_3)_5Br_2]SO_4}+BaCl_2 \rightarrow$

$$\underset{0.02\,\text{mole}(z)}{[Co\,(NH_3)_5Br]Cl_2}+BaSO_4$$

On using one *lit*. solution, we will get 0.01 mole y and 0.01 mole z.

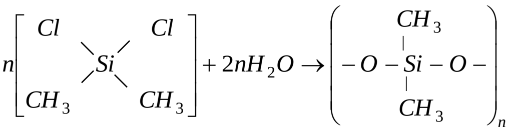
4. (b) $[Fe(\eta^5-C_5H_5)_2]$ is the organometallic compound which has σ and π bonds present.

5. (b) $[\underset{x}{Ni}\,(\underset{0}{NH_3})_4]\underset{-2}{SO_4}$

$x+0+(-2)=0 \Rightarrow x=+2$ is valency and 4 is *C.N.* of *Ni*.

6. (b) Co-ordination number is equal to total number of ligands in a complex.

7. (c)



$$n\left[\begin{matrix} Cl & & Cl \\ & Si & \\ CH_3 & & CH_3 \end{matrix}\right]+2nH_2O \rightarrow \left(\begin{matrix} & CH_3 & \\ -O- & Si & -O- \\ & CH_3 & \end{matrix}\right)_n$$

8. (c) Because it is a polydentate ligand which binds the central atom nickel forming a ring like structure.

9. (d) $4KCN+CuSO_4 \rightarrow \underset{\text{Potassium tetracyno cuprate}}{K_3[Cu(CN)_4]}$

10. (a) $\underset{\text{gold ore}}{\text{Roasted}}+CN^-+H_2O \xrightarrow{O_2} [Au\,(CN)_2]^-+OH^-$

$[Au\,(CN)_2]^-+Zn \rightarrow [Zn(CN)_4]^{2-}$.

11. (d) Potassium ferrocynide $K_4[Fe(CN)_6]$ will ionize as $K_4[Fe(CN)_6] \rightleftharpoons 4K^+ + [Fe\ (CN)_6]^{4-}$

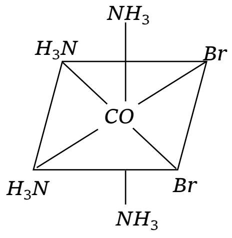
So, it will give five ions in solution.

12. (d)

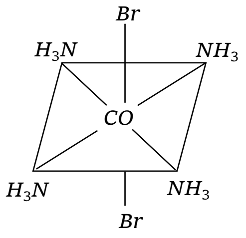
Complex ion	Hybridization of central atom
$[Fe(CN)_6]^{4-}$	d^2sp^3 (inner)
$[Mn(CN)_6]^{4-}$	d^2sp^3 (inner)
$[Co(NH_3)_6]^{3+}$	d^2sp^3 (inner)
$[Ni(NH_3)_6]^{2+}$	sp^3d^2 (outer)

13. (d) $[Co(en)_2Cl_2]^+$ shows geomerical as well as optical isomerism.

14. (a)



cis



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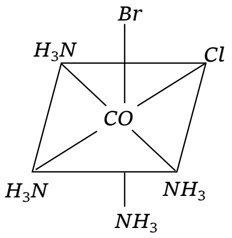

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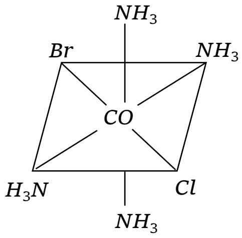

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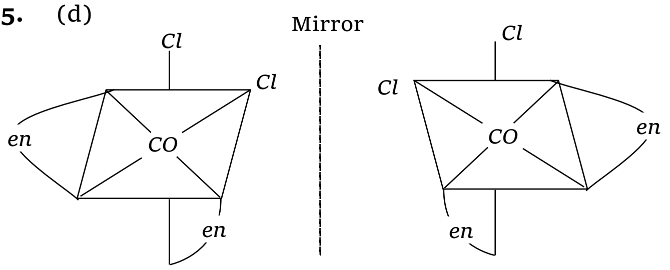
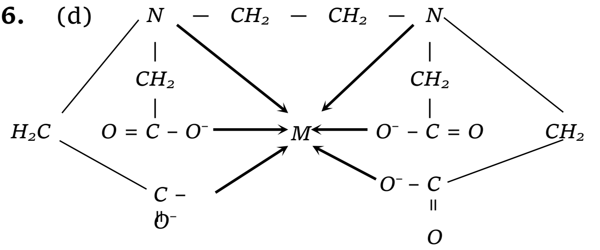
15. (d)



16. (d)



Ethylenediamine tetraacetate ion (EDTA)

They have six donor atoms. poly dentate ligands have flexidentate character. It is not necessary that all the donor atoms present in the polydentate ligands should form co-ordinate bonds with central metal atom or ion.

17. (a,d) In $K_3[Fe(CN)_6]$ the ligand are negative which is present in coordination spheres shows a dual behaviour. It may satisfied both primary & secondary valencies while neutral ligand satisfied only secondary valencies.

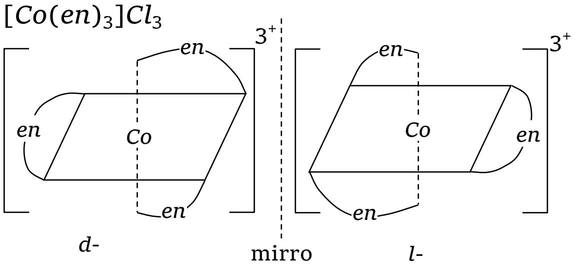
18. (a) Cis Isomer of $[Pt(NH_3)_2Cl_2]$ is used as an anticancer drugs for treating several type of malignant tumours. When it is injected into the blood stream the more reactive Cl groups are lost so the Pt atom bonds to a N atom in guanosine (a part of DNA) This molecule can bond to two different guanosine units & by bridging between them it upsets the normal reproduction of DNA.

19. (c) $CoCl_2$ is a weak Lewis acid, reacting with chloride ion to produce salt containing the tetrahedral $[CoCl_4]^{2-}$ ion. $CoCl_2$ is blue when anhydrous, and a deep magneta colour when hydrated, for this reason it is widely used as an indicator for water.

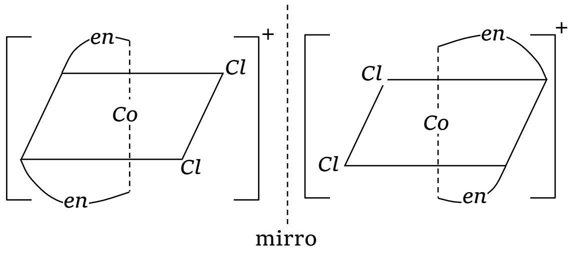
20. (a) The absorption of energy or the observation of colour in a complex transition compound depends on the charge of the metal ion and the nature of the ligands attached. The same metal ion with different ligands shows different absorption depending upon the type of ligand. The presence of weak field ligands make the central metal ion to absorb low energies *i.e.,* of higher wavelength. The field strength of ligands can be obtained from spectrochemical series. *i.e.*

(weak field) $I^- < Br^- < S^{2-} < Cl^- < NO_3^- < F^- < OH^- < H_2O < NH_3 < NO_2^- < CN^- < CO$ (strong field)

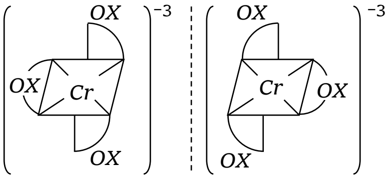
21. (b) $[Co(en)_3]Cl_3$



cis-$[Co(en)_2Cl_2]Cl$



22. (c)



Assertion and Reason

1. (d) Potassium ferrocyanide and potassium ferricyanide both are not diamagnetic because both do not have paired electrons. Assertion and reason both are false.

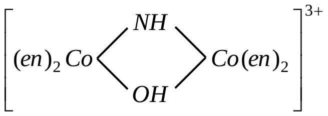
2. (c) It is correct statement that NF_3 is a weaker ligand than $N(CH_3)_3$, the reason is that fluorine is highly electronegative therefore, it with draw electrons from nitrogen atom. Hence, the lone pair of nitrogen atom cannot be ligated. While $N(CH_3)_3$ is a strong ligand because CH_3 has electron releasing group.

3. (d) Both assertion and reason are false. $[Ni(en)_3]Cl_2$ is a chelating compound and chelated complexes are more stable than similar complexes involves breaking of two bonds rather than one. In $[Ni(en)_3]Cl_2$, Ni with d^8 configuration shows octahedral geometry. Six electrons will occupy the t_{2g} orbitals and two electrons will occupy the e_g orbitals.

4. (a) Both assertion and reason are true and reason is the correct explanation of assertion . When a monodentate ligand has two possible donor atoms and attached in two ways to the central metal atom are called ambidentate ligands.

5. (c) Assertion is true but reason is false. Tetrahedral complexes do not show geometrical isomerism because the relative position of the atoms with respect to each other will be the same.

6. (e) Assertion is false but reason is frue.



is named as tetrakis (ethylene diamine)-μ-hydroxo-μ-imido dicobalt (III) ion. For more than one bridging group the word μ is repeated before each bridging group.

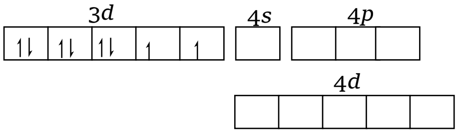
7. (b) Both assertion and reason are true but reason is not the correct explanation of assertion. $[Fe(CN)_6]^{3-}$ has EAN equal to 35 and thus possesses unpaired electron to show paramagnetic nature while $[Fe(CN)_6]^{4-}$ possesses no unpaired electron and thus shows diamagnetic nature.

8. (e) Assertion is false but reason is true. H_2N-NH_2 does not act as chelating ligand. The coordination by hydrazine leads to a three member highly unstable strained ring and thus it does not act as chelating agent.

9. (a) Both assertion and reason are true and reason is the correct explanation of assertion. $[Sc(H_2O)_6]^{3+}$ has no unpaired electron in its d subshell and thus $d-d$ transition is not possible whereas $[Ti(H_2O)_6]^{3+}$ has one unpaired electron in its d subshell which gives rise to $d-d$ transition to impart colour.

10. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

Ni^{2+} configuration



During rearrangement only one $3d$-orbital may be made available by pairing the electrons. Thus, inner d^2sp^3 hybridization is not possible, so, only sp^3d^2 (outer) hybridization can occur.

11. (c) $K_4[Fe(CN)_6]$ and $K_3[Fe(CN)_6]$ both are low spin complex due to strong ligand field. That is why it is false that crystal field splitting in ferrocyanide ion is greater than ferricyanide ion.

Co-odination Chemistry

SET Self Evaluation Test - 20

1. An, example for a double salt is **[KCET 2002]**
(a) Potassium ferricyanide
(b) Cobalt hexamine chloride
(c) Cuprous sulphate
(d) Mohr's salt

2. The complex $[Pt(NH_3)_6]Cl_4$ furnishes **[MP PET 1995]**
(a) 5 ions
(b) 4 ions
(c) 3 ions
(d) 2 ions

3. How many isomers are possible in $[Co(en)_2Cl_2]$ **[Orissa JEE 2004]**
(a) 2
(b) 4
(c) 6
(d) 1

4. π-bonding is not present in **[MP PET 2003]**
(a) Grignard reagent
(b) Dibenzene chromium
(c) Zeise's salt
(d) Ferrocene

5. Grignard reagent is a
(a) Coordinate compound
(b) Double salt
(c) Organometallic compound
(d) None of these

6. Which one of the following complexes is paramagnetic **[RPMT 1997]**
(a) $[Co(F)_6]^{3+}$
(b) $[Co(H_2O)_6]^{3+}$
(c) $[CoF_3(H_2O)_3]$
(d) All of these

7. The oxidation state of Fe in the complex $[Fe(CO)_5]$ is **[MP PMT 2003]**
(a) –1
(b) +2
(c) +4
(d) Zero

8. Which of the following is non-ionizable
(a) $[Co(NH_3)_3Cl_3]$
(b) $[Co(NH_3)_4Cl_2]Cl$
(c) $[Co(NH_3)_5Cl]Cl_2$
(d) $[Co(NH_3)_6]Cl_2$

9. The coordination and oxidation number of X in the compound $[X(SO_4)(NH_3)_5]Cl$ will be **[JIPMER 1997; DCE 2004]**
(a) 6 and 4
(b) 10 and 3
(c) 2 and 6
(d) 6 and 3

10. In $[NiCl_4]^{2-}$, the number of unpaired electron is **[BHU 2003]**
(a) 4.5
(b) 2
(c) 3
(d) 4

11. $AgCl$ precipitate dissolves in ammonia due to the formation of **[AIIMS 1991; MP PET 1993; CBSE PMT 1998]**
(a) $[Ag(NH_4)_2]OH$
(b) $[Ag(NH_4)_2]Cl$
(c) $[Ag(NH_3)_2]OH$
(d) $[Ag(NH_3)_2]Cl$

12. The oxidation number of cobalt in $K[Co(CO)_4]$ is **[MP PMT 2001; J & K CET 2005]**
(a) +1
(b) –1
(c) +3
(d) –3

13. The complex salt can be made by the combination of $[Co^{III}(NH_3)_5Cl]^x$ with: **[Pb. CET 2001]**
(a) PO_4^{3-}
(b) Cl^-
(c) $2Cl^-$
(d) $2K^+$

14. Which one of the following is an inner orbital complex as well as diamagnetic in behaviour (Atomic number : Zn = 30), Cr = 24, Co = 27, Ni = 28) **[CBSE PMT 2005]**
(a) $[Zn(NH_3)_6]^{2+}$
(b) $[Cr(NH_3)_6]^{3+}$
(c) $[Co(NH_3)_6]^{3+}$
(d) $[Ni(NH_3)_6]^{2+}$

15. The oxidation state of Fe in $K_4[Fe(CN)_6]$ is **[Pb. CET 2003; MP PET 2002]**
(a) +2
(b) –2
(c) +3
(d) +4

16. The number of moles of $AgCl$ precipitate when excess of $AgNO_3$ is added to one mole of $[Cr(NH_3)_4Cl_2]Cl$ is **[EAMCET 1998]**
(a) Zero
(b) 1.0
(c) 2.0
(d) 3.0

17. An anion solution gives a white ppt. With $AgNO_3$ solution. The ppt. dissolves in dil. ammonia due to the formation of **[MP PMT 1997]**
(a) $AgNO_3$
(b) NH_4NO_3

(c) $\lfloor Ag(NH_3)_2 \rfloor Cl$ (d) $\lfloor Ag(NH_3)_2 \rfloor Br$

18. The diamagnetic specie is **[AIIMS 2005]**

(a) $[Ni(CN)_4]^{2-}$ (b) $[NiCl_4]^{2-}$

(c) $[CoCl_4]^{2-}$ (d) $[CoF_6]^{2-}$

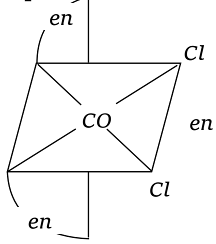
Answers and Solutions

(SET -20)

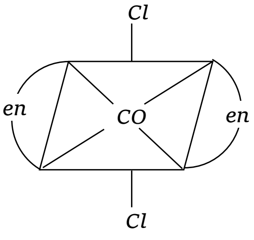
1. (d) Mohr's salt ($FeSO_4.(NH_4)_2SO_4.6H_2O$) is a double salt.

2. (a) $[Pt.(NH_3)_6]Cl_4 \rightleftharpoons [Pt.(NH_3)_6]^{4+} + 4Cl^-(5\text{ ions})$.

3. (b) $[Co(en)_2Cl_2]$ has 2 geometrical isomers & 2 optical isomers.



Cis isomer



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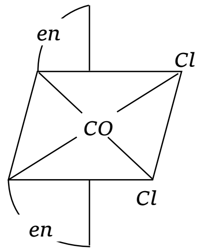
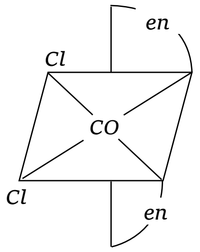
Again Cis isomer can give 2 optical isomers.



Cis isomer



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4. (a) Grignard reagent is, $R - Mg - X$.

5. (c) The organometallic compound of Mg is known as Grignard reagent $(R - Mg - X)$.

6. (d) As all the ligands are weak so they do to induce pairing of electrons so they show paramagnetism.

7. (d) In $[Fe(CO)_5]$, $x + 5(0) = 0$, so oxidation number of Fe is zero.

8. (a) Atoms present with in co-ordination sphere do not ionise.

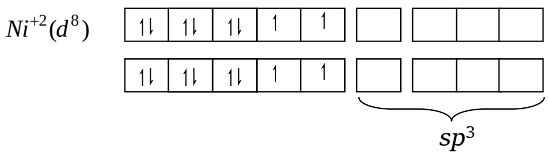
9. (d) Co-ordination no. is 6

oxidation state in $[\underset{x}{X}(\underset{-2}{SO_4})(\underset{0}{NH_3})_5]\underset{-1}{Cl}$ is

$x - 2 + 0 - 1 = 0, \quad x = +3.$

10. (b) $[NiCl_4]^{2-}$

O.N. of Ni = +2



$[NiCl_4]^{2-}$

Which has two unpaired electrons that is why it is paramagnetic.

11. (d) $AgCl + NH_3 \rightarrow \underset{\text{Diammine silver (I)chloride}}{[Ag(NH_3)_2]Cl}$

***

12. (b) $1 \times (+1) + x + 4 \times (0) = 0$

$1 + x = 0 \Rightarrow x = -1$ Oxidation number of $Co = -1$.

13. (c) In the complex ion $[Co^{(III)}(NH_3)_5Cl]^x$, charge on the complex ion

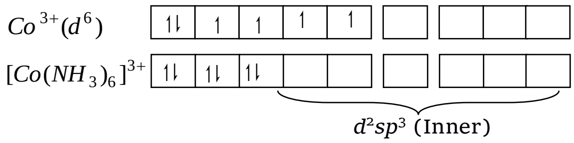
$x = 3 + (0 \times 5) + (-1)$

$x = 3 - 1 = 2$

Hence, it will combine with that species which have –2 charge to produce a neutral complex salt. So it will combine with $2Cl^-$ to produce $[Co(NH_3)_5Cl]Cl_2$ complex.

14. (c) $[Co(NH_3)_6]^{3+}$

O. N. of $Co = +3$



Due to paired e^- it is diamagnetic.

15. (a) $4 \times (+1) + x + 6 \times -1 = 0$

or $x = +6 - 4 = +2$

Oxidation state of $Fe = +2$

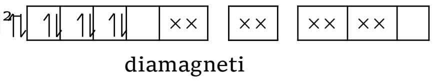
16. (b) In this complex chloride ion in the form of ionic isomerism and show primary valency.

$AgNO_3$ is added in excess then result precipitation will occur.

17. (c) $AgNO_3 + Cl^- \rightarrow AgCl + NO_3^-$

$AgCl + 2NH_3 \rightarrow \underset{\text{diammine silver (I)chloride.}}{[Ag(NH_3)_2]Cl.}$

18. (a) $[Ni(CN)_4]^{2-}$



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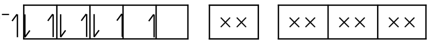
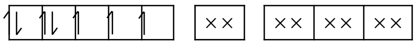
$[NiCl_4]^{2-}$ 

paramagneti

$[CoCl_4]^{2-}$ 

paramagneti

$[CoF_6]^{2-}$