

Coordination Compound

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Syllabus **IIT-JEE 2013**

Coordination compounds: nomenclature of mononuclear coordination compounds, colour (excluding the details of electronic transitions) and calculation of spin-only magnetic moment; cis-trans and ionisation isomerisms, hybridization and geometries of mononuclear coordination compounds (linear, tetrahedral, square planar and octahedral).

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COORDINATION COMPOUNDS

Coordination Compounds : Those addition compounds which retain their identity (i.e. doesn't lose their identity) in solution are called coordination compounds. For example, when KCN solution is added to $Fe(CN)_2$ solution, the species formed when dissolved in water no longer gives tests of Fe^{2+} and CN.

 $Fe(CN)_2 + 4KCN \longrightarrow Fe(CN)_2$. $4KCN \text{ or } K_4 [Fe(CN)_6] (aq.) \longrightarrow 4K^+ (aq.) + [Fe(CN)_6]^{4-} (aq.)$

Various Terms Used in co ordination compounds :

Central Atom/Ion :

In a coordination entity–the atom/ion to which are bound a fixed number of ligands in a definite geometrical arrangement around it, is called the central atom or ion. For example, the central atom/ion in the coordination entities : $[NiCl_2(OH_2)_4]$, $[CoCl(NH_3)_5]^{2+}$ and $[Fe(CN)_6]^{3-}$ are Ni²⁺, Co³⁺ and Fe³⁺, respectively. These central atoms / ions are also referred to as Lewis acids.

Ligands :

The neutral molecules, anions or cations which are directly linked with central metal atom or ion in the coordination entity are called ligands.

These may be simple ions such as Br⁻, small molecules such as H_2O or NH_3 , larger molecules such as $H_2NCH_2CH_2NH_2$ or $N(CH_2CH_2NH_2)_3$ or even macromolecules such as proteins.

Coordination Number :

The coordination number of the central atom/ion is determined by the number of sigma bonds between the ligands and the central atom/ions i.e. the number of ligand donor atoms to which the metal is directly attached. Pi-bonds.

Some common co-ordination number of important metals are as given below.

Metal	Coordination Number	Metal	Coordination Number
Cu+	2, 4	Ni ²⁺	4, 6
Ag+	2	Fe ²⁺	4, 6
Au+	2, 4	Fe ³⁺	6
Hg ₂ ²⁺	2	Co ²⁺	4, 6
Cu ²⁺	4, 6	Co ³⁺	6
Ag ²⁺	4	Al ³⁺	6
Pt ²⁺	4	Sc ³⁺	6
Pd ²⁺	4	Pt ⁴⁺	6
Mg ²⁺	6	Pd ⁴⁺	6





Common Name	IUPAC Name	Formula
methyl isocyanide	methylisocyanide	CH ₃ NC
triphenyl phosphine	triphenyl phosphine/triphenyl phosphane	PPh_3
pyridine	pyridine	C₅H₅N (py)
ammonia	ammine	NH_3
methyl amine	methylamine	MeNH ₂
water	aqua or aquo	H ₂ O
carbonyl	carbonyl	CO
thiocarbonyl	thiocarbonyl	CS
nitrosyl	nitrosyl	NO
fluoro	fluoro or fluorido*	F⁻
chloro	chloro or chlorido*	Cl⁻
bromo	bromo or bromido*	Br⁻
iodo	iodo or iodido*	F
cyano	cyanido or cyanido-C* (C-bonded)	CN⁻
isocyano	isocyanido or cyanido-N* (N-bonded)	NC ⁻
thiocyano	thiocyanato-S(S-bonded)	SCN⁻
isothiocyano	thiocyanato-N(N-bonded)	NCS ⁻
cyanato (cyanate)	cyanato-O (O-bonded)	OCN⁻
isocyanato (isocyanate)	cyanato-N (N-bonded)	NCO ⁻
hydroxo	hydroxo or hydroxido*	OH⁻
nitro	nitrito-N (N-bonded)	NO_2^-
nitrito	nitrito–O (O–bonded)	ONO-
nitrate	nitrato	NO_3^-
amido	amido	NH_2^-
imido	imido	NH ²⁻
nitride	nitrido	N ³⁻
azido	azido	N ₃ ⁻
hydride	hydrido	H⁻
oxide	oxido	0 ²⁻
peroxide	peroxido	02 ²⁻
superoxide	superoxido	0 ₂ -
acetate	acetato	CH₃COO⁻
sulphate	sulphato	SO4 ²⁻
thiosulphate	thiosulphato	S ₂ O ₃ ²⁻
sulphite	sulphito	SO32-
hydrogen sulphite	hydrogensulphito	HSO ₃ [−]
sulphide	sulphido or thio	S ²⁻
hydrogen sulphide	hydrogensulphido or mercapto	HS⁻
thionitrito	thionitrito	(NOS) [−]
nitrosylium	nitrosylium or nitrosonium	NO ⁺
nitronium	nitronium	NO ₂ +

Table : Common Monodentate Ligands





Chelating Points	Common Name	IUPAC Name	Abbreviation	Formula
bidentate	ethylenediamine	1,2-ethanediamine/ ethane-1,2-diamine	en	NH ₂ ,CH ₂ CH ₂ NH ₂
bidentate	propanediamine	1,2-propanediamine	pn	NH ₂ -CH-CH ₂ -NH ₂ I CH ₃
tridentate	diethylenetriamine	[N-(2-aminoethyl)-1 2-ethanediamine or diethylenetriamine	dien	NH ₂ CH ₂ CH ₂ NHCH ₂ CH ₂ NH ₂
tetradenate	triethylenetetraamine	[N, N'-bis-(2-aminoethyl)-1, 2-ethanediamine	trien	NH ₂ CH ₂ CH ₂ NHCH ₂ CH ₂ NHCH ₂ CH ₂ NH ₂
	triaminotriethylamine	or triethylenetetraamine β , β' , β'' -tris(2-aminoe-thyl) amine.	tren	NH ₂ CH ₂ CH ₂ NCH ₂ CH ₂ NH ₂ CH ₂ CH ₂ NH ₂
pentadentate	tetraethylenepentaamine	1,4,7,10 pentaazatridecar or tetraethylenepentaami	ne	NH ₂ CH ₂ CH ₂ NHCH ₂ CH ₂ NHCH ₂ CH ₂ NHCH ₂ CH ₂ NH ₂
hexadentate	ethylenediaminetetraacetate	1,2–ethanediyl (dinitrilo) tetraacetate or ethylenediaminetetraa	EDTA acetate	-OOCH ₂ C NCH ₂ CH ₂ N CH ₂ COO ⁻ CH ₂ COO ⁻

Table : Common Chelating Amines

Table : Common Multidentate (Chelating) Ligands

Common Name	IUPAC Name	Abbreviation	Formula	Structure
acetylacetonato	2,4-pentanediono or acetylacetonato	acac	сн₃соснсосн₃⁻	
2,2'-bipyridine	2,2'-bipyridyl	bipy	$C_{10}H_8N_2$	$\langle \bigcirc \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $
1,10-phenanthroline/ phenanthroline	1,10-diaminophenanthrene	phen,o-phen	$C_{12}H_8N_2$	
oxalato	oxalato	ox	C ₂ O ₄ ²⁻	
dialkyldithiocarbamato	dialkylcarbamodithioato	dtc	S₂CNR₂ [−]	S. CN R
1,2-bis(diphenylphophine)ethane	1,2-ethanediylbis (dipheylphosphene)	dppe	Ph2PC2H4PPh2	Ph Ph C_C Ph Ph
o-phenylenebis (dimethylarsine)	1,2-phenylenebis (dimethylarsene)	diars	$C_{6}H_{4}(As(CH_{3})_{2})_{2}$	Me As Mn Me Ma
dimethylglyoximato	butanedienedioxime or dimethylglyoximato	DMG	HONC(CH₃)C(CH₃)NO [−]	H, C, F, C, H, C,
ethylenediaminetetraacetato	1,2-ethanediyl (dinitrilo)tetraacetato or ethylenediaminetetraacetato	EDTA	([−] OOCCH ₂) ₂ NCH ₂ CH ₂ N(CH ₂ COO [−]) ₂	осн.с -осн.с -осн.с 0 -осн.с 0
pyrazolylborato	hydrotris- (pyrazo-1-yl)borato			





Nomenclature of Coordination Compounds

Writing the name of Mononuclear Coordination Compounds :

The following rules are followed when naming coordination compounds :

Names of the anionic ligands end in –o. Anionic ligands ending with 'ide' are named by replacing 'ide' by suffix 'ido'.

e.g . Symb

ol	Name
N ^{3–}	Nitrido
CI	Chlorido
0 ₂ ²⁻	Peroxido
Br	Bromido
O_2H^-	Perhydroxido
ĊN ⁻	Cyanido
S ²⁻	Sulphidido
O ^{2–}	Oxido
NH ^{2–}	Amidido
OH_	Hydroxido

Ligands whose names end in 'ite' or 'ate' become 'ito' or 'ato' i.e., by replacing the ending 'e' with 'o' as follows

Symbol	Name as ligand
CO3 ²⁻	Carbonato
C ₂ O ₄ ²⁻	Oxalato
SO4 ²⁻	Sulphato

C ₂ O ₄ ²⁻	Oxalato
SO4 ²⁻	Sulphato
NO_3^{-}	Nitrato
SO3 ²⁻	Sulphito
CH ₃ COO ⁻	Acetato

 NO_2^- (bonded through oxygen) nitrite (bonded through nitrogen) nitro Neutral ligands are given the same names at the neutral molecules. For example. Ethylene diamine as a ligand is named ethylene diamine in the complex. However some exceptions to this rule are

Aquo	H ₂ O
Ammine	NH ₃
Carbonyl	CO
Nitrosyl	NO
Thiocarbonyl	CS
tetraphosphorus	P ₄
dioxygen	0 ₂
octasulphur	S ₈
urea	$CO(NH_2)_2$

Names of positive ligands ends in 'ium' e.g.

NO⁺ Nitrosylium

NH₂NH₃⁺ Hydrazinium





Prefixes mono, di, tri, etc., are used to indicate the number of the one kind of ligands in the coordination entity. When the names of the ligands include a numerical prefix or are complicated or whenever the use of normal prefixes creates some confusion, it is set off in parentheses and the second set of prefixes is used.

2	di	bis
3	tri	tris
4	tetra	tetrakis
5	penta	pentakis
6	hexa	hexakis
7	hepta	heptakis

Examples ; $[CoCl_2(NH_2CH_2CH_2NH_2)_2]^+$, dichloridobis(ethane-1,2-diamine)cobalt(III). [NiCl_2(PPh_3)_2], dichloridobis(triphenylphosphine)nickel(II).

Oxidation state of the metal in cation, anion or neutral coordination entity is indicated by Roman numeral in the parentheses after the name of metal.

If the complex ion is a cation, the metal is named same as the element. For example, Co in a complex cation is called cobalt and Pt is called platinum. If the complex ion is an anion, the name of the metal ends with the suffix - ate. For example, Co in a complex anion, $[Co(SCN)_4]^{2-}$ is called cobaltate. For some metals, the Latin names are used in the complex anions.

iron (Fe)	ferrate	lead (Pb)	plumbate
silver (Ag)	argentate	tin (Sn)	stannate
aold (Au)	aurate		

Examples ; [Co(NH₃)₄Cl₂]⁺, pentaamminechloridocobalt(III).

 $(NH_4)_2$ [Co(SCN)₄], ammonium tetrathiocyanato-S-cobaltate(II).

The neutral complex molecule is named similar to that of the complex cation. **Example**; $[CrCl_3(py)_3]$, trichloridotris(pyridine)chromium(III).

BONDING IN COORDINATION COMPOUNDS :

Werner's Theory :

Alfred Werner (considered as the father of coordination chemistry) studied the structure of coordination complexes such as $CoCl_3$. $6NH_3$ and $CuSO_4$. $4NH_3$ in 1893. According to him-

- (a) Each metal in coordination compound possesses two types of valencies :
 - (i) primary valency or principal valencies or ionisable valencies.
 - (ii) Secondary valency or nonionisable valencies
- (b) Primary valencies are satisfied by anions only. The number of primary valencies depends upon the oxidation state of the central metal. It may change from one compound to other. These are represented by dotted lines between central metal atom and anion.
- (c) Secondary valencies are satisfied only by electron pair donor, the ions or the neutral species. These are represented by thick lines.
- (d) Each metal has a fixed number of secondary valencies also referred as coordination number. The coordination number depends mainly on the size and the charge on the central atom. The maximum number of ions or molecules that the central atom can hold by secondary valencies is known as coordination number.
- (e) The ions attached to primary valencies possess ionising nature whereas the ions attached to secondary valencies do not ionise when the complex is dissolved in a solvent.
- (f) Every central ion tends to satisfy its primary as well as secondary valencies.
- (g) The secondary valencies are directional and are directed in space about the central metal ion. The primary valencies are non-directional. The presence of secondary valencies gives rise to stereoisomerism in complexes.





Effective Atomic Number Rule given by Sidgwick :

It can be defined as the resultant number of electrons with the metal atom or ion after gaining electrons from the donor atoms of the ligands.

Effective Atomic Number (EAN) = No. of electron present on the metal atom/ion + No. of electrons donated by ligands to it.

OR

Effective Atomic Number (EAN) = Atomic no. of central metal – Oxidation state of central metal + No. of electrons donated by ligands.

The complexes in which the EAN of the central atom equals the atomic number of the next noble gas, are found to be extra stable.

Valence bond theory :

The salient features of the theory are summarised below.

(a) The central metal ion has a number of empty orbitals for accommodating electrons donated by the ligands. The number of empty orbitals is equal to the coordination number of the metal ion for the particular complex.

(b) The atomic orbitals (s, p or d) of the metal ion hybridize to form hybrid orbitals with definite directional properties. These hybrid orbitals now overlap with the ligand orbitals to form strong chemical bonds.

(c) The d-orbitals involved in the hybridization may be either inner (n - 1) d orbitals or outer n d-orbitals. The complexes formed in these two ways are referred to as low spin and high spin complexes, respectively. (d) Each ligand contains a lone pair of electrons.

(e) A covalent bond is formed by the overlap of a vacant hybridized metal orbital and a filled orbital of the ligand. The bond is also sometimes called as a coordinate bond.

(f) If the complex contains unpaired electrons, it is paramagnetic in nature, while if it does not contain unpaired electrons, it is diamagnetic in nature.

Co-ordination numbers, Hybridised orbitals and geometry of some co-ordination compounds

Coordination Number	Hybridised orbital	Geometrical shape of the complex	Examples of complex
2	sp	L <u>180°</u> L	[Ag(NH ₃) ₂] ⁺
		Linear	[Ag(CN) ₂]
3	sp ²	L Trigonal Planar	[HgI ₃]
4.	sp ³ dsp ²	Tetrahedral	$[FeCl_4]^-$ $[Ni(CO)_4]^0$ $Zn(NH_3)_4^{+2}$ $[ZnCl_4]^{-2}, [CuX_4]^{-2}$ where X = CN ⁻ Cl ⁻ , Br ⁻ , I ⁻ , CNS





COORDINATION COMPOUNDS



Crystal Field Theory :

The drawbacks of VBT of coordination compounds are, to a considerable extent, removed by the Crystal Field Theory.

The crystal field theory (CFT) is an electrostatic model which considers the metal-ligand bond to be ionic arising purely from electrostatic interaction between the metal ion and the ligand. Ligands are treated as point charges in case of anions or dipoles in case of neutral molecules. The five d orbitals is an isolated gaseous metal atom/ion have same energy, i.e., they are degenerate. This degeneracy is maintained if a spherically symmetrical field of negative charges surrounds the metal atom/ion. However, when this negative field is due to ligands (either anions or the negative ends of dipolar molecules like NH_3 and H_2O) in a complex, it becomes asymmetrical and the degeneracy of the d orbitals is lost. It results in splitting of the d orbitals. The pattern of spitting depends upon the nature of the crystals field.







Crystal field splitting in octahedral coordination entities :



Figure showing crystal field splitting in octahedral complex.

In general, ligands can be arranged in a series in the orders of increasing field strength as given below: $I^- < Br^- < SCN^- < CI^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < edta^{4-} < NH_3 < en < NO_2^- < CN^- < CO$

The two possibilites are :

(i) If $\Delta_0 < P$, the fourth electron enters one of the e_g orbitals giving the configuration $t_{2g}^3 e_g^1$. Ligands for which $\Delta_0 < P$ are known as weak field ligands and form high spin complexes.

(ii) If $\Delta_0 > P$, it becomes more energetically favourable for the fourth electron to occupy a t_{2g} orbital with configuration $t_{2g}^4 e_g^0$. Ligands which produce this effect are known as strong field ligands and form low spin complexes.

Crystal field splitting in tetrahedral coordination entities :



Figure showing crystal field splitting in tetrahedral complex.







Crystal field splitting in square planar coordination entities :



 $\Delta_{sp} = 1.3 \Delta_{o}$.

COLOUR IN COORDINATION COMPOUNDS :

Relationship between the wavelength of light absorbed and the colour observed In some coordination entitles Table

Coordination entity	Wavelength of light absorbed (nm)	Colour of light absorbed	Colour of coordination entity
[CoCl(HN ₃) ₅] ²⁺	535	Yellow	Violet
[Co(NH ₃) ₅ (H ₂ O)] ³⁺	500	Blue Green	Red
[Co(NH ₃) ₆] ³⁺	475	Blue	Yellow Orange
[Co(CN) ₆] ³⁻	310	Ultraviolet	Pale Yellow
[Cu(H ₂ O) ₄] ²⁺	600	Red	Blue
[Ti(H ₂ O) ₆] ³⁺	498	Yellow Green	Purple

ISOMERISM:

STRUCTURAL ISOMERISM :

(A) Ionisation isomerism :

This type of isomerism occurs when the counter ion in a coordination compound is itself a potential ligand and can displace a ligand which can then become the counter ion. For example, following complexes show ionisation isomerism.

$$\begin{split} & [Co(NH_3)_5SO_4]NO_3 \quad \text{and} \quad & [Co(NH_3)_5NO_3]SO_4 \\ & [Co(NH_3)_4(NO_2)CI]CI \quad \text{and} \quad & [Co(NH_3)_4Cl_2]NO_2. \\ & [Co(NH_3)_4(H_2O)CI]Br_2 \quad \text{and} \quad & [Co(NH_3)_4BrCI]Br.H_2O. \quad & [Also \ \text{an example of hydrate isomers.}] \\ & [Pt(NH_3)_4Cl_2]Br_2, \quad \text{and} \quad & [Pt(NH_3)_4Br_2]Cl_2. \\ & [CoCl(en)_2(NO_2)]SCN, \quad & [Co(en)_2(NO_2)SCN]CI \quad \text{and} \quad & [Co(en)_2(SCN)CI]NO_2 \end{split}$$





(B) Solvate / hydrate isomerism :

It occurs when water forms a part of the coordination entity or is outside it. This is similar to ionisation isomerism. Solvate isomers differ by whether or not a solvent molecule is directly bonded to the metal ion or merely present as free solvent molecules in the crystal lattice. For example, $CrCl_3 \cdot 6H_2O$ exists in three distinct isomeric forms : $[Cr(H_2O)_6]Cl_3$, violet ; $[CrCl(H_2O)_5]Cl_2 \cdot H_2O$, blue green : $[CrCl_2(H_2O)_4]Cl.2H_2O$, dark green. These three cationic isomers can be separated by cation ion exchange from commercial $CrCl_3 \cdot 6H_2O$. A fourth isomer $[Cr(H_2O)_3Cl_3]$, yellow green also occurs at high concentration of HCl. Apart from their distinctive colours, the three isomers can be identified by the addition of excess of aqueous silver nitrate to their aqueous solutions, which precipitates chloride in the molar ratio of 3 : 2 : 1 respectively.

Reaction with conc. H_2SO_4 (dehydrating agent) No water molecule is lost or no reaction one mole of water is lost per mole of complex two mole of water are lost per mole of complex

Other examples are :

 $\begin{array}{ll} [\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{CI}]\text{CI}_2 & \text{and} & [\text{Co}(\text{NH}_3)_4\text{CI}_2]\text{CI}.\text{H}_2\text{O} \\ [\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})](\text{NO}_3)_3 & \text{and} & [\text{Co}(\text{NH}_3)_5(\text{NO}_3)](\text{NO}_3)_2.\text{H}_2\text{O}. \end{array}$

(C) Linkage isomerism :

In some ligands, like ambidentate ligands, there are two possible coordination sites. In such cases, linkage isomerism exist. e.g., NO_2 group can be bonded to metal ions through nitrogen ($-NO_2$) or through oxygen (-ONO). SCN too can be bonded through sulphur (-SCN) thiocyanate or through nitrogen (-NCS) isothiocyanate.

For example : $[Co(ONO)(NH_3)_5] Cl_2 \& [Co(NO_2) (NH_3)_5] Cl_2$.

(D) Coordination isomerism :

Coordination compounds made up of cationic and anionic coordination entities show this type of isomerism due to the interchange of ligands between the cation and anion entities. Some of the examples are :

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

(ii) $[Cu(NH_3)_4][PtCI_4]$ and $[Pt(NH_3)_4][CuCI_4]$

(iii) $[Co(NH_3)_6][Cr(SCN)_6]$ and $[Cr(NH_3)_4(SCN)_2][Co(NH_3)_2(SCN)_4]$

(iv) $[Pt(NH_3)_4][PtCl_6]$ and $[Pt(NH_3)_4Cl_2][PtCl_4]$

Such isomers are expected to have significant differences in their physical and chemical properties.

(E) Ligand isomerism :

Since many ligands are organic compounds which have possibilities for isomerism, the resulting complexes can show isomerism from this source.

For example ; ligands 1,2-diaminopropane(propylenediamine or **pn)** and

1,3-diaminopropane(trimethylenediamine or **tn**) are such pairs. Similarly ortho-, meta- and para-toluidine $(CH_3C_6H_4NH_2)$.

(F) Polymerisation isomerism :

Considered to be a special case of coordination isomerism, in this the various isomers differ in formula weight from one another, so not true isomers in real sense. For example $[Co(NH_3)_4(NO_2)_2][Co(NH_3)_2(NO_2)_4]$, $[Co(NH_3)_6][Co(NO_2)_6]$, $[Co(NH_3)_5(NO_2)][Co(NH_3)_2(NO_2)_4]_2$, $[Co(NH_3)_6][Co(NH_3)_2(NO_2)_4]_3$, $[Co(NH_3)_4(NO_2)_2]_3[Co(NO_2)_6]$ and $[Co(NH_3)_5(NO_2)_2]_3[Co(NO_2)_6]_2$. These all have the empirical formula $Co(NH_3)_3(NO_2)_3$, but they have formula weights that are 2,2,3,4,4 and 5 times this, respectively.





Stereoisomerism

Geometrical Isomerism

This type of isomerism arises in heteroleptic complexes due to different possible geometric arrangements of the ligands. Geometrical isomerism is common among coordination compounds with coordination numbers 4 and 6.

Coordination Number Four :

Tetrahedral Complex :

The tetrahedral compounds can not show geometrical isomerism as we all know that all four positions are equivalent in tetrahedral geometry.

Square Planar Complex :

In a square planar complex of formula [Ma₂b₂] [a and b are unidentate], the two ligands 'a' may be arranged adjacent to each other in a cis isomer, or opposite to each other in a trans isomer as depicted.



Coordination Number Six :

Geometrical isomerism is also possible in octahedral complexes.



Optical Isomerism :

A coordination compound which can rotate the plane of polarised light is said to be optically active. When the coordination compounds have same formula but differ in their ability to rotate directions of the plane of polarised light are said to exhibit optical isomerism and the molecules are optical isomers. Optical isomers are mirror images that cannot be superimposed on one another. These are called as enantiomers.

Octahedral complex :

Optical isomerism is common in octahedral complexes involving didentate ligands. For example, $[Co(en)_3]^{3+}$ has d and ℓ forms as given below.



d and ℓ of $[Co(en)_3]^{3+}$

Cis-isomer of $[PtCl_2(en)_2]^{2+}$ show optical isomerism as shown below because of the absence of plane of symmetry as well as centre of symmetry.









d and ℓ of cis-[PtCl₂(en)₂]²⁺

But trans isomer of $[PtCl_2(en_2)]^{2+}$ does not show optical isomerism.



Tetrahedral complex :

Optical isomerism is expected in tetrahedral complexes of the type [Mabcd] analogous to tetrahedral carbon atom.

Organometallic compounds :

Bonding in Metal Carbonyls

The metal–carbon bond in metal carbonyls possess both s and p character. The M—C σ bond is formed by the donation of lone pair of electrons on the carbonyl carbon (CO is a weak base) into a vacant orbital of the metal. The M — C π bond is formed by the donation of a pair of electrons from a filled d orbital of metal into the vacant antibonding π^* orbital of carbon monoxide. Thus carbon monoxide acts as σ donor (OC \rightarrow M) and a π acceptor (OC \leftarrow M), with the two interactions creating a synergic effect which strengthens the bond between CO and the metal as shown in figure.



Synergic bonding

(i) As M — C π bonding increases, the C — O bond becomes weaken. The greater the positive charge on the central metal atom, the less readily the metal can donate electron density into the π^* orbitals of the carbon monoxide ligands to weaken the C — O bond.

(ii) In contrast, in the anionic complex (i.e. carbonylate anion) the metal has a greater electron density to be dispersed, with the result that $M - C \pi$ bonding is enhanced and the C - O bond is diminished in strength. For example ; in isoelectronic complexes the strength of metal-ligand bond increases and strength of C - O bond in CO decreases (because bond order decreases) as the negative charge on the complexes increases.

Thus order of CO bond strengths ; (a) $[M(CO)_6]^+ > [Cr(CO)_6] > [V(CO)_6]^- > [Ti(CO)_6]^{2-}$. (b) $[Ni(CO)_4] > [Co(CO)_4]^- > [Fe(CO)_4]^{2-}$.





Exercise # 1

PART - I : OBJECTIVE QUESTIONS

* Mark	ed Que	estions a	re hav	ing mo	re than	one cor	rect op	otion.					
SECT	ION (/	A) : INTI	RODU	CTION	OF CO	DORDIN	ATION		POUND	S			
A-1.	Some s (A) cor	salts althou nplex salt	ugh con	taining tv (B) dou	vo differe Ible salt	ent metalli	ic eleme (C) nor	ents give mal salt	test for o	ne of ther (D) non	n in solu e	tion. Such	salts are :
A-2.	All liga (A) Lev	nds are : wis acids		(B) Lev	vis base	S	(C) neu	utral		(D) non	e		
A-3.	Diethyl (A) che (C) tride	lenetriami elating age entatemor	ne is : ent noanion				(B) trid (D) (A)	entate no and (B)	eutral mo both	olecule			
A-4.	In brov (A) + 2	vn ring co 2	mplex	compon (B) + 3	d [Fe(H	₂ O) ₅ NO]S	60 ₄ , the (C) + 4	e oxidatio	on state	of Fe is : (D) + 1			
A-5.	In the c (A) 6 a	complex [(nd +3	CoCl ₂ (e	n) ₂]Br, tł (B) 3 a	ne co-or nd +3	dination n	umber (C) 4 a	and oxid nd +2	ation sta	te of cob (D) 6 ar	alt are : nd +1		
A-6.	What is (A) +3	s the charç	ge on th	e compl (B) +1	ex [Cr(C	² ₂ O ₄) ₂ (H ₂ O	O) ₂] forr (C) + 2	ned by C	r(III)?	(D) –1			
A-7.	Which (1) Ace	of the follo	owing a ato	re biden (2) Oxa	tate mor alato ion	noanion li	gands ? (3) Dim	nethylgly	oximato				
	Select (A) 1 o	the correc	ct answ	er using (B) 1 a	the code nd 3 onl	es given b y	celow : (C) 3 o	nly		(D) 2 aı	nd 3 onl	у	
A-8.	Match	the followi	ng				Calum	т. П					
	Colum	IU-T					Loium H,C、	ип-ш и ^N					
	(a) en					(p)		°, `0					
							H ₃ C	N N					
	(b) dm	g				(q)		✓ NH₂					
	(c) ED	TA				(r)	H ₂ N						
	(d) gly							1.1.12	÷ċ.	_			
	(e) ox					(s)	; <u>0</u>	<u> </u>	c o				
						(t)	:ŌОСН ₂ :ŌОСН ₂	C N-CH	₂ CH ₂ N :	-CH₂COŌ: -CH₂COŌ	:		
	(•)	(a)	(b)	(c)	(d)	(e)	(5)	(a)	(b)	(c)	(d)	(e)	
	(A) (C)	r p	p s	t q	q r	s t	(B) (D)	r S	р q	t t	q p	s r	
								4.1					



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A-9. The donor sites of (EDTA)⁴⁻ are ? (A) O atoms only (B) N atoms only (C) Two N atoms and four O atoms (D) Three N atoms and three O atoms SECTION (B) : IUPAC NOMENCLATURE OF COORDINATION COMPOUNDS B-1. The IUPAC name of [CoCI(NO₂)(en)₂] Cl is -(A) Chloridonitrito-O-bis(ethylene diammine)cobalt (III) chloride (B) Chloridonitrito-N-bis(ethylene diammine)cobalt (II) chloride (C) Chloridobis(ethane-1,2-diamine)nitrito-N-cobalt(III) chloride (D) Bis(ethylene diammine) chloridonitrito-N-cobalt(III) chloride B-2. IUPAC name of [Pt(NH₃)₃(Br)(NO₂)CI]Cl is -(A) Triamminechloridobromonitrito-N-platinum (IV) chloride (B) Triamminebromonitrito-N-chloridoplatinum (IV) chloride (C) Triamminebromidochloridonitrito-N-platinum(IV) chloride (D) Triamminenitrito-N-chloridobromidoplatinum (IV) chloride B-3. The IUPAC name for $[Co(NCS)(NH_3)_5]Cl_2$ is – (A) Pentaamminethiocyanato-N-cobalt(III) chloride (B) Pentaamminethiocyanato-S-cobalt(III) chloride (C) Pentaamineisothiocvanato-N.S-cobalt(III) chloride (D) Pentaammine (mercapto-N) cobalt(III) chloride The correct IUPAC name of the complex $Fe(C_5H_5)_2$ is – B-4. (A) Cyclopentadienyliron(II) (B) Bis(cyclopentadienyl)iron(II) (C) Dicyclopentadienylferrate(II) (D) Ferrocene B-5. The formula of the complex tris(ethane-1,2- diamine)cobalt(III) sulphate is -(A) $[Co(en)_2SO_4]$ (B) $[Co(en)_3SO_4]$ $(C) [Co(en)_3]SO_4$ (D) $[Co(en)_3]_2(SO_4)_3$ B-6. The IUPAC name of Fe(CO)₅ is -(A) Pentacarbonylferrate (0) (B) Pentacarbonylferrate(III) (D) Pentacarbonyliron(II) (C) Pentacarbonyliron (0) B-7. K₃[Fe(CN)₆] is -(a) Potassium hexacynoferrous(III) (b) Potassium hexacynoferrate(III) (c) Potassium ferricyanide (d) Hexacyano ferrate(III) potassium Correct answer is -(B) Only (b) and (c) (C) Only (a) and (c) (D) Only (b) and (d) (A) Only (a) and (b) B-8. The IUPAC name of the complex $[CrCl_2(H_2O)_4]NO_3$ is – (A) Dichloridotetraaquachromium(III) nitrate (B) Tetraaquadichloridochromium(III) nitrate (C) Chromiumtetraaquadichloridonitrate (D) Dichloridotetraaguachromium(II) nitrate B-9. The chloro-bis (ethylenediamine) nitro cobalt(III) ion is -(A) $[Co(NO_2)_2(en)_2Cl_2]^+$ (B) $[CoCl(NO_2)_2(en)_2]^+$ (C) $[Co(NO_2)Cl(en)_2]^+$ (D) $[Co(en)Cl_2(NO_2)_2]^-$ A complex anion is formed by Osmium (in some oxidation state) with ligands (in proper number so that coordination B-10. number of osmium becomes six). Which of the following can be its correct IUPAC name?

- (A) pentachloridonitridoosmium(VI) (C) azidopentachloridoosmate(VI)
- (B) pentachloridonitridoosmate(VI)
- (D) None of these







COORDINATION COMPOUNDS

- Complex ion [$FeN_2(O_2)(SCN)_4$]⁴⁻ is named as : (coordination number of central metal ion in complex is six) B-11. (A) azidosuperoxidotetrathiocyanato-S-ferrate(II) (B) azidodioxygentetrathiocyanatoferrate(III) (C) azidoperoxidotetrathiocyanato-S-ferrate(II) (D) azidodioxidotetrathiocyanato-S-ferrate(III)

, [BF₄]³⁺ , [BF₄]²-

B-12. Trioxalatoaluminate(III) and tetrafluoro-borate(III) ions are:

(A) [Al(C ₂ O ₄) ₃] , [BF ₄] ^{3–}	(B) [Al(C ₂ O ₄) ₃] ³⁺
(C) [Al(C ₂ O ₄) ₃] ^{3–} , [BF ₄] [–]	(D) [Al(C ₂ O ₄) ₃] ²⁻

- B-13. The correct IUPAC name for the compound [Co(NH₂), CI(ONO)]Cl is :
 - (A) Tetraamminechloridonitrito-N-cobalt(III)chloride
 - (B) Chloridonitrito-O-tetraamminecobalt(II) chloride
 - (C) Dichloridonitrito-O-tetraamminecobalt(III)
 - (D) Tetraamminechloridonitrito-O-cobalt(III) chloride
- B-14. A complex cation is formed by Pt (in some oxidation state) with ligands (in proper number so that coordination number of Pt becomes six). Which of the following can be its correct IUPAC name :
 - (A) Diammineethylenediaminedithiocyanato-S-platinum (II) ion
 - (B) Diammineethylenediaminedithiocyanato-S-platinate (IV) ion
 - (C) Diammineethylenediaminedithiocyanato-S-platinum (IV) ion
 - (D) Diamminebis (ethylenediamine) dithiocyanate-S- platinum (IV) ion

SECTION (C) : WARNER'S COORDINATION THEORY AND EXPERIMENTAL METHODS TO DETERMINE STRUCTURE OF COORDINATION COMPOUNDS

- C-1. When AgNO₃ is added to a solution of Co(NH₃)₅Cl₃, the precipitate of AgCl shows two ionisable chloride ions. This means that-
 - (A) two chlorine atom satisfy primary valency and one secondary valency.
 - (B) one chlorine atom satisfies primary as well as secondary valency.
 - (C) three chlorine atoms satisfy primary valency.
 - (D) three chlorine atoms satisfy secondary valency.
- C-2. A co-ordination complex of cobalt has molecular formula 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. In reacting this solution with excess of silver nitrate solution, two moles of AqCI get precipitated. The ionic formula of this complex would be -

(A) [(Co(NH ₃) ₄ .NO ₂ Cl].[(NH ₃)Cl]	(B) [(Co(NH ₃) ₅ Cl].[Cl(NO ₂)]
(C) $[(Co(NH_3)_5(NO_2)]Cl_2$	(D) [(Co(NH ₃) ₅].[(NO ₂) ₂ Cl ₂]

C-3. Which of the following complex will give white precipitate with barium chloride solution ? (A) $[Cr(NH_3)_5CI]SO_4$ (B) $[Cr(NH_3)SO_4]Cl$ $(C) [Co(NH_3)_6]Br_3$ (D) None of these

C-4. Give the correct increasing order of electrical conductivity of aqueous solutions of following complex entities. II. $[Cr(NH_3)_6]Cl_3$ I. [Pt(NH₃)₆]Cl₄ III. $[Co(NH_3)_4Cl_2]Cl$ IV. K₂[PtCl₆] (A) ||| < |V < || < | (B) IV < II < III < I (C) || < | < |V < |||(D) | < || < |V < |||

- C-5. When potassium hexachloroplatinate (II) is dissolved in water. The solution -
 - (A) contains 6 ions per molecule
- (B) reacts with AgNO₃ to give 6 moles of AgCI
- (C) does not contain any CI⁻ ion
- (D) contains K⁺, Pt⁴⁺ and Cl⁻ ions





C-6.	Consider the following s According the Werner's (1) ligands are connected (2) secondary valencies (3) secondary valencies	tatements. theory, ed to the metal ions by io have directional propertie are non-ionisable.	nic bonds. es.			
	(A) 1, 2 and 3 are correct (C) 1 and 3 are correct	ct	(B) 2 and 3 are correct (D) 1 and 2 are correct			
C-7.	A compound is made by solution of the compound is made. The compound six electrical charges. T	mixing cobalt(III) nitrite a d showed 4 particles per he formula of the compo	nd potassium nitrite soluti molecule whereas molar und is :	ions in the ratio of $1:3$. The aqueous conductivity reveals the presence of		
	(A) $CO(NO_2)_3$. 2KNO ₂	(B) $CO(NO_2)_3$. $3KNO_2$	$(C) K_3 [CO(NO_2)_6]$	(D) $K[CO(NO_2)_4]$		
C-8.	Which of the following w (A) K_4 [Fe(CN ₆]	vill exhibit maximum ionic (B) [Co(NH ₃) ₆] Cl ₃	conductivity? (C) [Cu(NH ₃) ₄] Cl ₂	(D) [Ni (CO) ₄]		
C-9.	A co-ordination complex of three ion in one formu number of Pt in this con	has the formula PtCl ₄ .2KC la unit. Treatment with Ag pplex ?	Cl. Electrical conductance NO ₃ produces no precipita	measurements indicate the presence ate of AgCI. What is the co-ordination		
	(A) 5	(B) 6	(C) 4	(D) 3		
• • •						
C-10.	(A) Br ⁻	Br ₂ ICI gives the test for : (B) CI ⁻	(C) Cr ³⁺	(D) Br [_] and Cl [_] both		
C-11.	How many moles of Ag AgNO ₂ ?	CI would be obtained, w	when 100 ml of 0.1 M Co	$(NH_3)_5Cl_3$ is treated with excess of		
	(Ă) 0.01	(B) 0.02	(C) 0.03	(D) none of these		
C-12.	Concentrated H_2SO_4 wi (A) [Cr(H_2O) ₅ Cl]Cl ₂ . H_2O (C) [Cr(H_2O) ₆]Cl ₃	ll not dehydrate the follow	wing complex : (B) [Cr(H ₂ O) ₄ Cl ₂]Cl.2H ₂ O (D) all of these			
C-13.	On adding AgNO ₃ soluti (A) 100	on to a solution of [Pt(NH (B) 75	I_3 , CI_3]CI, the percentage (C) 50	e of total chloride ion precipitated is: (D) 25		
C-14.	CoCl ₃ .4H ₂ O is an anhyo	frous binary solute hence	e its Werner's representat	tion is :		
	$(A) \begin{array}{c} CI OH_2 \\ \downarrow \\ H_2O CI OH_2 \\ H_2O CI OH_2 \end{array}$	$(B) \begin{array}{c} CI & OH_2 \\ \downarrow \\ H_2O \end{array} \begin{array}{c} CI = C_0 - OH_2 \\ H_2O \end{array} \begin{array}{c} CI & OH_2 \end{array}$	$\begin{array}{c} CI & OH_2 \\ (C) & H_2O & C_0 & OH_2 \\ CI & OH_2 & CI \end{array}$	(D) none		

SECTION (D) : VALENCE BOND THEORY

- **D-1.** Which of the following statements is correct for complex $[Cr(NH_3)(CN)_4(NO)]^2$ (given that n = 1)? (A) It is d²sp³ hybridised.
 - (B) The chromium is in + 1 oxidation state.
 - (C) It is heteroleptic complex and its aqueous solution is coloured.
 - (D) All of these.







1					
D-2.	Match the geometry g Column (A)	ven in column A with the	comple Col	x given in colum umn (B)	n B using the codes given below :
	i) Tetrahedral		(a)	[Cu(NH_)] ²⁺	
	ii) Octahedral		(b)	[Ag(NH ³)] ⁺	
	iii) Square planar		(\mathbf{c})	$F_{0}(CO)$	
		midal	(d)	$1 = (00)_5$	
	iv) Thgonarbipyra	IIIIuai	(u)	$[\bigcup_{1}(\square_2\bigcup)_6]^{\circ}$	
	v) Linear		(e)	[NICI ₄] ²⁻	
	(A) (i)-(e), (ii)-(d), (iii)-(a), (iv)-(c) ,(v)-(b)		(B) (i)-(d), (ii)-(€	e), (iii)-(a), (iv)-(c) ,(v)-(b)
	(C) (i)-(d), (ii)-(e), ((iii)-(b), (iv)-(a) ,(v)-(c)		(D) (i)-(c), (ii)-(e), (iii)-(b), (iv)-(a) ,(v)-(d)
D-3.	Match the following us	ing the codes given belo	w:		
	1. Double salt	6 6	(a)	[Co(NH) CI1	
	2 Zeise's salt		(h)	Hexadentate	
	2 Noutral malao	ulo.	(\mathbf{O})	hidantata	
		lie	(C) (-1)		
	4. EDIA		(a)	Paramagnetic	
	5. $NI(CO)_4$		(e)	$FeSO_4.(NH_4)SC$	0 ₄ .6H ₂ O
	6. $[Cr(NH_3)_6]^{3+}$		(f)	K ₄ Fe(CN) ₆	
	7. Low spin com	blex	(g)	Diamagnetic	
	8. Glycine		(h)	An organometa	allic compound
	(A) $(1-e)$; $(2-h)$; $(3-a)$	(4-b); (5-a); (6-d); (7-f); (<u>8</u> –c).	U	•
	(B) $(1-b)$; $(2-e)$; $(3-a)$	(4-b); (5-a); (6-d); (7-f)	(8-c)		
	(C) (1 h); (2 c); (3 c)	(4 - b); (5 - g); (0 - a); (7 - a)	(0-0).		
	(C)(1-n),(2-e),(3-a)	(4-b), (5-d), (6-g), (7-d)	(0-1).		
	(D) (1–h); (2–a); (3–e)	; (4–b); (5–d); (6–g); (7–f); (8–c)		
SECT	ION (E) : CRYSTAL	FIELD THEORY AN	ID ITS	APPLICATIC	NS
E-1.	The number of unpaire	d electrons in d ⁶ , low spin,	octahed	Iral complex is :	
	(A) 4	(B) 2	(C) 1		(D) 0
		· · ·	()		< <i>'</i> ,
E-2 .	Low spin complex is fo	rmed by ·			
	(A) sn^3d^2 hybridization	(B) sp ³ d hybridization	$(C) d^2 s$	o ³ hybridization	(D) sn^3 hybridization
			(0) 0 0	o hybriaization	
E 2	The number of uppeire	d alastrona propont in con	anlov ion	[EoE 13- io :	
⊑-э.		d electrons present in con		[rer ₆]° is .	
	(A) 5	(B) 4	(C)6		(D) 0
E-4.	The crystal field splitting	energy for octahedral cor	nplex (Δ_{c}) and that for tetra	ahedral complex (Δ_t) are related as:
	4				9
	(A) $\Delta_t = \frac{1}{2} \Delta_0$	(B) $\Delta_t = 0.5 \Delta_o$	(C) $\Delta_t =$: 0.33 Δ _o	(D) $\Delta_t = \frac{1}{4} \Delta_0$
	9				4
E-5.	The complex [Pt(NH ₃) ₄ ,	²⁺ has structure :			
	(A) square planar	(B) tetrahedral	(C) pyra	amidal	(D) pentagonal
E-6	What is the shape of E	(CO) molecule 2 Given	that its di	inala moment - (
∟-0.					
	(A) Tetrahedral	(B) Octahedral	(C) Trig	onal bipyramidal	(D) Square pyramidal
E-7.	Which of the following i	s a high spin complex ?			
	(A) [Co(NH _a) _a] ³⁺	(B) [Fe(CN)_14-	(C) [Ni(CN).12-	(D) [FeF_] ³⁻
	(, L = - (3)61	() [(/6]	(-/[···(- /41	() r P1
_					
E-8.	Which has maximum p	aramagnetic nature ?			
	(A) [Cu(H ₂ O) ₄] ²⁺	(B) [Cu(NH ₃) ₄] ²⁺	(C) [Mn	(H ₂ O) ₆] ²⁺	(D) [Fe(CN) ₆] ⁴⁻
	- · ∠ / T			∠ · ∪ -	
E-9.	Which of the following of	complexes has a deometr	v differen	t from others?	
_ 0.	(Δ) [Ni CI 12–	(B) Ni (CO)		CN) 12–	(D) $[7n(NH)]^{12+}$
	(1) $[1]$ $[1]$ $[1]$	(\mathbf{D}) $(\mathbf{U}, \mathbf{U})_4$		U141	(¹) [-1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,





- **E-10.** Select the correct statement.
 - (A) Complex ion $[MoCl_6]^{3-}$ is paramagnetic. (C) Both (A) and (B) are correct.
- (B) Complex ion $[Co(en)_3]^{3+}$ is diamagnetic.

(D) [Fe(Cl)₆]³⁻

(D) None of these is correct.

(C) $[Fe(C_2O_4)_3]^{3-}$

- **E-11.** Amongst Ni(CO)₄, $[Ni(CN)_4]^{2-}$ and NiCl₄²⁻:
 - (A) Ni(CO)₄ and NiCl₄²⁻ are diamagnetic and [Ni(CN)₄]²⁻ is paramagnetic. (B) NiCl₄²⁻ 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 NiCl₄²⁻ is paramagnetic.
 - (D) $Ni(CO)_4$ is diamagnetic and, $NiCI_4^{2-}$ and $[Ni(CN)_4]^{2-}$ are paramagnetic.

SECTION : (F) STABILITY IN COORDINATION COMPOUNDS

- **F-1.** In complexes more stability is shown by : (A) $[Fe(H_2O)_6]^{3+}$ (B) $[Fe(CN)_6]^{3-}$
- F-2. From the stability constant (hypothetical values), given below, predict which is the most stable complex ?
 - $\begin{array}{ll} \text{(A) } \text{Cu}^{2+} + 4\text{NH}_3 & \longrightarrow [\text{Cu}(\text{NH}_3)_4]^{2+} , & \text{K} = 4.5 \times 10^{11} \\ \text{(B) } \text{Cu}^{2+} 4\text{CN}^- & \longrightarrow [\text{Cu}(\text{CN})_4]^{2-} , & \text{K} = 2.0 \times 10^{27} \\ \text{(C) } \text{Cu}^{2+} + 2\text{en} & \longrightarrow [\text{Cu}(\text{en})_2]^{2+} , & \text{K} = 3.0 \times 10^{15} \\ \end{array}$
 - (D) $Cu^{2+} + 4H_2O \longrightarrow [Cu(H_2O)_4]^{2+}, \quad K = 9.5 \times 10^8$
- F-3. Which of the following statements is incorrect ?
 - (A) The stability constant of $[Co(NH_3)_6]^{3+}$ is greater than that of $[Co(NH_3)_6]^{2+}$.
 - (B) Among F^- , CI^- , Br^- and I^- , F^- forms strongest complexes due to small size.
 - (C) $[Cu(NH_3)_4]^{2+}$ is thermodynamically more stable than $[Zn(NH_3)_4]^{2+}$.
 - (D) Among $[Fe(CN)_6]^{3-}$, $[Fe(H_2O)_6]^{2+}$ and $[Fe(en)_3]^{3+}$, $[Fe(CN)_6]^{3-}$ is most stable.

SECTION : (G) : ISOMERISM IN COORDINATION COMPOUNDS

- $\begin{array}{lll} \textbf{G-1.} & \mbox{Which of the following is pair of ionization isomers ?} \\ (A) [Co(NH_3)_5Br]SO_4 \mbox{ and } [Co(NH_3)_5SO_4]Br \\ (B) [Cr(H_2O)_5CI]CI_2.H_2O \mbox{ and } [Cr(H_2O)_4.CI_2]CI.2H_2O \\ (C)[Co(NH_3)_6]Cr(CN)_6 \mbox{ and } [Cr(NH_3)_6][Co(CN)_6] \\ (D) \mbox{ cis-}[Pt(NH_3)_2CI_2] \mbox{ and } ran-[Pt(NH_3)_2CI_2] \end{array}$
- **G-2.** In coordination compounds, the hydrate isomers differ :
 - (A) In the number of water molecules of hydration only.
 - (B) In the number of water molecules only present as ligands.
 - (C) Both (A) and (B).
 - (D) In their coordination number of the metal atom.
- G-4. cis-trans-isomerism is found in square planar complexes of the molecular formula (a and b are monodentate ligands) –
 (A) Mo (B) Ma_b (C) Ma_b (D) Mab_3

	(A) Ma ₄	(B) Ma ₃ b	$(C) Ma_2b_2$	(D) Mat
G-5.	Which would exhibit co	o-ordination isomerism?		
	(A) [Cr(NH ₃) ₆][Co (CN) ₆]	(B) [Co(en) ₂ Cl ₂] ⁺	
	(C) [Cr(NH ₃) ₆][Cl ₃		(D) [Cr(en) ₂ Cl ₂] ⁺	







- G-6. [Co(NH₃)₅Br] SO₄ and [Co(NH₃)₅SO₄] Br are..... isomers. (C) Ionization (A) Linkage (B) Geometrical
- G-7. Which of the following is not optically active ? (A) $[Co(en)_3]^{3+}$ (B) $[Cr(ox)_3]^{3-1}$
- G-8. A complex shown below :
 - (A) exhibits optical isomerism only
 - (B) exhibits geometrical isomerism only
 - (C) exhibits both optical and geometrical isomerism (D) none



(C) cis- $[CoCl_2(en)_2]^+$

- (D) trans-[CoCl₂(en)₂]⁺

(D) Optical

G-9. The phenomenon of optical activity will be shown by?



G-10. A square planar complex represented as it will show which isomerism ?



- (A) Geometrical isomerism
- (C) Linkage isomerism



The complexes given below are : G-11.



(B) position isomers

(D) identical

- (A) geometrical isomers
- (C) optical isomers
- G-12. Theoretically the number of geometrical isomers expected for octahedral complex [Mabcdef] is : (A) Zero (B) 30 (C) 15 (D) 9
- G-13. The complexes $[Pt(NH_3)_4]$ $[PtCl_6]$ and $[Pt(NH_3)_4Cl_2]$ $[PtCl_4]$ are : (A) linkage isomers (B) optical isomers (C) co-ordination isomers (D) ionisation isomers
- G-14. Which of the following complexes show geometrical as well as optical isomerism ? $(1) [Cr(OX)_3]^{3-}$ (2) [Rh(en)₂Cl₂]+ (3) [Co(NH₃)₂(Cl)₂(en)]⁺ (A) 1 only (B) 1 and 2 only (C) 2 and 3 only (D) All 1, 2, 3







SECTION (H) : EAN RULE AND ITS APPLICATIONS IN METAL CARBONYLS

H-1.	The EAN of metal atoms (A) 34, 35	s in [Fe(CO) ₂ (NO ⁺) ₂] and (B) 34, 36	Co ₂ (CO) ₈ respectively are (C) 36, 36	e : (D) 36, 35				
H-2.	The EAN of platinum in ((A) 90	ootassium hexachloridop (B) 86	latinate(IV) is: (C) 76	(D) 88				
H-3.	In which of the followin (A) $[Fe(CN)_6]^{3-}$ and $[Fe(CN)_6]^{3-}$ and $[Fe(CN)_6]^{3-}$ and $[Fe(CN)_6]^{3-}$ and $[Fe(CN)_6]^{3-}$	g pair the EAN of centra $[CN)_6]^{4-}$	al metal atom is same? (B) [Cr(NH ₃) ₆] ³⁺ and [Cri (D) [Ni(CO)₄] and [Ni(C	(CN) ₆] ^{3–} N)₄] ^{2–}				
H-4.	EAN of a metal carbony (A) 4	l M(CO) _x is 36. If atomic (B) 8	number of metal M is 26, (C) 5	what is the value of x ? (D) 6				
H-5.	Following Sidwick's rule (A) $\text{Co}_2(\text{CO})_4$	of EAN, $Co(CO)_x$ will be (B) $Co_2(CO)_3$: (C) Co ₂ (CO) ₈	(D) Co ₂ (CO) ₁₀				
SECT	ION (I) : SOME IMP	ORTANT COORDIN	ATION COMPOUNE	DS				
I-1.	Which of the following statements is correct ? (A) Chlorophyll contains magnesium metal. (B) Wilkinson catalyst is used for the hydrogenation of alkenes . (C) Metal carbonyls possess both σ and π bonds. (D) All of these .							
I-2.	Which of the following is correct for the Zeise's salt ? (A) The complex ion is square planar. (B) The central metal ion, platinum is in + 2 oxidation state. (C) $H_2C = CH_2$ molecules is perpendicular to the PtCl ₃ plane (D) All of these.							
I-3.	Which amongst the follo	owing are organometallic	compounds ?					
	1. Al ₂ (CH ₃) ₆ (A) 1 only	2. K[PtCl ₃ C ₂ H ₂] (B) 3 only	3. N(CH ₃) ₃ (C) 1 and 2 only	(D) 1, 2 and 3				
I-4.	In Ziesses salt C = C bo	and length is :						
	Note : $\begin{cases} C - C & bond len \\ C = C & bond len \\ C \equiv C & bond len \end{cases}$	$\left.\begin{array}{c} \text{agth in ethane is } 1.54\text{\AA}\\ \text{agth in ethene is } 1.34\text{\AA}\\ \text{agth in ethyne is } 1.20\text{\AA} \end{array}\right\}$						
	(A) 1.37Å	(B) 1.19Å	(C) 1.87Å	(D) 1.34 Å				
I-5.	Which is not a π -bonded (A) Zeise's salt (C) bis(benzene) chromi	l complex ? um	(B) Ferrocene (D) Tetraethyl lead					
I-6.	What is wrong about the (A) It is called Zeise's sa (C) Oxidation number o	e compound Κ[Pt (η² – 0 alt. f Pt is +4.	C ₂ H ₄) Cl ₃] ? (B) It is π bonded compl (D) Four ligands surrour	ex. nd the platinum atom.				
I-7.	Formula of ferrocene is: (A) [Fe(CN) ₆] ^{4–}	(B) [Fe(CN) ₆] ³⁺	(C) [Fe(CO) ₅]	(D) $[Fe(C_5H_5)_2]$				





PART - II : MISCELLANEOUS QUESTIONS

COMPREHENSION

Comprehension #1

Read the following passage carefully and answer the questions.

Splitting energy (Δ_0) can usually be measured from the absorption spectra of the complex ions. In simple cases when light is absorbed by a complex ion, an electron in one of the lower energy orbitals is excited to one of the higher energy orbital. The energy corresponding to the frequency of absorbed light is equal to Δ_0 . If value of Δ_0 for the complex is in visible region, the complex is coloured and the value of Δ_0 lies in ultraviolet or infrared region, the complex is colourless. For octahedral complexes the crystal field stabilisation energy is given by CFSE = [- 0.4 t_{2g}N + 0.6 e_gN¹] Δ_0 where N and N¹ are number of electrons in t_{2g} and e_g orbitals respectively. The values of CFSE can be used for the correction of the experimental values of heats of hydration of divalent

The values of CFSE can be used for the correction of the experimental values of heats of hydration of divalent ions of first row transition metals. The correction value can be obtained by substracting the calculated CFSE values from the experimental values.

1. The value of crystal field splitting (Δ_0) for $[Ti(H_2O)_6]^{3+}$ is 243 kJ mol⁻¹. The crystal field stabilization energy (CFSE) in this complex is : (in kJ mol⁻¹).

(A)
$$\frac{3}{5} \times 243$$
 (B) $\frac{2}{5} \times 243$ (C) $3 \times \frac{2}{5} \times 243$ (D) 243

- Which of the following statements is correct ?
 (A) Zinc(II) ion has a zero CFSE for any geometry.
 (B) A solution of [Ti(H₂O)₆]³⁺ is purple as the value of ∆ for the H₂O complex is in the visible region.
 (C) Solutions of [Fe(CN)₆]⁴⁻ and [Fe(H₂O)₆]²⁺ appear colourless in dilute solutions.
 (D) All of these.
- **3.** The heat of hydration of Cr^{2+} ion is 460 k cal/mole. For $[Cr(H_2O)_6]^{2+}$, $\Delta_0 = 13,900 \text{ cm}^{-1}$. What heat of hydration would be, if there were no crystal field stabilisation energy? (A) – 436 k cal/mole (B) – 245 k cal/mole (C) – 4.84 k cal/mole (D) none of these

Comprehension # 2

In metal carbonyls, there is synergic bonding interaction between metal and carbon monoxide. This leads to increase in strength of metal ligand bond and decrease in bond order of CO in carbonyl complex as compared to bond order in carbon monoxide.

Simple carbonyls are invariably spin-paired complexes except for vanadium metal.

- 4. The increase in bond length in CO as compared to carbon monoxide is due to :
 (A) the donation of lone pair of electrons on the carbon into a vacant orbital of the metal atom
 (B) due to the donation of a pair of electrons from a filled d-orbital of metal into the vacant antibonding π* orbital of carbon monoxide.
 (C) (A) and (B) both
 (D) none.
- Which of the following statement is false for Nickel carbonyl [Ni(CO)₄]?
 (A) It is a colourless compound.
 - (B) The Ni C— O group is linear.
 - (C) The four carbonyl group are lying at the corners of a regular tetrahedron
 - (D) The metal carbon bond length (for σ bond) does not alter.





6.	Which (I) Ni((amongst the following metal carb $CO)_4$; (II) $Fe(CO)_5$; the correct answer from the code	onyls ar (III) V	e inner o (CO) ₆	rbital complexes (IV) Cr	s with diamagnetic property ? (CO) ₆			
	(A) I a	ind II only (B) II, III and	IV only	(C) II	and IV only	(D) I , II and IV only			
7.	Which bonds (A) [Cr	one of the following metal carbon and is paramagnetic ? $(CO)_{6}$] (B) [V(CO) ₆]	yls involv	ves the d (C) [M	² sp ³ hybridisatic o(CO) ₆]	In for the formation of metal-carbon σ (D) [W(CO) ₆]			
8.	Which of the following statement is correct for metal carbonyls? (A) In general, the effective atomic number for a stable monomeric carbonyl is equal to the atomic number of the next inert gas except $[V(CO)_6]$. (B) The metal -carbon bond in metal carbonyls possess both s and p character. (C) The C-O bond length in $[Cr(CO)_6]$ is greater than that in $[W(CO)_6]$. (D) All of these.								
МАТС	сн тні	E COLUMN							
9.	Match	the pair of complexes given in col	umn-I ar	nd the ch	aracteristic(s) gi	ven in column-II.			
	Colum	IN - 1		Colum					
	(A)	$(NH_4)_2[NiCl_4]$ and $(NH_4)_2[Ni(CN)_4]$	4]	(p)	Both show same electrical conductance.				
	(B)	$CoCl_3.6NH_3$ and $PtCl_4.5NH_3$		(q)	Both show san	ne effective atomic number.			
	(C)	$[Pt(NH_3)_2Cl_2]$ and $(NH_4)_2[PtCl_4]$		(r)	Both show san	ne primary valencies.			
	(D)	$K_2[Fe(H_2O)_6]$ and $K_4[FeCl_6]$		(s)	Both gives whi	te participate with AgNO ₃ solution.			
10.	Match	the complexes given in column-I	with thei	r charact	eristic(s) given i	n column-II.			
	Colum	ın – I	Column – II						
	(A)	[Ni(gly) ₂]	(p)	Square	e planar geometr	у			
	(B)	[Ni(CO) ₄]	(q)	Tetrahe	edral geometry				
	(C)	[NiCl(PPh ₃) ₃]	(r)	Oxidat	ion state of nick	el is + 2			
	(D)	[Ni(dmg) ₂]	(s)	Chelat	ing ligand				
			(t)	Geom	etrical isomerism	1			
11.	Match	the column.							
	Colum	n - I	Colum	n - 11					

- (A) $[Cr(H_2O)_5Br]^{2+}$
- (B) $[Cu(NH_2CH_2CH_2NH_2)Cl_4]^{2-}$
- (C) $[Pt(OX)_2]^{2-}$
- (D) [Fe(OH)₄]^r

- (p) Paramagnetic in nature
- (q) Geometrical isomerism is exhibited
 - (r) Optical isomerism is exhibited
 - (s) Do not follow Sidewick E.A.N. rule
 - (t) Complex having symmetrical bidentate ligand





ASSERTION / REASONING

DIRECTIONS:

- Each question has 5 choices (A), (B), (C), (D) and (E) out of which ONLY ONE is correct.
- (A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
- (B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
- (C) Statement-1 is True, Statement-2 is False.
- (D) Statement-1 is False, Statement-2 is True.
- (E) Statement-1 and Statement-2 both are False.
- Statement-1 : In the co-ordination complex [Pt(NH₃)₄ Cl₂] Br₂, a yellow precipitate of AgBr is obtained on treating it with AgNO₃.

Statement-2 : Bromide ions are present as counter ions in the ionization sphere.

13. Statement-1 : In the complex $[Co(NH_3)_3 Cl_3]$, chloride ions satisfy the primary valencies as well as the secondary valencies of cobalt metal.

Statement-2 : [Co(NH₃)₃Cl₃] shows geometrical as well as optical isomerism.

Statement-1 : All the complexes of Pt (+II) and Au(+ III) with strong field as well as with weak field ligands are square planar.
 Statement-2 : The crystal field splitting Δ_o is larger for second and third row transition elements , and for more

highly charged species. This larger value of Δ_0 energetically favours the pairing of electron for square planar geometry.

15. Statement-1 : The value of Δ_0 for M³⁺ complexes are always much higher than value for M²⁺ complexes (for the same set of ligands)

Statement-2: The crystal field stabilization energy of $[Co(NH_3)_6]^{3+} < [Rh(NH_3)_6]^{3+}$

- **16.** Statement-1 : The complex $[Cr(SCN)(NH_3)_5]Cl_2$ is linkage isomeric with $[Cr(NCS)(NH_3)_5]Cl_2$. Statement-2 : SCN⁻ is an ambident ligand in which there are two possible coordination sites.
- **17. Statement-1** : The $[Ni(en)_3] Cl_2$ has higher stability than $[Ni(NH_3)_6] Cl_2$ **Statement-2** : In $[Ni(en)_3] Cl_2$, the geometry of Ni is octahedral.
- Statement-1 : Potassium ferrocyanide is diamagnetic where as potassium ferricyanide is paramagnetic.
 Statement-2 : Crystal field splitting in ferrocyanide ion is greater than that of ferricyanide ion.
- Statement-1 : In the reaction [CoCl₂(NH₃)₄]⁺ + Cl⁻ → [CoCl₃(NH₃)₃] + NH₃, when reactant is in cis-form two isomers of the product are obtained.
 Statement-2 : Third chloride ion replaces an ammonia cis to both chloride ion or trans to one of the chloride ion.







- **20.** Statement-1 : $[NiF_6]^{4-}$ and $[NiF_6]^{2-}$ both are high spin complexes. Statement-2 : F^- is a weak field ligand.
- Statement-1 : The correct order for the wave length of absorption in the visible region is ; [Ni(NO₂)₆]⁴⁻ < [Ni(NH₃)₆]²⁺ < [Ni(H₂O)₆]²⁺
 Statement-2 : The stability of different complexes depends on the strength of the ligand field of the various ligands.
- Statement-1 : The cis-[CoCl₂(en)₂]⁺ has two enantiomers.
 Statement-2 : 'en' is an bidentate mono anion.

TRUE / FALSE

- **23.** $[Ni(DMG)_2]$ has geometry as that of the $[Ni(PPh_3)_3Br]$.
- 24. The 'spin only' magnetic movement of an octahedral complex having CFSE = $-0.6 \Delta_0$ and surrounded by weak field ligands can be 4.9 BM or 1.73 BM
- **25.** $[Cr(C_2O_4)_3]^{3-}$ and $[Cr(NH_3)_2Cl_2(en)]^+$ both show cis-trans as well as optical isomerism.
- **26.** The IUPAC name of the complex $K_2[OsCl_5N]$ is Potassium azidopentachloridoosmate(VI)
- 27. Sodium nitroprusside has iron in + II oxidation state and the complex is diamagnetic in nature.
- **28.** The complex $[Cu(NH_3)_4]^{2+}$ is tetrahedral with paramagnetic nature.
- **29.** In iron pentacarbonyl, the oxidation state of iron is zero.
- **30.** The correct formula of the coordination compound, Bromidochloridobis(ethane-1,2diamine)platinum(IV) nitrate is $[PtBrCl(en)_2](NO_3)_2$.
- **31.** Violet colour complex $[Ti(H_2O)_6]^{3+}$ becomes colourless on heating.
- **32.** The complex $[Cr(H_2O)_6]Cl_3$ loses six water molecules to conc. H_2SO_4 and does not give any precipitate with AgNO₃.









Exercise # 2

PART - I : MIXED OBJECTIVE

OBJECTIVE QUESTIONS (SINGLE CHOICE TYPE)

- 1. The IUPAC name of $K_2[Cr(CN)_2O_2(O)_2(NH_3)]$ is :
 - (A) Potassiumamminedicyanodioxoperoxo chromate(VI)
 - (B) Potassiumamminecyanoperoxodioxo chromium(VI)
 - (C) Potassiumamminecyanoperoxodioxo chromium(VI)
 - (D) Potassiumamminecyanoperoxodioxo chromate(IV)
- **2.** The correct name of $[Pt(NH_3)_4Cl_2]$ $[PtCl_4]$ is :
 - (A) Tetraamminedichloroplatinum(IV) tetrachloroplatinate(II)
 - (B) Dichlorotetraammineplatinum(IV) tetrachloro platinate(II)
 - (C) Tetrachloro platinum(II) tetraammine platinate(IV)
 - (D) Tetrachloro platinum(II) dichloro tetraamine platinate(IV)
- 3. The IUPAC name $[Co(NH_3)_6]$ $[Cr(CN)_6]$ is :
 - (A) Hexaamminecobalt(III) hexacyano chromate(III)
 - (B) Hexacyanochromiumcobalt hexaammine(VI)
 - (C) Hexaammine cobalt(III)hexacyano chromium(VI)

(B) + 4

- (D) Hexacyanochromium(III)hexaammine cobalt(III)
- 4. What is the oxidation number of chromium in the dimeric hydroxo bridged species ?

$$\left[(H_2O)_4 Cr \begin{pmatrix} H \\ O \\ O \\ H \end{pmatrix} Cr (H_2O)_4 \right]^4$$

(A) + 6

(C) + 3 (D) + 2

- 5. Which of the following name is impossible ? (A) Potassiumtetrafluoridooxidochromate(VI) (C) Dichlorobis(urea)copper(II)
- (B) Bariumtetrafluoridobromate(III)
- (D) All are impossible.
- 6. Which of the following is most likely formula of platinum complex, if $\frac{1}{4}$ of total chlorine of the compound is

precipitated by adding AgNO₃ to its aqueous solution ? (A) $PtCl_4.6H_2O$ (B) $PtCl_4.5H_2O$ (C) $PtCl_4.2H_2O$ (D) $PtCl_4.3H_2O$

- 50 ml of 0.2 M solution of a compound with empirical formula CoCl₃.4NH₃ on treatment with excess of AgNO₃(aq) yields 1.435 g of AgCl. Ammonia is not removed by treatment with concentrated H₂SO₄. The formula of the compound is :

 (A) Co(NH₃)₄Cl₃
 (B) [Co(NH₃)₄Cl₂]Cl
 (C) [Co(NH₃)₄Cl₃
 (D) [CoCl₃(NH₃)]NH₃
- 8. If excess of AgNO₃ solution is added to 100 mL of a 0.024 M solution of dichlorobis(ethylenediamine)cobalt (III) chloride. How many moles of AgCl be precipitated ?
 (A) 0.0012
 (B) 0.0016
 (C) 0.0024
 (D) 0.0048



E	TOOS										COORD	INATION C	OMPOUNDS
9.	How r AaNO	many m _» ?	oles of A	gCl wo	uld be ol	otained, wher	ו 100) ml of	0.1 M C	Co(NH ₃) ₅	Cl ₃ is treate	ed with e	xcess of
	(A) 0.0)1		(B) 0.	02	(C	;) 0.0	3		(D) no	one of these	;	
10.	Which	n of the f	ollowing i	s non–o	conductir	ıg?							
	(A) Cc	Cl ₃ .6NH	H ₃	(B) C	oCl ₃ .5N⊦	l ₃ (C	;) Co	Cl ₃ .4N⊦	H ₃	(D) C	oCl ₃ .3NH ₃		
11.	 Consider the following statements : S₁ : [MnCl₆]³⁻, [FeF₆]³⁻ and [CoF₆]³⁻ are paramagnetic having four, five and four unpaired electror respectively. S₂ : Valence bond theory gives a quantitative interpretation of the thermodynamic stabilities of coordinate compounds. S₂ : The crystal field splitting ∧ , depends upon the field produced by the ligand and charge on the metal ion a stability of the splitting ∧ . 									electrons rdination Il ion and			
	arrang	arrange in the order of true/ false.				-	-		-	-	-		
	(A) T 1	ГТ		(B) T	FΤ	(C	;) F T	F		(D) T	FF		
12. 13.	Which of the following comple (A) $[NiCl_2(Ph_3P)_2]$ – tetrahedral (C) $[Cu(CN)_4]^3$ – tetrahedral Match Column-I with Column-II				x is not o l and sele	correctly matc (B (D ect the correct	hed) [Co) [Fe מחמי	with its $p(Py)_4]^2$ $p(CO)_4]^2$ wer with	geomet ⁺ – squai ²⁻ – squa n respec	ry ? re planar re planar t to hybrid	: : disation usir	ng the coc	les given
	below	:				Oshumu							
	(I) (II) (III) (I∨) Code:	(Cond [Au F [Cu(C [Co(C [Fe(H s :	mn - I nplex) [₄] ⁻ [² N) ₄] ³⁻ [² O ₄) ₃] ³⁻ [² O) ₅ NO] ²	+	(p) (q) (r) (s)	Column - (Hybridisa dsp ² hybridi sp ³ hybridi sp ³ d ² hybr d ² sp ³ hybr	II atior disat satic idisa idisa	1) ion on tion tion					
	(•)	(I)	(II)	(III)	(IV)	(5		(I)	(II)	(III)	(IV)		
	(A) (C)	q	p	r r	S	(B	·) i)	p	q	S	r r		
14.	(C) All the (A) [Fe	p metal i eCl(CN)	ч ons conta) ₄ (O ₂)] ⁴⁻	ins t _{2g} (B) K ₄ [F	e _g ⁰ confiç ⁻e(CN) ₆]	gurations. Wh (C) [Co() nich ((NH ₃	ч of the fo) ₆]Cl ₃	p bllowing (complex (D) [Fe(C	will be para CN) ₅ (O ₂)] ⁻⁵	amagnetio	c?
15.	The co for the (A) Its (B) Th (C) Th (D) Th Which	omplex comple magne ne oxida ne hybrid ne brown	[Fe (H ₂ C ex. tic mome tion state disation c n colour c the follow) ₅ NO ⁺ ont is ap of iron of centra f the rin ving sta] ²⁺ is forr proxima is + 1 al metal i ng is due tement is	ned in the 'bro tely 3.9 B.M. on is sp ³ d ² to d – d trans s false for nick	own ition. <el-d< th=""><th>ring tes imethyl</th><th>t' for niti</th><th>rates. Ch</th><th>oose the in</th><th>correct st</th><th>tatement</th></el-d<>	ring tes imethyl	t' for niti	rates. Ch	oose the in	correct st	tatement
	(A) Th (B) Th (C) Th (D) A a	ie stabil ie comp ie comp and B bi	ity of com lex is stab lex is stal oth.	plex is ble beca ble as it	only due ause tride has five	to the presen entate dimeth membered c	ce o yl gly helat	f intra-r yoxime te rings	nolecula ligand fo as well	ir hydrog orms a fiv as intra r	en bonding ve member nolecular h	ed chelate ydrogen t	e rings. oonding.





17.	 Which of the following s 1. Cobalt is in + 3 oxida 2. Cobalt is in + 3 oxida 3. It shows ionisation a 4. It also shows googe 	tatements are correct fo ation state involving d ² sp ation state involving sp ³ c as well as linkage isome atrical isomerism	r the complex [Co(NH ₃) ₄ (b ³ hybridisation. d ² hybridisation. rism.	CI) (NO ₂)]CI ?
	(A) 1, 3 and 4 only	(B) 2, 3 and 4 only	(C) 1 and 4 only	(D) 2 and 4 only.
18.	Which of the following s (A) It is paramagnetic a (C) It is diamagnetic an	statements about Fe(CO nd high spin complex d low spin complex) ₅ is correct? (B) It is diamagnetic ar (D) It is paramagnetic a	nd high spin complex and low spin complex
19.	Which of the following s (A) MnCl ^{$\frac{1}{4}$} ion has tetra (B) [Mn(CN) ₆] ^{2–} ion has (C) [Cu(CN) ₄] ^{3–} has squ (D) [Ni(Ph ₃ P) ₂ Br ₃] has t	statements is not true? hedral geometry and is octahedral geometry and lare planar geometry and rigonal bipyramidal geor	paramagnetic. d is paramagnetic. d is diamagnetic. netry and is paramagnetic	с.
20.	Arrange the following in I : [Fe(H ₂ O) ₆] ²⁺ (A) IV, I, II, III	order of decreasing nun II : [Fe(CN) ₆] ³⁻ (B) I, II, III, IV	hber of unpaired electrons III : [Fe(CN) ₆] ^{4–} (C) III, II, I, IV	s ? IV : [Fe(H ₂ O) ₆] ³⁺ (D) II, III, I, IV
21.	Which of the following (A) [Co $(NH_3)_4 Cl_2$] ⁺	complex does not show (B) [Co $(NH_3)_3 (NO_2)_3$	geometrical isomerism ?] (C) [Cr (en) ₃] ³⁺	(D) [Pt (gly) ₂]
22.	$[Fe(en)_2(H_2O)_2]^{2+} + en$ (A) it is a low spin com (C) it shows geometrica	→ complex(X). The corr plex. al isomerism.	ect statement about the c (B) it is diamagnetic. (D) (A) and (B) both.	complex (X) is :
23.	The complexes given b	elow show :		
	Cl Cl Cl Cl Cl Cl Cl Cl	Pt Pt $P(C_2H_5)_3$ and	$(C_2H_5)_3P$ Pt Cl Cl Cl	Pt Pt $P(C_{2}H_{5})_{3}$
	(A) optical isomerism (C) geometrical isomeri	sm	(B) co-ordination isome (D) bridged isomerism	erism
24.	The total number of pos (A) 3	ssible isomers of the con (B) 5	npound [Cu ^{ll} (NH ₃) ₄] [Pt ^{ll} C (C) 4	l ₄] are: (D) 6
25.	On treatment of [Pt(NH [Pt(NH ₃) ₂ Cl ₂] are obtain oxalic acid to form [Pt(N (A) (I) cis, (II) trans; bot	$(H_3)_4]^{2+}$ with concentrated ned, (I) can be converted $(H_3)_2(C_2O_4)]$ whereas (II) h tetrahedral	d HCI, two compounds (d into (II) by boiling with d does not react. Point out (B) (I) cis, (II) trans; bo	I) and (II) having the same formula, lilute HCI. A solution of (I) reacts with the correct statement of the following. th square planar

(C) (I) trans, (II) cis; both tetrahedral

- (D) (I) trans, (II) cis; both square planar
- 26. Which of the following complex will show optical activity? (A) trans-[Co(NH₃)₄Cl₂]⁺ (B) $[Cr(H_2O)_6]^{3+}$ (C) cis-[Co(NH₃)₂(en)₂]³⁺ (D) trans-[Co(NH₃)₂(en)₂]³⁺





27. The complex ion has two optical isomers. Their correct configurations are :



- **28.** Of the following complex ions, the one that probably has the largest overall formation constant, K_f , is : (A) $[Co(NH_3)_6]^{3+}$ (B) $[Co(H_2O)_6]^{3+}$ (C) $[Co(NH_3)_2(H_2O)_4]^{3+}$ (D) $[Co(en)_3]^{3+}$
- **29.** What is the ratio of uncomplexed to complexed Zn^{2+} ion in a solution that is 10 M in NH₃, if the stability constant of $[Zn(NH_3)_4]^{2+}$ is 3×10^9 ? (A) 3.3×10^{-9} (B) 3.3×10^{-11} (C) 3.3×10^{-14} (D) 3×10^{-13}

More than one choice type

- **30.** In which of the following pairs of complexes the central metals/ions do have same effective atomic number ? (A) [Cr (CO)₆] and [Fe (CO)₅] (B) [Co (NH₃)₆]²⁺ and [Ni (NH₃)₆]²⁺ (C) [Cu (CN)₄]³⁻ and [Ni (CO)₄] (D) [V(CO)₆]⁻ and [Co(NO₂)₆]³⁻
- Which of the following is/are correctly matched ?

 (A) Ni(CO)₄ tetrahedral, paramagnetic
 (B) Ni(CN)₄]²⁻ square planar, diamagnetic
 (C) Ni(dmg)₂ square planar, diamagnetic
 (D) [NiCl₄]²⁻ tetrahedral, paramagnetic

 32 'Spin only' magnetic moment of Ni in [Ni/dmg) 1 is same as that found in :
- **32.**'Spin only' magnetic moment of Ni in $[Ni(dmg)_2]$ is same as that found in :

 (A) Ni in $[NiCl_2 (PPh_3)_2]$

 (B) Mn in $[MnO_4]^-$

 (C) Co in $[CoBr_4]^{2-}$

 (D) Pt in $[Pt (H_2O)_2 Br_2]$
- Which of the following statements is/are true for [Pt(NH₃)(H₂O)(Cl)₂]?
 (A) It has diamagnetic character
 (B) It has square planar geometry
 (C) It shows geometrical and optical isomerism
 (D) It shows only geometrical isomerism
- Which of the following statement(s) is /are correct ?
 (A) In K₃[Fe(CN)₆], the ligands has satisfied only the secondary valencies of ferric ion.
 (B) In K₃[Fe(CN)₆], the ligands has satisfied both primary and secondary valencies of ferric ion.
 (C) In K₄[Fe(CN)₆], the ligands has satisfied only the secondary valencies of ferrous ion.
 (D) In [Cu(NH₃)₄]SO₄, the ligands has satisfied only the secondary valencies of copper.
- **35.** Which of the following statements is/are incorrect for the complex $[Cr(H_2O)_6]Cl_3$?
 - (A) It has a magnetic moment of 3.83 BM.
 - (B) The distribution of 3d electrons is $3dxy^1$, $3dyz^1$, $3dzx^1$
 - (C) The ligand has satisfied both primary and secondary valencies of chromium.
 - (D) It shows ionization as well as hydrate isomerism.







- Which statements is/are correct ?
 (A) [Ni(PPh₃)₂Br₂] tetrahedral and paramagnetic. (B) [Ni (CO)₄] tetrahedral and diamagnetic.
 (C) [Ni(CN)₄]²⁻ square planar and diamagnetic. (D) [Ni(Cl)₄]²⁻ square planar and diamagnetic.
- Which of the following statements is/are true for the complexes, [Fe(H₂O)₆]²⁺, [Fe(CN)₆]⁴⁻, [Fe(C₂O₄)₃]³⁻ and [Fe(CO)₅]?
 (A) Only [Fe(C₂O₄)₃]³⁻ show optical isomerism.
 (B) [Fe(C₂O₄)₃]³⁻ is less stable than [Fe(CN)₆]²⁻
 - (C) All complexes have same effective atomic number.
 - (D) $[Fe(CO)_{5}]$ shows back bonding.
- 38. [CoCl₂(en)₂]Br will show :
 (A) coordinate position isomerism
 (C) geometrical isomerism

(B) ionization isomerism(D) optical isomerism.

PART - II : SUBJECTIVE QUESTIONS

- Name the following compounds (All these are important compounds, will be used in different fields of chemistry)
 (c) [Fe(CO),], A highly toxic volatile liquid.
 - (d) $[Fe(C_2O_4)_3]^3$, The ion formed when Fe₂O₃ rust is dissolved in oxalic acid, H₂C₂O₄.
 - (e) $[Cu(NH_3)_4]SO_4$, A deep blue compound obtained when $CuSO_4$ is treated with excess of NH_3 .
 - (f) $Na[Cr(OH)_{4}]$, The compound formed when $Cr(OH)_{3}$ precipitate is dissolved in excess of NaOH.
 - (g) **Co(gly)**₃, A complex that contains the anion of amino acid, glycine.
 - (h) $[Fe(H_2O)_{5}(SCN)]^{2+}$, The red complex ion formed in the qualitative analysis test of Fe³⁺ ion.
 - (i) **K**₂[Hgl₄], Alkaline solution of this complex is called **Nessler's Reagent**.
 - (j) **Co[Hg(SCN)**₄], Deep blue crystalline precipitate obtained in qualitative detection of Hg²⁺.
 - (k) $Fe_{4}[Fe(CN)_{e}]_{3}$, Prussian blue, deep blue colored complex obtained in detection of Fe^{2+} .
 - (I) $K_3[Co(NO_2)_6]$, Potassium cobaltinitrite or Fischer salt yellow precipitate obtained in detection of Co^{2+} .
 - (m) [Ni(dmg)₂], Rosy red precipitate obtained in detection of Ni²⁺ ions.
 - (n) $K_2[PtCl_6]$, Yellow precipitate obtained in detection of potassium ions(similar complex is formed with NH₄⁺ions also).
 - (o) **Na₂[Fe(CN)₅NO⁺]**, **Sodium nitroprusside** used for detection of sulphide ions/sulphur.
 - (p) $[Fe(H_2O)_5(NO^*)]SO_4$, Brown ring complex, obtained in detection of Fe²⁺ ions.
 - (q) $[Cu(CN)_4]^{3-}$, Colourless stable soluble complex obtained in detection of Cu²⁺ on adding excess of KCN solution.







- 2. Write down the formulae of the following compounds.
 - diamminetriaguahydroxidochromium (III) nitrate (a)
 - (b) tetrakis(pyridine)platinum(II) tetraphenylborate(III)
 - (c) dibromidotetracarbonyliron (II)
 - (d) tetraamminecobalt(III)-µ-amido-µ-hydroxidobis(ethylenediamine)cobalt(III) chloride
 - (e) ammonium diamminetetrakis(isothiocyanato)chromate(III).
 - (f) pentaamminedinitrogenruthenium(II) chloride
 - bis(cyclopentadienyl)iron(II) (g)
 - barium dihydroxidodinitrito-O-oxalatozirconate(IV) (h)
 - tetrapyridineplatinum(II) tetrachloridonickelate(II) (i)
 - tetraammineaquacobalt(III)-µ-cyanidotetraamminebromidocobalt(III) (i)
- 3. (a) Arrange the following compounds in order of increasing molar conductivity. (i) K[Co(NH₂)₂(NO₂)₄] (ii) $[Cr(NH_3)_3(NO_2)_3]$ (iii) $[Cr(NH_3)_5(NO_2)]_3[Co(NO_2)_6]_2$ $(iv) [Cr(NH_3)_{e}]Cl_3$ (b) Deduce the value of x in the formulae of following complexes (i) Mo(CO), (ii) $H_Cr(CO)_5$ (iii) H_vCo(CO)₄
- 4. Complete the following table (using concepts of VBT). Geometry Hybridisation Number of unpaired electrons(n) Mag. moment

Complex	
CN -2	

	1			
(a)	[Ag(NH ₃) ₂] ⁺		 0	
(b)	[Cu(CN) ₂] ⁻	Linear	 	
(c)	[AuCl₂]⁻		 	0
	CN = 4			
(d)	$[PtCl_2(NH_3)_2]$		 0	
(e)	[Zn(CN) ₄] ²⁻		 0	
(f)	[Cu(CN) ₄] ³⁻		 0	
(g)	[MnBr ₄] ^{2–}		 5	
(h)	[Cu(NH ₃) ₄] ²⁺	Square Planar	 	
(i)	[Col ₄] ²⁻		 3	
	CN = 6			
(j)	[Mn(CN) ₆] ³⁻		 2	
(k)	[Cr(NH ₃) ₆] ³⁺		 3	
(I)	[Fe(CN) ₆] ³⁻		 1	
(m)	[lr(NH ₃) ₆] ³⁺		 0	
(n)	[V(CO) ₆]		 1	
(o)	[Fe(H ₂ O) ₆] ²⁺		 4	
(p)	[MnCl ₆]³−		 4	

5.

(A), (B) and (C) are three complexes of chromium(III) with the empirical formula H₁₂O₆Cl₃Cr. All the three complexes have water or chloride ion as ligands. Complex (A) does not react with concentrated H₂SO₄, whereas complexes (B) and (C) lose 6.75% and 13.5% of their original weight, respectively, on treatment with concentrated H_2SO_4 . (ii)

- (i) Identify (A), (B) and (C)
- Write their formulae
- (iii) Calculate their EAN.
- By the addition of AgNO₃ what happens with each complex.



(iv)



- 6. A metal complex having composition $Cr(NH_3)_4Cl_2Br$ has been isolated in two forms A and B. The form A reacts with AgNO₃ to give a white precipitate readily soluble in dilute aqueous ammonia, whereas B gives a yellow precipitate soluble in concentrated ammonia.
 - (i) Write the formulae of A and B.
 - (ii) State hybridisation of chromium in each.
 - (iii) Calculate their magnetic moments for each (spin-only value).
 - (iv) Calculate the EAN for both.
 - (v) Will they conduct electricity or not.
 - (vi) Write the formula of the complexes formed when the precipitates dissolve in aqueous ammonia & the concentrated ammonia respectively.
- 7. (a) Which of the complexes (a) $[Cr(edta)]^-$, (b) $[Ru(en)_3]^{2+}$ and (c) $[Pt(dien)Cl]^+$ are chiral?
 - (b) Give the IUPAC name of the complex, $[IrH(CO) (PMe_3)_2]$ and also give the hybridisation of the central atom along with the magnetic moment.
- 8. Draw all the possible isomers of $[Co(NH_3)_2(en) Cl_2]^+$.
- (a) Draw all possible constitutional isomers of the compound Ru(NH₃)₅(NO₂)Cl. Label the isomers as linkage isomers or ionization isomers.
 - (b) There are six possible isomers for a square planar palladium(II) complex that contains two Cl⁻ and two SCN⁻ ligands. Sketch the structures of all six, and label them according to the classification.
- **10.**Tell how many diastereoisomers are possible for each of the following complexes, and draw their structures.
(a) $[Cr(NH_3)_2Cl_4]^-$ (b) $[Co(NH_3)_5Br]^{2+}$ (c) $[FeCl_2(NCS)_2]^{2-}$
(d) $[PtBr_2Cl_2]^{2-}$ (e) $[Co(en)(SCN)_4]^-$ (f) $[Cr(NH_3)_2(H_2O)_2Cl_2]^+$ (g) $[Ru(NH_3)_4l_3]$
- $\begin{array}{ll} \textbf{11.} & \text{Which of the following complexes can exist as enantiomers? Draw their structures.} \\ (a) cis-[Co(NH_3)_4Br_2]^+ & (b) cis-[Cr(H_2O)_2(en)_2]^{3+} & (c) [Cr(gly)_3] \\ (d) [Cr(en)_3]^{3+} & (e) cis-[Co(NH_3)Cl(en)_2]^{2+} & (f) trans-[Co(NH_3)_2(en)_2]^{2+} \\ \end{array}$
- Predict the number of unpaired electrons in a tetrahedral d⁶ ion and in a square planar d⁷ ion.
 Note : If answer in 1 and 2 represent as 12.
- **13.** From Meridional and facial isomer of $[Ma_3b_3]^{n\pm}$ on replacement of only one 'a' by 'b', the number of isomer of the product obtained are _____ and ____ respectively. [If answer is 2 and 5 represent as 25]
- 14. In how many of the following entities the central metal ions have the oxidation state of +2? [MnBr₄]²⁻ (a) [NiBr₄]^{2−} (b) [Fe(CN)₆]³⁻ [AuCl_] (c) (d) [Fe(H₂O)₂]²⁺ [Pt(NH_),]²⁺ [Co(SCN),]2-(f) (e) (q)
- **15.** In $H_{v}[Pt y_{e}]$, y is monodentate negatively charged ligand then find out the value of x.
- **16.** The total number of possible coordination isomer for the given compound is $[Pt(NH_3)_4Cl_2][PtCl_4]$.
- **17.** E.A.N. of K[PtCl₃($\eta^2 C_2H_4$)] is :
- 18. The number of optically active isomer for [Pt(NH₃)₂(F)(Cl)(Br)(l)]° is _____





- **19.** How many of the following statements are incorrect ? **(i)** : cis - $[M(NH_3)_2Cl_2]$ would react with $Ag_2C_2O_4$ but trans - isomer not. **(ii)** : Considering Δ_0 to be same for Co(II) and Co(III), the complex $[Co(NH_3)_6]^{3+}$ is more stable than $[Co(NH_3)_6]^{2+}$. **(iii)** : $[V(CO)_6]$ is more paramagnetic than $[V(CO)_6]^{-}$. **(iv)** : $[Cr(gly)_3]$ exists in two geometrical isomeric forms.
 - (v) $[Co(NH_3)_3(NO_3)_3]$ has fac-and mer isomers.

(vi) $[RhCl(PPh_3)_3]$ is diamagnatic with square planar geometry.

 $[Pt(NH_3)_6]^{4+}$ $[Ni(NH_3)_6]Cl_2$ $[Fe(C_5H_5)_2]$

 $K[PtCl_{3}(\eta^{2} - C_{2}H_{4}) Mn_{2}(CO)_{10} ZnCl_{4}^{2-}$

- 21. Total number of stereoisomers of the complex with formula $[Cr(gly)_2(NH_3)_2]^+$
- 22. Total Number of stereoisomers of the complex with formula $[Co(en)_2(NH_3)(H_2O)]^{3+}$
- **23.** Number of (n 1) d orbitals involved in the hybridisation of central metal ion in brown ring complex, [Fe(H₂O)₅NO⁺]SO₄ is :
- 24. How many of the following statements are correct for Nickel carbonyl $[Ni(CO)_4]$?
 - (i) It is a colourless compound.
 - (ii) The Ni C— O group is linear.
 - (iii) The four carbonyl group are lying at the corners of a regular tetrahedron.
 - (iv) The metal carbon bond length (for σ bond) does not alter.
 - (v) There is synergic interaction between nickel metal and ligand CO.
 - (vi) The oxidation state of nickel is zero.
 - (vii) The effective atomic number (EAN) of nickel atom is 34.
- 25. Number of pair of enantiomer of [Ma₂b₂cd] is :
- **26.** In Na₂[Fe(CN)₅NOS], complex the number of unpaired electrons is :
- 27. How many of the following statements are correct ?
 - (i) Both $[Fe(CN)_6]^{3+}$ and $[Cu(en)_2 (H_2O)_2]^{2+}$ are paramagnetic and both species contain one unpaired electron.
 - (ii) Complex ion, $[Mn(SCN)_6]^4$ having $t_{2g}^3 e_g^2$ configuration is a high spin complex with 'spin only' magnetic moment close to 5.93 BM.
 - (iii) Coordination compounds, CoCl₃. 6NH₃ and PtCl₄. 5NH₃ have the same magnetic properties and approximately the same electric conductance for their 0.001 M aqueous solutions.
 - (iv) The complex $[W(CO)_{\lambda}(py)_{2}]$ can exist in cis-and trans-isomers and its cis-form is optically inactive.
 - (v) $[Cu(CN)_{4}]^{-}$ is paramagnetic with tetrahedral geometry.
 - (vi) $[Ti(H_2O)_6]CI_3$ develops violet colouration in aqueous solution.
- 28. How many complexes among the following are paramagnetic?

[Mn(CN) ₆] ^{3–} ,	[Cr(H ₂ O) ₆] ³⁺ ,	[Co(en) ₃] ³⁺ ,
[V(CO) ₆],	[Ni(NH ₃) ₆] ²⁺ ,	[Ni(dmg) ₂],
$[Pt(Cl)_{2}(NH_{3})_{2}],$	[Cu(NH ₃) ₄] ²⁺ ,	[Cu(CN) ₄] ^{3–} .







1.

2.

[JEE-2000, 3/100]

[JEE-2001, 1/35]

(D) $[Cr(H_2O)_6]^{3+}$

EXERCISE # 3

PART - I : IIT-JEE PROBLEMS (PREVIOUS YEARS)

Draw the structures of $[Co(NH_3)_6]^{3+}$, $[Ni(CN)_4]^{2-}$ and $[Ni(CO)_4]$. Write the hybridisation of atomic orbitals of the

(C) [Fe(CN)_c]³⁻

* Marked Questions are having more than one correct option.

[Atomic number Cr = 24, Mn = 25, Fe = 26, Co = 27]

The complex ion which has no 'd' electrons in the central metal atom is :

(B) [Co(NH₂)₂]³⁺

transition metal in each case.

(A) [MnO₄]

3.	A meta with Ag precipit in each	l complex having NO ₃ to give a whi ate soluble in con . Calculate their r	composition Cr te precipitate rea centrated ammo magnetic mome	$(NH_3)_4 Cl_2 I_2$ adily solublonia. Write ents (spin c	Br has been le in dilute a the formula only value).	i isolated in tr queous amm of A and B an	wo form: Ionia, wł d state ti	s A and B here as B he hybrid	The form A reacts gives a pale yellow ization of chromium [JEE–2001, 5/100]
4.	Deduce magne	e the structure of tic moment (spin	[NiCl ₄] ^{2–} and [N only) of the spe	$\operatorname{Ni}(\operatorname{CN})_4]^{2-}$ cecies.	onsidering	the hybridisa	ation of t	he meta	l ion. Calculate the [JEE–2002, 5/60]
5.	A greer comple	IUPAC name of the [JEE-2003, 4/60]							
6.	The sp (A) [Pd	ecies having tetra Cl ₄] ^{2–}	ahedral shape is (B) [Ni(CN) ₄] ^{2–}	S:	(C) [Pd(CN)) ₄] ^{2–}	(D) [Ni	Cl ₄] ^{2–}	[JEE-2004, 3/84]
7.	The spi (A) √3	in magnetic mom	tient of cobalt in (B) $\sqrt{8}$	the compo	ound, Hg [C (C) √15	o(SCN) ₄] is	: (D) √2	24	[JEE-2004, 3/84]
8.	When c solutior (a) Dra (b) Writ (c) Stat	dimethyl glyoxime n, a bright red col w the structure of te the oxidation s e whether the su	e is added to the oured precipitat f bright red subs tate of nickel in bstance is para	e aqueous te is obtain stance. the substa magnetic c	solution of r ed. ance and hy or diamagne	nickel (II) chl /bridisation. etic.	oride in	presence	e of dilute ammonia [JEE–2004, 4/60]
9.	Which kind of isomerism is exhibited by octahedral $[Co(NH_3)_4Br_2]Cl$?(A) Geometrical and ionization(B) Geometrical and optical(C) Optical and ionization(D) Geometrical only						[JEE–2005, 3/84]		
10.	In the g	iven reaction sec $Fe^{3+} + \frac{SCN^-}{(Excess)}$	uence, Identify → A Blood red	(A) and (B). • colourless	s(B)			
	(a) (b)	Write the IUPAC Find out the spi	C name of (A) ar n only magnetic	nd (B). c moment o	of B.				[JEE-2005, 4/60]

 11.
 The bond length in CO is 1.128 Å. What will be the bond length of CO in Fe(CO)₅?
 [JEE-2006, 5/184]

 (A) 1.158 Å
 (B) 1.128 Å
 (C) 1.178 Å
 (D) 1.118 Å





Comp	rehensi	on # (Q.12 to (Q.14)			
	NiCl ₂	−KCN HCN	complex A			
	NiCl ₂	KCI excess	complex B			
	A & B o	complexes hav	e the co-ordination number	er 4.		
12.	The IU (A) Pot (B) Pot (C) Pot (D) Pot	IPAC name of tassium tetracy tassium tetracy tassium cyanol tassium cyanol	complexes 'A' & 'B' are res ranonickelate(II) and Potas ranonickel(II) and Potassiun nickelate(II) and Potassium cl nickel(II) and Potassium cl	spectively : ssium tetrachloroni um tetrachloronicke n chloronickelate(II hloronickel(II)	ckelate(II) el(II) I)	[JEE–2006, 5/184]
13.	The hy (A) dsp	/bridisation of b	ooth complexes are : (B) sp ² & dsp ²	(C) dsp ² & sp ³	(D) both sp ³	[JEE-2006, 5/184]
14.	What a (A) Bo (B) 'A' (C) 'A' (D) Bo	are the magne th diamagnetic is diamagnetic is diamagnetic th are paramag	tic nature of 'A' & 'B' ? • & 'B' is paramagnetic wit • & 'B' is paramagnetic wit gnetic.	h one unpaired ele h two unpaired ele	ctrons. ctrons.	[JEE–2006, 5/184]
15.	Amono (A) [Mr	g the following ∩(CO) ₆]⁺	metal carbonyls, the C – $(B) [V(CO)_6]^{-1}$	O bond order is low (C) [Cr(CO) ₆)]	vest in : (D) [Fe(CO) ₅]	[JEE-2007, 3/162]
16.	Match	the complexes	in Column-I with their pro	perties listed in Co	lumn-II.	[JEE-2007,6/162]
	Colum (A) (B) (C) (D)	In-I [Co(NH ₃) ₄ (H ₂) [Pt(NH ₃) ₂ Cl ₂] [Co(H ₂ O) ₅ Cl] [Ni(H ₂ O) ₆]Cl ₂	O) ₂]Cl ₂ Cl	Column (p) (q) (r) (s)	n-II Geometrical isomers Paramagnetic Diamagnetic Metal ion with +2 oxic	lation state
17.	The IU (A) Tet (C) Tet	IPAC name of [rachloronickel(raamminenicke	$Ni(NH_3)_4] [NiCl_4] is : II) tetraamminenickel (II) el(II) tetrachloronickelate (I$	(B) Tetraammin I) (D) Tetraammin	enickel(II) tetrachloronio enickel(II) tetrachloronio	[JEE–2008, 3/163] ckel (II) ckelate (0)
18.	Both [N	$Ni(CO)_4]$ and [N	$i(CN)_4]^{2-}$ are diamagnetic.	The hybridisation of	f nickel in these complex	kes, respectively, are :
	(A) sp ³	³, sp³	(B) sp ³ , dsp ²	(C) dsp ² , sp ³	(D) dsp², sp²	=−2008, 3/163]
19.	Staten Staten (A) Sta (B) Sta (C) Sta (D) Sta	nent - 1 : The g nent - 2 : Both atement-1 is Tr atement-1 is Tr atement-1 is Tr atement-1 is Tr	geometrical isomers of the geometrical isomers of the ue, Statement-2 is True; S ue, Statement-2 is True; S ue, Statement-2 is False alse, Statement-2 is True	e complex [M(NH ₃) ne complex [M(NH ₃ tatement-2 is a cor tatement-2 is NOT	⁴ Cl ₂] are optically inacti ³) ⁴ Cl ₂] possess axis of s [JE rect explanation for Sta a correct explanation for	ve, and symmetry. E–2008, 3/163] atement-1. or Statement-1
20.	Staten Staten (A) Sta (B) Sta (C) Sta (D) Sta	nent - 1 : [Fe(H nent - 2 : The H atement-1 is Tr atement-1 is Tr atement-1 is Tr atement-1 is Fa	$H_2O)_5NO]SO_4$ is paramagr Fe in [Fe($H_2O)_5NO]SO_4$ ha ue, Statement-2 is True; S ue, Statement-2 is True; S ue, Statement-2 is False alse, Statement-2 is True	netic, and as three unpaired el atatement-2 is a cor tatement-2 is NOT	lectrons. [JE rrect explanation for Sta a correct explanation f	E–2008, 3/163] atement-1. or Statement-1





21.	The compound(s) that e $(A) [Pt(en)Cl_2]$	exhibit(s) geometrical isom (B) [Pt(en) ₂]Cl ₂	nerism is(are) : (C) [Pt(en) ₂ Cl ₂]Cl ₂	(D) [Pt(NH ₃) ₂ Cl ₂]	[JEE-2009, 4/160]
22.	The spin only magnetic (A) 0	moment value (in Bohr ma (B) 2.84	agneton units) of Cr(CO), (C) 4.90	sis : (D) 5.92	[JEE-2009, 3/160]
23.	The correct structure of $HOOC - CH_2$ (A) $HOOC - CH_2$ N - HOOC (B) $N - CH_2 - HOOC$ $HOOC - CH_2$ $HOOC - CH_2$ $N - HOOC - CH_2$	ethylenediaminetetraace $-CH = CH - N CH_{2} - CH_{2} - CH_{2} - CH_{2} - CH_{2} - CH_{2} - COOH CH_{2} - CH_$	tic acid (EDTA) is : COOH - COOH - COOH - COOH	(0) 0.32	[JEE–2010, 3/163]
24.	The ionization isomer of (A) [Cr(H ₂ O) ₄ (O ₂ N)]Cl ₂ (C) [Cr(H ₂ O) ₄ Cl(ONO)]C	CH_2 HOOC $(Cr(H_2O)_4Cl(NO_2)]Cl is :$	(B) [Cr(H ₂ O) ₄ Cl ₂](NO ₂) (D) [Cr(H ₂ O) ₄ Cl ₂ (NO ₂)].H	I ₂ O	[JEE–2010, 3/163]
25.	The complex showing a $(A) \operatorname{Ni}(\operatorname{CO})_4$	a spin-only magnetic mom (B) [NiCl ₄] ^{2–}	ent of 2.82 B.M. is : (C) Ni(PPh ₃) ₄	(D) [Ni(CN) ₄] ²⁻	[JEE-2010, 5/163]
26.	Total number of geomet	rical isomers for the comp	lex [RhCl(CO)(PPh ₃)(NF	l ₃)] is :	[JEE-2010, 3/163]
27.	Geometrical shapes of (A) octahedral, tetrahed (C) square planar, tetrah	the complexes formed by ral and square planar nedral and octahedral	the reaction Ni²+ with Cl⁻, (B) tetrahedral, square p (D) octahedral square pl	CN ⁻ and H₂O, re lanar and octahe anar and octaheo	espectively, are : [JEE–2011, 3/240] dral Iral
28.	Among the following cor $K_{3}[Fe(CN)_{6}]$ (K), [Co(NH $K_{2}[Pt(CN)_{4}]$ (O) and [Zn the diamagnetic completion (A) K, L, M, N	mplexes (K-P) I ₃) ₆]CI ₃ (L) , Na ₃ [Co(oxalate (H ₂ O) ₆] (NO ₃) ₂ (P) exes are : (B) K, M, O, P) ₃] (M), [Ni(H ₂ O) ₆]Cl ₂ (N), (C) L, M, O, P	(D) L, M, N, O	[JEE-2011, 3/240]
29.	The colour of light abso (A) orange-red	rbed by an aqueous soluti (B) blue-green	ion of CuSO ₄ is : (C) yellow	(D) violet	[JEE-2012, 3/210]
30.	As per IUPAC nomencla (A) Tetraaquadiamineco (C) Diaminetetraaquaco	ature, the name of the cor balt (III) chloride balt (III) chloride	nplex [Co(H ₂ O) ₄ (NH ₃) ₂] (B) Tetraaquadiamminec (D) Diamminetetraaquad	Cl ₂ is : cobalt (III) chloride cobalt (III) chloride	[JEE-2012, 3/210]
31.	NiCl ₂ {P(C ₂ H ₅) ₂ (C ₆ H ₅)} ₂ coordination geometries (A) tetrahedral and tetra (C) tetrahedral and squa	exhibits temperature depe s of Ni ²⁺ in the paramagnet hedral are planar	endent magnetic behavior ic and diamagnetic states (B) square planar and sc (D) square planar and te	ur (paramagnetic are respectively juare planar trahedral	/diamagnetic). The [JEE-2012, 3/198]





PART - II : AIEEE PROBLEMS (PREVIOUS YEARS)

 A square planar complex is formed by hybridization of which atomic orbitals ? (1) s, p_x, p_y, d_{yz} (2) s, p_x, p_y, d_{x²-y²} (3) s, p_x, p_y, d_{z²} (4) s, The type of isomerism present in nitropentaamminechromium(III) chloride is : 	1. 2. 3. 4.	A square planar complet (1) s, p_x , p_y , d_{yz} The type of isomerism p (1) optical In the complex [Fe(H ₂ O (1) [Fe(H ₂ O) ₆] ³⁺ One mole of Co(NH ₃) ₅ Cl AgNO ₃ to give two mole (1) [Co(NH ₃) ₄ Cl ₂]Cl.NH ₃	ix is formed by hybridizati (2) s, p_x , p_y , $d_{x^2-y^2}$ resent in nitropentaammin (2) linkage) ₆] ³⁺ [Fe(CN) ₆] ³⁻ , [Fe(C ₂ O (2) [Fe(CN) ₆] ³⁻] ₃ gives 3 moles of ions on s of AgCI. The complex is (2) [Co(NH) CIICL NH	on of which atomic orbita (3) s, p_x , p_y , d_{z^2} nechromium(III) chloride (3) ionization $_4)_3]^{3-}$ and $[FeCl_6]^{3-}$, more (3) $[Fe(C_2O_4)_3]^{3-}$ dissolution in water. One	ls ? (4) s, p _x , p _y , d _{xy} is : (4) polymerization stability is showr (4) [FeCl ₆] ^{3–} mole of this react	[AIEEE- 2002] [AIEEE- 2002] on h by : [AIEEE- 2002] s with two moles of
 The type of isomerism present in nitropentaamminechromium(III) chloride is : (1) optical (2) linkage (3) ionization (4) present (1) optical (2) linkage (3) ionization (4) present (1) optical (2) linkage (3) ionization (4) present (1) optical (1) [Fe(H₂O)_e]³⁺ (2) [Fe(CN)_e]³⁻, [Fe(C₂O₄)₃]³⁻ and [FeCl_e]³⁻, more stabilities (1) [Fe(H₂O)_e]³⁺ (2) [Fe(CN)_e]³⁻ (3) [Fe(C₂O₄)₃]³⁻ (4) [F One mole of Co(NH₃)₅Cl₃ gives 3 moles of ions on dissolution in water. One mole of AgNO₃ to give two moles of AgCl. The complex is : (1) [Co(NH₃)₄Cl₂]Cl.NH₃ (2) [Co(NH₃)₄Cl]Cl₂.NH₃ (3) [Co(NH₃)₅Cl]Cl₂ (4) [C Ammonia forms the complex [Cu(NH₃)₄]²⁺ with copper ions in alkaline solution reason for it is :	2. 3. 4. 5.	The type of isomerism p (1) optical In the complex $[Fe(H_2O)(1)] [Fe(H_2O)_6]^{3+}$ One mole of Co(NH_3) ₅ Cl AgNO ₃ to give two mole (1) $[Co(NH_3)_4Cl_2]Cl.NH_3$	resent in nitropentaammin (2) linkage $)_{6}^{3+}$ [Fe(CN) $_{6}^{3-}$, [Fe(C $_{2}^{O}$ (2) [Fe(CN) $_{6}^{3-}$ $_{3}^{3}$ gives 3 moles of ions on s of AgCI. The complex is (2) [Co(NH) CIICL NH	nechromium(III) chloride (3) ionization $_{4})_{3}$] ³⁻ and [FeCl ₆] ³⁻ , more (3) [Fe(C ₂ O ₄) ₃] ³⁻ dissolution in water. One	is : (4) polymerization stability is showr (4) [FeCl ₆] ^{3–} mole of this react	[AIEEE- 2002] on h by : [AIEEE- 2002] s with two moles of
 In the complex [Fe(H₂O)_e]³⁺ [Fe(CN)_e]³⁻, [Fe(C₂O₄)₃]³⁻ and [FeCl_e]³⁻, more stabil (1) [Fe(H₂O)_e]³⁺ (2) [Fe(CN)_e]³⁻ (3) [Fe(C₂O₄)₃]³⁻ (4) [F One mole of Co(NH₃)₅Cl₃ gives 3 moles of ions on dissolution in water. One mole of AgNO₃ to give two moles of AgCl. The complex is : (1) [Co(NH₃)₄Cl₂]Cl.NH₃ (2) [Co(NH₃)₄Cl]Cl₂.NH₃ (3) [Co(NH₃)₅Cl]Cl₂ (4) [C Ammonia forms the complex [Cu(NH₃)₄]²⁺ with copper ions in alkaline solution reason for it is : (1) in alkaline solution Cu(OH)₂ is precipitated which is soluble in excess of alka (2) copper hydroxide is amphoteric. (3) in acidic solution hydration protects Cu²⁺ ions. (4) in acidic solution protons coordinates with ammonia molecule forming NH₄⁺ io available. In the coordination compound K₄[Ni(CN)₄], the oxidation state of nickel is : (1) -1 (2) 0 (3) +1 (4) + 	3. 4. 5.	In the complex $[Fe(H_2O_1)]^{3+}$ (1) $[Fe(H_2O_6)]^{3+}$ One mole of Co(NH ₃) ₅ C AgNO ₃ to give two mole (1) $[Co(NH_3)_4Cl_2]Cl.NH_3$	$[fe(CN)_6]^{3+}$ [Fe(CN)_6]^{3-}, [Fe(C ₂ O (2) [Fe(CN)_6]^{3-} gives 3 moles of ions on s of AgCI. The complex is	$_{4})_{3}]^{3-}$ and $[FeCl_{6}]^{3-}$, more (3) $[Fe(C_{2}O_{4})_{3}]^{3-}$ dissolution in water. One	stability is showr (4) [FeCl ₆] ³⁻ mole of this react	n by : [AIEEE– 2002] s with two moles of
 (1) [Fe(H₂O)_e]³⁺ (2) [Fe(CN)_e]³⁻ (3) [Fe(C₂O₄)₃]³⁻ (4) [F 4. One mole of Co(NH₃)₅Cl₃ gives 3 moles of ions on dissolution in water. One mole of AgNO₃ to give two moles of AgCl. The complex is : (1) [Co(NH₃)₄Cl₂ICI.NH₃ (2) [Co(NH₃)₄CI]Cl₂.NH₃ (3) [Co(NH₃)₅CI]Cl₂ (4) [C 5. Ammonia forms the complex [Cu(NH₃)₄]²⁺ with copper ions in alkaline solution reason for it is : (1) in alkaline solution Cu(OH)₂ is precipitated which is soluble in excess of alka (2) copper hydroxide is amphoteric. (3) in acidic solution hydration protects Cu²⁺ ions. (4) in acidic solution protons coordinates with ammonia molecule forming NH₄⁺ io available. 6. In the coordination compound K₄[Ni(CN)₄], the oxidation state of nickel is : (1) -1 (2) 0 (3) +1 (4) + 7. The co-ordination number of a central metal atom in a complex is determined by (1) the number of only anionic ligands bonded to metal ion (2) the number of ligands around a metal ion bonded by pi bonds (3) the number of ligands around a metal ion bonded by sigma and pi bonds (4) the number of ligands around a metal ion bonded by sigma bonds 	4. 5.	(1) $[Fe(H_2O)_6]^{3+}$ One mole of Co(NH_3)_5C AgNO_3 to give two mole (1) $[Co(NH_3)_4Cl_2]Cl.NH_3$	(2) [Fe(CN) ₆] ^{3–} ³ gives 3 moles of ions on s of AgCI. The complex is (2) [Co(NH) CIICL NH	(3) $[Fe(C_2O_4)_3]^{3-}$ dissolution in water. One	(4) [FeCl ₆] ^{3–} mole of this react	[AIEEE-2002]
 One mole of Co(NH₃)₅Cl₃ gives 3 moles of ions on dissolution in water. One mole of AgNO₃ to give two moles of AgCl. The complex is : (1) [Co(NH₃)₄Cl₂]Cl.NH₃ (2) [Co(NH₃)₄Cl]Cl₂.NH₃ (3) [Co(NH₃)₅Cl]Cl₂ (4) [Co Ammonia forms the complex [Cu(NH₃)₄]²⁺ with copper ions in alkaline solution reason for it is : (1) in alkaline solution Cu(OH)₂ is precipitated which is soluble in excess of alka (2) copper hydroxide is amphoteric. (3) in acidic solution hydration protects Cu²⁺ ions. (4) in acidic solution protons coordinates with ammonia molecule forming NH₄⁺ io available. In the coordination compound K₄[Ni(CN)₄], the oxidation state of nickel is : (1) -1 (2) 0 (3) +1 (4) + The co-ordination number of a central metal atom in a complex is determined by (1) the number of only anionic ligands bonded to metal ion (2) the number of ligands around a metal ion bonded by sigma and pi bonds (4) the number of ligands around a metal ion bonded by sigma bonds 	4. 5.	One mole of Co(NH ₃) ₅ Cl AgNO ₃ to give two mole (1) [Co(NH ₃) ₄ Cl ₂]Cl.NH ₃	$_{3}$ gives 3 moles of ions on s of AgCI. The complex is (2) ICo(NH) CIICL NH	dissolution in water. One	mole of this react	s with two moles of
 6. In the coordination compound K₄[Ni(CN)₄], the oxidation state of nickel is : (1) -1 (2) 0 (3) +1 (4) + (4) + (4) + (5) The co-ordination number of a central metal atom in a complex is determined by (1) the number of ligands around a metal ion bonded by sigma and pi bonds (4) the number of ligands around a metal ion bonded by sigma bonds 	5.			(3) [Co(NH) CI]CI		[AIEEE-2003]
 6. In the coordination compound K₄[Ni(CN)₄], the oxidation state of nickel is : (1) - 1 (2) 0 (3) + 1 (4) + 7. The co-ordination number of a central metal atom in a complex is determined by (1) the number of only anionic ligands bonded to metal ion (2) the number of ligands around a metal ion bonded by pi bonds (3) the number of ligands around a metal ion bonded by sigma and pi bonds (4) the number of ligands around a metal ion bonded by sigma bonds 		Ammonia forms the correason for it is : (1) in alkaline solution C (2) copper hydroxide is a (3) in acidic solution hydroxide (4) in acidic solution pro- available.	mplex $[Cu(NH_3)_4]^{2+}$ with c Cu(OH) ₂ is precipitated wh amphoteric. dration protects Cu ²⁺ ions tons coordinates with amr	opper ions in alkaline so nich is soluble in excess o nonia molecule forming N	Nution but not in of alkali. H_4^+ ions and NH_2^+	acid solution. The [AIEEE– 2003] , molecules are not
 7. The co-ordination number of a central metal atom in a complex is determined by (1) the number of only anionic ligands bonded to metal ion (2) the number of ligands around a metal ion bonded by pi bonds (3) the number of ligands around a metal ion bonded by sigma and pi bonds (4) the number of ligands around a metal ion bonded by sigma bonds 	6.	In the coordination com (1) – 1	pound $K_4[Ni(CN)_4]$, the ox (2) 0	idation state of nickel is : (3) + 1	(4) + 2	[AIEEE-2004]
	7.	The co-ordination numb (1) the number of only a (2) the number of ligand (3) the number of ligand (4) the number of ligand	per of a central metal aton nionic ligands bonded to a around a metal ion bond s around a metal ion bond s around a metal ion bond	ו in a complex is determin metal ion ded by pi bonds ded by sigma and pi bonc ded by sigma bonds	ned by : Is	[AIEEE-2004]
8. Which one is an outer orbital complex ? (1) $[Ni(NH_3)_6]^{2+}$ (2) $[Mn(CN)_6]^{4-}$ (3) $[Co(NH_3)_6]^{3+}$ (4) $[Factorial equation (2) - 1]{(2)} = 1$	8.	Which one is an outer o (1) $[Ni(NH_3)_6]^{2+}$	rbital complex ? (2) [Mn(CN) ₆] ^{4–}	(3) [Co(NH ₃) ₆] ³⁺	(4) [Fe(CN) ₆] ⁴⁻	[AIEEE-2004]
 9. Co-ordination compounds have great importance in biological systems. In this incorrect ? (1) Carboxypeptidase–A is an enzyme and contains zinc. (2) Haemoglobin is the red pigment of blood and contains iron. 					In this contact .	
 (3) Cyanocobalmin is B₁₂ and contains cobalt. (4) Chlorophylls are green pigments in plants and contain calcium. 	9.	Co-ordination compour incorrect ? (1) Carboxypeptidase-/ (2) Haemoglobin is the r (3) Cyanocobalmin is B (4) Chlorophylls are gre	Ids have great importance A is an enzyme and contand red pigment of blood and e_{12} and contains cobalt. en pigments in plants and	e in biological systems. ins zinc. contains iron. contain calcium.	In this context, v	Alexandrian (Alexandrian and Alexandrian and Alexandri and Alexandrian and Alexandrian and Alexandrian and Ale
(3) Cyanocobalmin is B_{12} and contains cobalt. (4) Chlorophylls are green pigments in plants and contain calcium. 10. Which one has largest number of isomers ? (1) [Co(en)_2Cl_2] ⁺ (2) [Co(NH_3)_5Cl]^{2+} (3) [Ir(PhR_3)_2H(CO)]^{2+} (4) [R_3]^{2+}	9. 10.	Co-ordination compour incorrect ? (1) Carboxypeptidase-// (2) Haemoglobin is the r (3) Cyanocobalmin is B (4) Chlorophylls are gre Which one has largest r (1) $[Co(en)_2Cl_2]^+$	Ids have great importance A is an enzyme and contained pigment of blood and e_{12} and contains cobalt. Then pigments in plants and the pigments in plants and the pigments of isomers ? (2) [Co(NH ₃) ₅ Cl] ²⁺	e in biological systems. ins zinc. contains iron. contain calcium. (3) [Ir(PhR ₃) ₂ H(CO)] ²⁺	(4) [Ru(NH ₃) ₄ Cl ₂	[AIEEE- 2004]



E	TOOS			COO	RDINATION COMPOUNDS
12.	The oxidation state of	of Cr in [Cr(NH ₃) ₄ Cl ₂] ⁺ is :			[AIEEE-2005]
	(1) 0	(2) +1	(3) +2	(4) +3	
13.	The IUPAC name of	K ₃ Fe(CN) ₆ is :			[AIEEE-2005]
	(1) Potassium hexac	yanoferrate(II)	(2) Potassium hexad	cyanoferrate(III)	
	(3) Potassium hexac	yanoiron(II)	(4) Tripotassium he	kacyanoiron(II)	
14.	Which of the following	ng will show optical isomeri	ism ?		[AIEEE-2005]
	(1) [Cu(NH ₃) ₄] ²⁺	(2) [ZnCl ₄] ^{2–}	(3) [Cr(C ₂ O ₄) ₃] ³⁻	(4) [Co(CN) ₆] ^{3–}	
15.	The value of 'spin on	ly' magnetic moment for or	ne of the following confi	gurations is 2.84 BM	1. The correct one is:
	(1) d⁴ (in strong field	ligand)	(2) d ⁴ (in weak field	ligand)	[AIEEE-2005]
	(3) d ³ (in weak as we	ell as strong field ligand)	(4) d⁵ (in strong field	l ligand)	
16.	Which one of the foll	owing complexes would ex	chibit the lowest value o	f paramagnetic beha	aviour ? [AIEEE– 2005]
	(1) [Co(CN) ₆] ³⁻	(2) [Fe(CN) ₆] ³⁻	(3) [Mn(CN) ₆] ^{3–}	(4) [Cr(CN) ₆] ³⁻	
17.	Nickel (Z = 28) comb number of unpaired (1) one, tetrahedral (3) one, square plana	ines with a uninegative mor electron(s) in the nickel an ar	nodentate ligand X ⁻ to fo d geometry of this com (2) two, tetrahedral (4) two, square plan	orm a paramagnetic plex ion are, respec ar	complex [NiX₄]²- The tively : [AIEEE– 2006]
18.	The IUPAC name fo	r the complex [Co(NO ₂) (NF	H_),]Cl_ is :		[AIEEE-2006]
	(1) Nitrito-N-pentaam	nminecobalt(III) chloride	(2) Nitrito-N-pentaar	nminecobalt(II) chlo	ride
	(3) Pentaamminenitr	ito-N-cobalt(II) chloride	(4) Pentaamminenit	rito-N-cobalt(III) chlo	ride
19.	In Fe(CO),, the Fe –	C bond possesses :			[AIEEE-2006]
	(1) π -character only	·	(2) both σ and π cha	iracters	
	(3) ionic character o	nly	(4) σ -character only		
20.	How many EDTA (et a Ca²+ ion ?	hylenediaminetetraacetic a	cid) molecules are requ	ired to make an octa	ahedral complex with [AIEEE– 2006]
	(1) Six	(2) Three	(3) One	(4) Two	
21.	The 'spin only' magr	etic moment (in units of Bo	ohr magneton, μ_{B}) of Ni	²⁺ in aqueous solutic	on would be
	(atomic number Ni =	28)			[AIEEE-2006]
	(1) 2.84	(2) 4.80	(3) 0	(4) 1.73	
22.	Which one of the foll	owing has a square planar	geometry?	[A]	EEE 2007, 2/120]
	(1) [NiCl₄]²- (At. no. Co = 27, Ni	(2) [PtCl₄]²- = 28, Fe = 26, Pt = 78)	(3) [CoCl ₄] ^{2–}	(4) [FeCl ₄] ²⁻	





23.	The coordination numbers is ethylene diamine) are	er and the oxidation state o	of the element 'E' in the co	mplex [E(en) ₂ (C ₂ O ₄)] NO ₂ (when 'en' [AIEEE 2008. 3/105]
	(1) 4 and 2	(2) 4 and 3	(3) 6 and 3	(4) 6 and 2
24.	In which of the following	octahedral complexes of	f Co (at no. 27), will the m	agnitude of Δ_0 be the highest? [AIEEE 2008, 3/105]
	(1) [Co(C ₂ O ₄) ₃] ³⁻	(2) [Co(H ₂ O) ₆] ³⁺	(3) [Co(NH ₃) ₆] ³⁺	(4) [Co(CN) ₆] ³⁻
25.	Which of the following h (1) $[Co(en)(NH_3)_2]^{2+}$	as an optical isomer ? (2) [Co(H ₂ O) ₄ (en)] ³⁺	(3) $[Co(en)_2(NH_3)_2]^{3+}$	[AIEEE 2009, 4/144] (4) [Co(NH ₃) ₃ Cl]⁺
26.	Which of the following p (1) $[Pd(PPh_3)_2 (NCS)_2]$ a (3) $[PtCl_2 (NH_3)_4 Br_2$ and	airs represents linkage is nd [Pd(PPh ₃) ₂ (SCN) ₂] [Pt $Br_2(NH_3)_4$] Cl ₂	omers ? (2) [Co(NH ₃) ₅ NO ₃] SO ₄ ; (4) [Cu (NH ₃) ₄] [Pt Cl ₄] a	[AIEEE 2009, 4/144] and [Co (NH ₃) ₅ (SO ₄)] NO ₃ nd [Pt (NH ₃) ₄ [CuCl ₄]
27.	A solution containing 2 exchanger. The chloride (molar mass = 143.5 g r	.675 g of CoCl ₃ . 6 NH ₃ e ions obtained in solutio nol ⁻¹). The formula of the	(molar mass = 267.5 g n were treated with exce complex is (At. mass of a	mol ⁻¹) is passed through a cation ess of $AgNO_3$ to give 4.78 g of AgCl Ag = 108 u) [AIEEE 2010, 8/144]
	(1) [Co(NH ₃) ₆] Cl ₃	(2) $[CoCl_2(NH_3)_4]$ Cl	(3) $[CoCl_{3}(NH_{3})_{3}]$	(4) $[CoCl(NH_3)_5] Cl_2$
28.	Which one of the followi (1) $[Zn(en)(NH_3)_2]^{2+}$ (en = ethylenediamine)	ng has an optical isomer (2) [Co(en) ₃]³+	? (3) [Co(H ₂ O) ₄ (en)] ³⁺	[AIEEE 2010, 4/144] (4) [Zn(en) ₂] ²⁺
29.	Which of the following fa (1) The complex involve (2) The complex is paran (3) The complex is an or (4) The complex gives w	acts about the complex [C is d ² sp ³ hybridisation and magnetic uter orbital complex /hite precipitate with silve	Cr(NH ₃) ₆] Cl ₃ is wrong ? I is octahedral is shape r nitrate solution	[AIEEE 2011, 4/144]
30.	The magnetic moment ((1) 1.82 BM	(spin only) of [NiCl ₄] ^{2–} is : (2) 5.46 BM	(3) 2.82 BM	[AIEEE 2011, 4/144] (4) 1.41 BM
31.	Which among the follow	ing will be named as dibro	omidobis(ethylene diamin	e) chromium(III) bromide ? [AIEEE 2012, 4/120]
	(1) $[Cr(en)_3 Br_3]$	(2) $[Cr(en)_2 Br_2] Br$	(3) [Cr (en)Br ₄] ⁻	(4) [Cr (en) Br ₂] Br
32.	Which of the following c	omplex species is not ex	pected to exhibit optical	isomerism ? [AIEEE 2013]
	(1) [Co(en) ₃] ³⁺	(2) $[Co(en)_2 Cl_2]^+$	$(3) [Co(NH_3)_3Cl_3]$	(4) $[Co(en)(NH_3)_2Cl_2]^+$



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EXERCISE # 4

NCERT QUESTIONS

- 1. Explain the bonding in coordination compounds in terms of Werner's postulates.
- **2.** $FeSO_4$ solution mixed with $(NH_4)_2SO_4$ solution in 1 : 1 molar ratio gives the test of Fe²⁺ ion but CuSO₄ solution mixed with aqueous ammonia in 1 : 4 molar ratio does not give the test of Cu²⁺ ion. Explain why?
- **3.** Explain with two examples each of the following: coordination entity, ligand, coordination number, coordination polyhedron, homoleptic and heteroleptic.
- 4. What is meant by unidentate, didentate and ambidentate ligands? Give two examples for each.
- **5.** Specify the oxidation numbers of the metals in the following coordination entities : (i) $[Co(H_2O)(CN)(en)_2]^{2+}$ (ii) $[CoBr_2(en)_2]^+$ (iii) $[PtCI_4]^{2-}$ (iv) $K_3[Fe(CN)_6]$ (v) $[Cr(NH_3)_3CI_3]$
- 6. Using IUPAC norms write the formulas for the following :

 (i) Tetrahydroxozincate(II)
 (ii) Potassium tetrachloridopalladate(II)
 (iii) Diamminedichloridoplatinum(II)
 (iv) Potassium tetracyanonickelate(II)
 (v) Pentaamminenitrito-O-cobalt(III)
 (vi) Potassium tri(oxalato)chromate(III)
 (vii) Potassium tri(oxalato)chromate(III)
 (viii) Hexaamminenitrito-N-cobalt(III)
 (x) Pentaamminenitrito-N-cobalt(III)
 (x) Pentaamminenitrito-N-cobalt(III)

- 8. List various types of isomerism possible for coordination compounds, giving an example of each.
- 9. How many geometrical isomers are possible in the following coordination entities? (i) $[Cr(C_2O_4)_3]^{3-}$ (ii) $[Co(NH_3)_3Cl_3]$
- **10.** Draw the structures of optical isomers of : (i) $[Cr(C_2O_4)_3]^{3-}$ (ii) $[PtCl_2(en)_2]^{2+}$ (iii) $[Cr(NH_3)_2Cl_2(en)]^+$
- 12. Write all the geometrical isomers of [Pt(NH₃)(Br)(Cl)(py)] and how many of these will exhibit optical isomers?
- Aqueous copper sulphate solution (blue in colour) gives :
 (i) a green precipitate with aqueous potassium fluoride and
 (ii) a bright green solution with aqueous potassium chloride. Explain these experimental results.







- 14. What is the coordination entity formed when excess of aqueous KCN is added to an aqueous solution of copper sulphate? Why is it that no precipitate of copper sulphide is obtained when $H_2S(g)$ is passed through this solution?
- **15.** Discuss the nature of bonding in the following coordination entities on the basis of valence bond theory : (i) $[Fe(CN)_{e}]^{4-}$ (ii) $[FeF_{e}]^{3-}$ (iii) $[Co(C_{2}O_{4})_{3}]^{3-}$ (iv) $[CoF_{e}]^{3-}$
- **16.** Draw figure to show the splitting of d orbitals in an octahedral crystal field.
- 17. What is spectrochemical series? Explain the difference between a weak field ligand and a strong field ligand.
- **18.** What is crystal field splitting energy? How does the magnitude of Δ_0 decide the actual configuration of d orbitals in a coordination entity?
- **19.** $[Cr(NH_3)_{e}]^{3+}$ is paramagnetic while $[Ni(CN)_{a}]^{2-}$ is diamagnetic. Explain why?
- **20.** A solution of $[Ni(H_2O)_{\alpha}]^{2+}$ is green but a solution of $[Ni(CN)_{a}]^{2-}$ is colourless. Explain.
- **21.** $[Fe(CN)_{\beta}]^{4-}$ and $[Fe(H_{2}O)_{\beta}]^{2+}$ are of different colours in dilute solutions. Why?
- 22. Discuss the nature of bonding in metal carbonyls.
- 23. Give the oxidation state, d orbital occupation and coordination number of the central metal ion in the following complexes:
 (i) K₂[Co(C₂O₄)₂]
 (ii) (NH₄)₂[CoF₄]
 (ii) cis-[Cr(en)₂Cl₂]Cl
 (iv) [Mn(H₂O)₆]SO₄
- **24.** Write down the IUPAC name for each of the following complexes and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex : (i) $K[Cr(H_2O)_2(C_2O_4)_2]$.3H₂O (ii) $CrCl_3(py)_3$ (iv) $Cs[FeCl_4]$ (v) $K_4[Mn(CN)_6]$
- **25.** What is meant by stability of a coordination compound in solution? State the factors which govern stability of complexes.
- **26.** What is meant by the chelate effect? Give an example.
- 27. Discuss briefly giving an example in each case the role of coordination compounds in :
 (i) biological systems
 (ii) medicinal chemistry and
 (iii) analytical chemistry
 (iv) extraction/metallurgy of metals.
- **28.** How many ions are produced from the complex $Co(NH_3)_6Cl_2$ in solution? (i) 6 (ii) 4 (iii) 3 (iv) 2
- **29.** Amongst the following ions which one has the highest magnetic moment value? (i) $[Cr(H_2O)_6]^{3+}$ (ii) $[Fe(H_2O)_6]^{2+}$ (iii) $[Zn(H_2O)_6]^{2+}$
- **30.** The oxidation number of cobalt in $K[Co(CO)_4]$ is : (i) + 1 (ii) + 3 (iii) - 1 (iv) - 3
- **31.** Amongst the following, the most stable complex is : (i) $[Fe(H_2O)_6]^{3+}$ (ii) $[Fe(NH_3)_6]^{3+}$ (iii) $[Fe(C_2O_4)_3]^{3-}$ (iv) $[FeCl_6]^{3-}$
- **32.** What will be the correct order for the wavelengths of absorption in the visible region for the following : $[Ni(NO_2)_6]^{4-}$, $[Ni(NH_3)_6]^{2+}$, $[Ni(H_2O)_6]^{2+}$?

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ANSWERS

EXERCISE # 1

							PA	RT # I						
A-1, A-8, B-6, B-1, C-6, C-1, E-3, E-10 G-3 G-1 H-3, L5	3. 3. 3. 0.	 (A) (A) (C) (D) (B) (D) (A) (C) (A) (D) (B) (D) 	A-2. A-9. B-7. C-7. C-14. E-4. E-11. G-4. G-11. H-4.	 (B) (C) (B) (C) (C) (C) (A) (C) (C) (D) (C) 	A-3. B-1. B-8. C-1. C-8. D-1. E-5. F-1. G-5. G-12. H-5.	 (D) (C) (B) (A) (A) (D) (A) (C) (A) (C) (C) (C) (D) 	A-4. B-2. B-9. C-2. C-9. D-2. E-6. F-2. G-6. G-13. I-1.	 (D) (C) (C) (B) (A) (C) (B) (C) (C) (C) (D) 	A-5. B-3. B-10. C-3. C-10. D-3. E-7. F-3. G-7. G-14. I-2.	 (A) (A) (B) (A) (B) (A) (D) (D) (D) (C) (D) 	A-6. B-4. B-11. C-4. C-11. E-1. E-8. G-1. G-8. H-1. I-3.	 (D) (B) (A) (A) (B) (D) (C) (A) (C) (C) (C) (C) (C) 	A-7. B-5. B-12. C-5. C-12. E-2. E-9. G-2. G-9. H-2. I-4.	 (B) (D) (C) (C) (C) (C) (C) (C) (B) (A)
I-J.		(D)	1-0.	(0)	1-7.	(D)	PA	RT # II						
1.		(B)	2.	(D)	3.	(A)	4.	(B)	5.	(D)	6.	(C)	7.	(B)
8.		(D)	9.	(A – p,	q, r) ; (B	– p, s);	(C – q, I	r);(D – (q, r)					
10.		(A – p,	r, s, t) ; (B – q) ;	(C – q) ;	(D – p, r	r,s) 11 .		(A– p,s);(B-p	o, s, t) ; (C – s, t)	; (D – p	, s)
12.		(A)	13.	(C)	14.	(A)	15.	(B)	16.	(A)	17.	(B)	18.	(C)
19.		(A)	20.	(D)	21.	(B)	22.	(C)	23.	False	24.	True	25.	False
26.		False	27.	True	28.	False	29.	True	30.	True	31.	True	32.	False
	EXERCISE # 2													
1. 8. 15. 22. 29. 26.		(A) (C) (D) (C) (ABC)	2. 9. 16. 23. 30. 37.	(A) (B) (A) (C) (ACD) (AD)	3. 10. 17. 24. 31. 38.	(A) (D) (A) (C) (BCD) (BCD)	4. 11. 18. 25. 32. 39. PAI	(C) (B) (C) (B) (BD) (ABCD) RT # II	5. 12. 19. 26. 33. (AE	(A) (D) (C) (C) BD)	6. 13. 20. 27. 34.	(D) (B) (A) (D) (BD)	7. 14. 21. 28. 35.	(B) (A) (C) (D) (CD)
1.	(c) (d)	[Fe(CO [Fe(C ₂ C)₅],)₄)₃]³−,		Pentaca Trioxala	arbonyliro toferrate	on(0) (III)	OR	Tris(oxa	alato)ferra	ate(III)			

- (e) $[Cu(NH_3)_4]SO_4$, Tetraamminecopper(II) sulphate
- (f) **Na[Cr(OH)**₄], Sodium tetrahydroxidochromate(III)
- (g) **Co(gly)**₃, Triglycinatocobalt(III) OR Tris(glycinato)cobalt(III)
- (h) $[Fe(H_2O)_5(SCN)]^{2+}$, Pentaaquathiocyanato-S-iron(III)
- (i) **K**₂[**Hgl**₄], Potassium tetraiodidomercurate(II)
- (j) **Co[Hg(SCN)**₄], Cobalt(II) tetrathiocyanato–S–mercurate(II)





- (k) $Fe_{4}[Fe(CN)_{6}]_{3}$, Iron(III) hexacyanidoferrate(II)
- (I) K₃[Co(NO₂)₆], Potassium hexanitrito–N–cobaltate(III)
- (m) [Ni(dmg)₂], Bis(dimethylglyoximato)nickel(II)
- (n) K₂[PtCl₆], Potassium hexachloridoplatinate(IV)
- (o) Na₂[Fe(CN)₅NO⁺], Sodium pentacyanidonitrosoniumferrate(II)
- (p) $[Fe(H_2O)_{5}(NO^{*})]SO_{4}$, Pentaaquanitrosoniumiron(I) sulphate
- (q) **[Cu(CN)₄]³⁻**, Tetracyanidocuperate(I)
- 2. (a) Diamminetriaquahydroxidochromium(III) nitrate
 - (b) Tetrakis(pyridine)platinum(II) tetraphenylborate(III)
 - (c) Dibromidotetracarbonyliron(II)
 - $(d) Tetraammine cobalt (III)-\mu-amido-\mu-hydroxidobis (ethylene diamine or ethane-1, 2-diamine) cobalt (III) chloride (diamine) cobalt (III)-\mu-amido-\mu-hydroxidobis (ethylene diamine) cobalt (III)-hydroxidobis (ethyle$

(ii) 2

(iii) 1

	$(NH_3)_4$ Co OH Co(en) ₂	Cl ₄
	$\begin{bmatrix} (NH_4)[Cr(NH_3)_2(NCS)_4] \\ (NH_4)[Cr(NH_3)_2(NCS)_4] \end{bmatrix}$	
	$[Fe(NH_{3})_{5}N_{2}]CI_{2}$ $[Fe(\eta^{5}-C_{5}H_{5})_{2}]$	
)	Ba[Zr(OH) ₂ (ONO) ₂ (ox)] [Pt(py) ₄][PtCl ₄] [(NH.) (H.O)Co–CN–Co(NH.)	.Br] ⁴⁺

 $[Cr(NH_3)_2(H_2O)_3(OH)](NO_3)_2$

 $[Pt(Py)_4][B(ph)_4]_2$

 $[Fe(Br)_{2}(CO)_{4}]$

(e) Ammonium diamminetetrakis(isothiocyanato)chromate(III).

(b)

- (f) Pentaamminedinitrogenruthenium(II) chloride
- (g) Bis(cyclopentadienyl)iron(II)

ii < i < iv < iii.

3.

(a)

- $(h) \ \ Barium \ dihydroxidodinitrito-O-oxalatozirconate(IV)$
- (i) Tetrapyridineplatinum(II) tetrachloridoplatinate(II)
- $(j) \quad Tetraammine a quacobalt (III) \mu cyanidote traammine bromido cobalt (III) c$

(i) 6

4.		Complex CN =2	Geometry	Hybridisation	Number of unpaired electrons(n)	Mag. moment
	(a)	[Ag(NH₃)₂]*	Linear	sp	0	0
	(b)	[Cu(CN)]	Linear	sp	0	0
	(c)	[AuCl ₂]	Linear	sp	0	0
		CN = 4				
	(d)	$[PtCl_2(NH_3)_2]$	Square Planar	dsp ²	0	0
	(e)	[Zn(CN)] ^{2–}	Tetrahedral	sp ³	0	0
	(f)	[Cu(CN)] ^{3–}	Tetrahedral	sp ³	0	0
	(g)	[MnBr ₄] ²⁻	Tetrahedral	sp ³	5	5.92 BM
	(h)	[Cu(NH ₂) ₄] ²⁺	Square Planar	dsp ²	1	1.73 BM
	(i)	[Col ₄] ²⁻	Tetrahedral	sp ³	3	3.87 BM
		CN = 6				
	(j)	[Mn(CN) _e] ³⁻	Octahedral	d ² sp ³	2	2.83 BM
	(k)	[Cr(NH ₃) ₆] ³⁺	Octahedral	d ² sp ³	3	3.87 BM
	(I)	[Fe(CN) ₆] ³⁻	Octahedral	d ² sp ³	1	1.73 BM
	(m)	[lr(NH ₃) ₆] ³⁺	Octahedral	d²sp³	0	0
	(n)	[V(CO) ₆]	Octahedral	d²sp³	1	1.73 BM
	(o)	[Fe(H ₂ O) ₆] ²⁺	Octahedral	sp ³ d ²	4	4.90 BM
	(p)	[MnCl̃ _s] ^{3_}	Octahedral	sp ³ d ²	4	4.90 BM
		-				





6.

5. (i) H₁₂O₆Cl₃Cr

A should be $[Cr(H_2O)_6]Cl_3$ because it is not reacting with H_2SO_4 if there would have some moles of water outer the coordination sphere then it will be reacting with H_2SO_4

(B) weight of $H_{12}O_6CI_3Cr = 266.5$

266.5 × $\frac{6.73}{100}$ = 17.96 ≈ 18 (H₂O weight)

It means one mole of H₂O in B complex outer the coordination sphere

 $B = [Cr[H_2O]_5C\overline{I}]CI_2.H_2O$

(C)
$$266.5 \times \frac{13.5}{100} \approx 36 (2H_2O \text{ weight})$$

It means $C = [Cr(H_2O)_4Cl_2]Cl_2H_2O$

(ii) $A = [Cr(H_2O)_6]Cl_3^2; B = [Cr(H_2O)_5Cl]Cl_2.H_2O; C = [Cr(H_2O]_4Cl_2]Cl.2H_2O$

(iv) C – 1 mole AgCl ppt; B – 2 mole AgCl ppt; A – 3 mole AgCl ppt

(i) $[Cr(NH_3)_4Cl Br]Cl \stackrel{aq.}{\longleftarrow} [Cr(NH_3)_4Cl Br]^+ + Cl^-; Ag^+ + Cl^- \longrightarrow AgCl \downarrow (white); soluble in dilute NH_3.$

 $[Cr(NH_3)_4Cl_2]Br \stackrel{aq.}{\longleftarrow} [Cr(NH_3)_4Cl_2]^+ + Br^- ; \qquad Ag^+ + Br^- \longrightarrow AgBr \downarrow (yellow) ; soluble in conc. NH_3.$ So, A = [Cr(NH_3)_4Cl Br]Cl and B = [Cr(NH_3)_4Cl_2]Br.

(ii) In both complexes chromium is in +3 oxidation state. Chromium with 3d³ configuration has 3 unpaired electrons with weak field as well as strong field ligand. So, the hybridisation scheme is as follow :



(iii) $\mu = \sqrt{n(n+2)} = \sqrt{15}$ (iv) EAN = 24 - 3 + 12 = 33 (v) Yes, both have two ions per formula unit. (vi) AgCl + 2NH₃ \implies [Ag(NH₃)₂]Cl ; AgBr + 2NH₃ \implies [Ag(NH₃)₂]Br

7. (a)



[Cr(edta)]⁻ enantiomers

[Ru(en)₃]²⁺ enantiomers



[Pt(dien)]⁺

diethylenetriamine

dien NH₂CH₂CH₂NHCH₂CH₂NH₂

tridentate

Neither $[Cr(edta)]^-$ nor $[Ru(en)_3]^{2+}$ has a mirror plane or a centre of inversion; so both are chiral (they also have no higher S_n axis); [Pt (dien)Cl]⁺ has a plane of symmetry and hence is achiral. **(b)** Carbonylhydridobis(trimethylphosphine)irridium(I).

Ir is in +1 oxidation state; 5d⁸ configuration has higher CFSE and thus the complex is square planar.









10.



Both cis and trans isomers do not show optical activity because of the presence of plane and centre of symmetries. (b) It will not exhibit geometrical isomerism as it exists only in one form as given below.



(c) In tetrahedral geometry all positions are adjacent to each other so it will not exhibit geometrical isomerism. (d) In square planar geometry there is plane of symmetry. So it does not show optical isomerism.









(e) It will not exhibit geometrical isomerism as it exists only in one form as given below.

(f) $Cr(NH_3)_2(H_2O)_2Cl_2]^+$ is of $Ma_2b_2c_2$ type which has following isomeric forms.

(aa)(bb)(cc) (aa)(bc)(bc) (bb)(ac)(ac) (cc)(ab)(ab) (ab)(ac)(bc)



11. (a) No ; (b) Yes ; (c) Yes ; (d) Yes ; (e) Yes ; (f) No.

12. \Rightarrow Electronic distribution in a tetrahedral d⁶ ion











EXERCISE # 3

PART # I

1.	In $[Co(NH_3)_6]^{3+}$, the oxidation state of cobalt is +3 and coordination number is 6. So
	$\begin{array}{cccc} 3d & 4s & 4p \\ \hline Co^{3+} ion & 1 & 1 & 1 & 1 \\ \hline \end{array}$
	NH ₃ is stronger field ligand. So it compels for the pairing of electrons. Then
	$[Co(NH_3)_6]^{3+}$
	d^2sp^3 - hybridisation Thus with 6 coordination number, the complex [Co(NH $_3)_6$] is octahedral as given below.
	$ \begin{bmatrix} NH_3 \\ NH_3 \\ NH_3 \\ NH_3 \end{bmatrix}^{3+} $
	In $[Ni(CN)_4]^{2-}$, the oxidation state of nickel is +2 and coordination number is 4. So
	Ni ²⁺ $3d$ $4s$ $4p$ $1l$ $1l$ $1l$ 1 1
	CN ⁻ is stronger field ligand. So it compels for the pairing of electrons. Then
	$[Ni(CN)_4]^2 - 1l $
	dsp ² - hybridisation Thus with 4 coordination number four, the complex is square planar as given below
	$\begin{bmatrix} CN & \dots & CN \\ \vdots & Ni & \vdots \\ CN & \dots & CN \end{bmatrix}^{2-}$
	In [Ni(CO) ₄], the oxidation state of nickel is zero and the coordination number is four. So
	Ni (O) $\begin{array}{cccccccccccccccccccccccccccccccccccc$
	CO is strong field ligand. So it compels for the pairing of electrons; so nickel under goes rearrangement. Then
	$[Ni(CO)_4] \qquad 1 1 1 1 1 1 1 1 1 1$
	Thus with 4 coordination number, the complex is tetrahedral as given below.
	O = C



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2. (A)

3. As form(A) gives white precipitate with $AgNO_3$ solution and precipitate is readily soluble in dilute aqueous ammonia, the complex must be having the Cl⁻ ion in the ionisation sphere. Hence(A) must be having the formula [Cr(NH₃)₄ClBr]⁺Cl⁻.

 $Ag^+ + Cl^- \rightarrow AgCl \downarrow (white).$

AgCl + 2NH₃ \rightarrow [Ag(NH₃)₂]⁺Cl⁻ (soluble complex).

Similarly form (B) gives pale yellow precipitate with AgNO₃ and precipitate is soluble in concentrated ammonia, the complex must be having the Br⁻ in the ionisation sphere. Hence (B) must be having the formula [Cr(NH₃)₄Cl₂]⁺Br⁻.

Ag⁺ + Br⁻ → AgBr \downarrow (pale yellow).

AgBr + 2NH₃ \rightarrow [Ag(NH₃)₂]⁺ Br (soluble complex).

In both complexes, the chromium is the central metal ion with +3 oxidation state. In both, the ammonia is a strong field ligand so it compels for pairing of electrons. Thus,



As it contains three unpaired electrons, So, $\mu = \sqrt{3(3+2)} = 3.872$ B.M.

4. In $[NiCl_{a}]^{2-}$ nickel is in+2 oxidation state and Cl⁻ is weak field ligand. So,



 $\label{eq:main} \begin{array}{ll} \mu=\sqrt{n(n+2)} \ = \ \sqrt{2(2+2)} \ = \ 2.82 \ B.M. & ; \\ \end{array} \\ \begin{array}{ll} n=No. \ of \ unpaired \ electrons. \\ Hence \ with \ coordination \ number \ four, \ the \ structure \ is \end{array}$



 $In[Ni(CN)_4]^2$ - nickel is in+2 oxidation state and CN^- is strong field ligand. So it compels for pairing of electrons. Then,



As all electrons are paired so diamagnetic. Hence with coordination number four, the structure is



5. Let n is the number of unpaired electron in the chromium ion.

Since $\mu = \sqrt{n(n+2)}$ or $1.73 = \sqrt{n(n+2)}$ B.M. or $1.73 \times 1.73 = n^2 + 2n$. Hence n = 1.



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As the CN⁻ and NH_a are strong fields ligands, they compel for pairing of electrons. So,



Hence, the oxidation state of chromium is +1 (having $3d^5$ configuration). So according to charge on the complex NO should be NO⁺ and the structure of this complex is octahedral with d^2sp^3 hybridisation as given below



According to IUPAC nomenclature its name is : Potassium amminetatracyanidonitrosoniumchromate(I) **OR** Potassium amminetatracyanidonitrocyliumchromate(I).

6. (D) **7.** (C)

8. $Ni^{2+} + 2dmg \xrightarrow{NH_4OH} [Ni(dmg)_2] \downarrow (bright red).$

It acquires stability through chelation and intra molecular H-bonding.

In $[Ni(dmg)_2]$ the nickel is in +2 oxidaiton state and to have square planar geometry because of chelation the pairing of electrons takes place. So

	3d						_4s_		<u>4p</u>		
[Ni(DMG) ₂]	11	11	11	1,1						N	i I
						dsp	<u></u> ²-hyb	rid	isati	on	-

As all electrons are paired, so complex is diamagnetic. Nickel with coordination number four will have the structure as given below.



rosy red ppt

- **9.** (A)
- 10. (a) $Fe^{3+} \xrightarrow{SCN^{-}} blood red[Fe((H_2O)_5(SCN)]^{2+}(A) \xrightarrow{F^{-}(excess)} colourless(B) [Fe(F_6)]^{3-} + SCN^{-} + 5H_2O.$ (A) Pentaaquathiocyanato-S-iron(III) ; (B) Hexafluoridoferrate(III)

(b) Fe³⁺ CFSE electron configuration, $t_{2g}^{1,1,1} e_{g}^{1,1}$; as F⁻ being weak field ligand does not compel for pairing of electrons. So it contains five unpaired electrons.

So,
$$\mu = \sqrt{5(5+2)} = 5.93$$
 B.M.

The magnetic moment value of B is 5.93 B.M.

11.	(A)	12.	(A)	13.	(C)	14.	(C)	15.	(B)					
16.	(A) – p), q, s ;	(B) – p,	r, s ; (C)	— q, s;	(D) – q,	s 17.	(C)	18.	(B)	19.	(B)	20. (A))
21.	(C), (D) 22.	(A)	23.	(C)	24.	(B)	25.	(B)	26.	3	27.	(B) Č	,
28.	(C)	29.	(A)	30.	(D)	31.	(C)							





	PART # II												
1.	(2)	2.	(2), (3)	3.	(3)	4.	(3)	5.	(4)	6.	(2)	7.	(4)
8.	(1)	9.	(4)	10.	(1)	11.	(4)	12.	(4)	13.	(2)	14.	(3)
15.	(1)	16.	(1)	17.	(2)	18.	(4)	19.	(2)	20.	(3)	21.	(1)
22.	(2)	23.	(3)	24.	(4)	25.	(3)	26.	(1)	27.	(1)	28.	(2)
29.	(3)	30.	(3)	31.	(2)	32.	(3)						

EXERCISE # 4

1. (i) $[Co(NH_3)_4(H_2O)_2]Cl_3$ (iv) $[Pt(NH_3)BrCl(NO_2)]^-$ (ii) $K_2[Ni(CN)_4]$ (v) $[PtCl_2(en)_2](NO_3)_2$ (iii) $[Cr(en)_3]Cl_3$ (vi) $Fe_4[Fe(CN)_6]_3$

- 2. (i) Hexaamminecobalt(III) chloride
 - (ii) Pentaamminechloridocobalt(III) chloride
 - (iii) Potassium hexacyanoferrate(III)
 - (iv) Potassium trioxalatoferrate(III)
 - (v) Potassium tetrachloridopalladate(II)
 - (vi) Diamminechlorido(methanamine)platinum(II) chloride
- 3. (i) Both geometrical (cis-, trans-) and optical isomers for cis can exist.
 - (ii) Two optical isomers can exist.
 - (iii) There are 10 possible isomers. (Hint: There are geometrical, ionisation and linkage isomers possible).
 - (iv) Geometrical (cis-, trans-) isomers can exist.
- 4. The ionisation isomers dissolve in water to yield different ions and thus react differently to various reagents : $\begin{bmatrix} Co(NH_3)_5Br]SO_4 + Ba^{2+} \rightarrow BaSO_4 (s) \\ \begin{bmatrix} Co(NH_3)_5SO_4]Br + Ba^{2+} \rightarrow No \text{ reaction} \\ \begin{bmatrix} Co(NH_3)_5Br]SO_4 + Ag^+ \rightarrow No \text{ reaction} \\ \begin{bmatrix} Co(NH_3)_5SO_4]Br + Ag^+ \rightarrow AgBr (s) \end{bmatrix}$
- 6. In Ni(CO)₄, Ni is in zero oxidation state whereas in NiCl₄²⁻, it is in +2 oxidation state. In the presence of CO ligand, the unpaired d electrons of Ni pair up but Cl⁻ being a weak ligand is unable to pair up the unpaired electrons.
- 7. In presence of CN^- , (a strong ligand) the 3d electrons pair up leaving only one unpaired electron. The hybridisation is d^2sp^3 forming inner orbital complex. In the presence of H_2O , (a weak ligand), 3d electrons do not pair up. The hybridisation is sp^3d^2 forming an outer orbital complex containing five unpaired electrons, it is strongly paramagnetic.
- 8. In the presence of NH_3 , the 3d electrons pair up leaving two d orbitals empty to be involved in d^2sp^3 hybridisation forming inner orbital complex in case of $[Co(NH_3)_6]^{3+}$. In $Ni(NH_3)_6^{2+}$, Ni is in +2 oxidation state and has d^8 configuration, the hybridisation involved is sp^3d^2 forming outer orbital complex.
- **9.** For square planar shape, the hybridisation is dsp². Hence the unpaired electrons in 5d orbital pair up to make one d orbital empty for dsp² hybridisation. Thus there is no unpaired electron.
- **11.** The overall dissociation constant is the reciprocal of overall stability constant i.e. $1/\beta_4 = 4.7 \times 10^{-14}$

