FREE NOTES · NCERT + JEE/NEET LEVEL

Coordination Compounds

Werner's theory, zaroori terms, ligands aur denticity, IUPAC naming aur formulas, isomerism, valence bond theory, crystal field theory, rang aur magnetism, metal carbonyls aur uses.

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01 Werner's theory

- Metal do tarah ki valency dikhata: **primary** (ionisable, = oxidation state, negative ions se poori) aur **secondary** (non-ionisable, = coordination number, ligands se poori).
- Secondary valencies space me fixed direction me ⇒ fixed shape (6 ⇒ octahedral, 4 ⇒ tetrahedral ya square planar).
- Aise likhte: $[Co(NH_3)_6]Cl_3$: bracket ke andar = coordination sphere; bahar = counter ions (ionisable).

Compound	Formula	Per mol AgCl ppt
$CoCl_3{\cdot}6NH_3$ (peela)	$[Co(NH_3)_6]Cl_3$	3
$CoCl_3{\cdot}5NH_3$ (purple)	$[CoCl(NH_3)_5]Cl_2$	2
$CoCl_3{\cdot}4NH_3$ (hara/violet)	$[CoCl_2(NH_3)_4]Cl$	1

Double salt (Mohr's salt, potash alum) paani me poora simple ions me toot jaata; **complex** apna complex ion bachaye rakhta.

02 Key terms & ligands

- **Central atom/ion:** Lewis acid jo electron pairs leta ($[NiCl_2(H_2O)_4]$ me Ni).
- **Ligand:** Lewis base jo electron pair deta. **Donor atom** = jo sach me bond banata.
- **Coordination number** = ligands se metal tak σ bonds ki ginti.
- **Homoleptic** (ek hi type ka ligand, $[Co(NH_3)_6]^{3+}$) vs **heteroleptic** ($[Co(NH_3)_4Cl_2]^{+}$).

Type	Examples
Unidentate	Cl^-, H_2O, NH_3, CN^-, CO
Bidentate	en ($H_2NCH_2CH_2NH_2$), oxalate $C_2O_4^{2-}$ (ox)
Hexadentate	$EDTA^{4-}$ (2 N + 4 O)
Ambidentate (do possible donor atoms)	NO_2^- (nitro N / nitrito O), SCN^- (thiocyanato S / isothiocyanato N), CN^-

CHELATE

Polydentate ligand metal ke saath ring banata ⇒ **chelate**, jo unidentate wale complex se zyada stable (chelate effect). EDTA se Pb poisoning hatate aur paani ki hardness (Ca^{2+}, Mg^{2+}) naapte.

03 IUPAC naming & formulas

1. Pehle cation, phir anion.
2. Sphere ke andar: pehle ligands **alphabetical order** me, phir metal.
3. Anionic ligands -o pe khatam (chlorido, cyanido, hydroxido, oxalato); neutral ke naam same, siwaay **aqua** (H_2O), **ammine** (NH_3), **carbonyl** (CO), nitrosyl (NO).
4. Prefix di, tri, tetra (en jaise complex naam ke liye bis, tris); alphabetical order me prefix ginte nahi.
5. Metal ki oxidation state Roman number me bracket me.
6. Anionic complex: metal ka naam **-ate** pe khatam (cobaltate, ferrate, cuprate, argentate, plumbate).

Formula	Naam
$[Cr(NH_3)_3(H_2O)_3]Cl_3$	triamminetriaquachromium(III) chloride
$[Co(H_2NCH_2CH_2NH_2)_3]_2(SO_4)_3$	tris(ethane-1,2-diamine)cobalt(III) sulphate
$K_3[Fe(CN)_6]$	potassium hexacyanidoferrate(III)
$[Ag(NH_3)_2][Ag(CN)_2]$	diamminesilver(I) dicyanidoargentate(I)
$[Pt(NH_3)_2Cl(NO_2)]$	diamminechloridonitrito-N-platinum(II)

04 Isomerism

Type	Kya badalta	Example
Geometrical (cis/trans)	Ligands ki position	$[Pt(NH_3)_2Cl_2]$ square planar; $[Co(NH_3)_4Cl_2]^+$ octahedral; $[Co(NH_3)_3(NO_2)_3]$ me fac/mer
Optical	Mirror images jo ek doosre pe fit nahi hote	$[Co(en)_3]^{3+}$; cis-$[PtCl_2(en)_2]^{2+}$ (trans optically active nahi)
Linkage	Ambidentate ligand ka donor atom	$[Co(NH_3)_5(NO_2)]Cl_2$ vs $[Co(NH_3)_5(ONO)]Cl_2$
Coordination	Cation aur anion complex ke beech ligands ki adla-badli	$[Co(NH_3)_6][Cr(CN)_6]$ vs $[Cr(NH_3)_6][Co(CN)_6]$
Ionisation	Counter ion aur ligand ki adla-badli	$[Co(NH_3)_5(SO_4)]Br$ vs $[Co(NH_3)_5Br]SO_4$
Solvate (hydrate)	Paani andar vs bahar	$[Cr(H_2O)_6]Cl_3$ (violet) vs $[CrCl(H_2O)_5]Cl_2 \cdot H_2O$ (hara)

Tetrahedral complexes geometrical isomerism nahi dikhate.

05 Valence bond theory (VBT)

CN	Hybridisation	Shape	Example
4	sp^3	Tetrahedral	$[NiCl_4]^{2-}$ (paramagnetic, 2 unpaired), $[Ni(CO)_4]$
4	dsp^2	Square planar	$[Ni(CN)_4]^{2-}$ (diamagnetic)
6	d^2sp^3 (inner orbital, low spin)	Octahedral	$[Co(NH_3)_6]^{3+}$ diamagnetic, $[Fe(CN)_6]^{3-}$
6	sp^3d^2 (outer orbital, high spin)	Octahedral	$[CoF_6]^{3-}$ paramagnetic (4 unpaired)

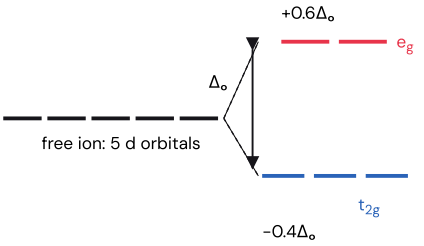
VBT KI KAMIYAN

Rang explain nahi karta, kuch ligands strong ya weak kyun hain nahi batata, thermodynamic/kinetic stability ka quantitative hisaab nahi deta.

06 Crystal field theory (CFT)

Ligands ko point charges maante. Octahedral field me paanch d orbitals bant jaate: **e_g** ($d_{x^2-y^2}$, d_{z^2}, ligands ki taraf, upar) aur **t_{2g}** (d_{xy}, d_{yz}, d_{xz}, neeche). Beech ka gap Δ_o.

- Δ_o > P (pairing energy) ⇒ strong field ⇒ electrons t_{2g} me pair ⇒ **low spin**.
- Δ_o < P ⇒ weak field ⇒ **high spin**.
- Tetrahedral: $\Delta_t = (4/9)\Delta_o$, hamesha high spin; order ulta (e neeche, t_2 upar).



Octahedral field me d orbitals ka splitting

SPECTROCHEMICAL SERIES (WEAK → STRONG)

$$I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < edta^{4-} < NH_3 < en < CN^- < CO$$

CFSE (octahedral) = $(-0.4\, n_{t2g} + 0.6\, n_{eg})\, \Delta_o$ + pairing energies.

07 Rang, metal carbonyls & uses

Rang: electron $t_{2g} \rightarrow e_g$ koodta, Δ energy ki light absorb karke; hume complementary rang dikhta. $[Ti(H_2O)_6]^{3+}$ hara-peela absorb karta ⇒ violet dikhta. Anhydrous $CuSO_4$ safed (paani ka ligand field nahi); ligands nahi to splitting nahi.

Metal carbonyls: CO σ bond banata (C → M) aur **π back bond** (metal ke bhare d → CO ka khaali π*). Is synergic bonding se M–C mazboot aur C≡O kamzor hota. $[Ni(CO)_4]$ tetrahedral, $[Fe(CO)_5]$ trigonal bipyramidal, $[Cr(CO)_6]$ octahedral.

USES

- Paani ki hardness: Na_2EDTA se titration.
- Metallurgy: Ag aur Au $[Ag(CN)_2]^-$, $[Au(CN)_2]^-$ ke roop me nikalte; Ni ko $Ni(CO)_4$ se shuddh karte (Mond process).
- Biology: chlorophyll (Mg), haemoglobin (Fe), vitamin B_{12} (Co).
- Dawai: cis-platin $[Pt(NH_3)_2Cl_2]$ cancer ke khilaaf; lead poisoning me EDTA.
- Analysis: Ni^{2+} dimethylglyoxime ke saath laal ppt; photography me $[Ag(S_2O_3)_2]^{3-}$.

08 JEE Extra + Tricks

JEE LEVEL

- EAN rule: EAN = Z − (oxidation state) + 2 × (coordination number); $Ni(CO)_4$, $Fe(CO)_5$, $Cr(CO)_6$ me 36 (Kr).
- Spectrochemical series (kamzor → tez): $I^- < Br^- < Cl^- < F^- < OH^- < H_2O < NH_3 <$ en $< CN^- <$ CO. Strong field ⇒ pairing ⇒ low spin (inner orbital d^2sp^3).
- $\Delta_t = (4/9)\Delta_o$, isliye tetrahedral lagbhag hamesha high spin.
- Isomers: $[MA_4B_2]$ 2 geometrical (cis, trans); $[MA_3B_3]$ fac aur mer; $[M(AA)_2B_2]$ ka cis optically active.
- CFSE (octahedral) = $(-0.4\ n_{t2g} + 0.6\ n_{eg})\Delta_o$ + pairing energy.
- Upyog: hardness me EDTA (hexadentate), cancer me cisplatin, hydrogenation me Wilkinson catalyst.

09 Solved questions

Q1. $[Fe(CN)_6]^{4-}$ me oxidation state, CN aur unpaired electrons?

x − 6 = −4 ⇒ Fe(+2), d^6. CN = 6. CN^- strong field ⇒ t_{2g}^6 ⇒ **0 unpaired**, diamagnetic, d^2sp^3.

Q2. $[NiCl_4]^{2-}$ paramagnetic par $[Ni(CN)_4]^{2-}$ diamagnetic kyun?

Ni^{2+} d^8 hai. Cl^- weak: pairing nahi, sp^3, 2 unpaired. CN^- strong: pairing karwata, dsp^2, square planar, 0 unpaired.

Q3. Formula likho: tetraamminediaquacobalt(III) chloride.

$[Co(NH_3)_4(H_2O)_2]Cl_3$.

Q4. $[Pt(NH_3)_2Cl_2]$ ke kitne geometrical isomers?

2 (cis aur trans).

10 Common mistakes

- Naam likhte waqt ligands ko charge se order karna, alphabetical nahi.
- Anionic complex me "-ate" bhool jaana ($K_4[Fe(CN)_6]$ me ferrate, iron nahi).
- en ko ek bond ginna: ye bidentate hai, isliye $[Co(en)_3]^{3+}$ ka CN 6.
- Kehna ki tetrahedral complex cis-trans isomerism dikhate.
- Maan lena ki har Ni(II) complex tetrahedral hai.

11 Practice questions

1. $[Co(NH_3)_5Cl]Cl_2$ ka naam?
2. $[Co(NH_3)_5(NO_2)]^{2+}$ aur $[Co(NH_3)_5(ONO)]^{2+}$ kaun si isomerism dikhate?
3. $[CoF_6]^{3-}$ ka hybridisation?
4. CO strong field ligand kyun?
5. EDTA ki denticity?

ANSWERS

1) pentaamminechloridocobalt(III) chloride · 2) Linkage · 3) sp^3d^2 (outer orbital, high spin) · 4) π back bonding splitting badhata · 5) 6

12 Quick revision: exam se 5 minute pehle

WERNER & NAMING

- Primary = OS, secondary = CN.
- Ligands alphabetical, phir metal(OS).
- Anionic complex: -ate.

VBT

- sp^3 tetrahedral, dsp^2 square planar.
- d^2sp^3 inner (low spin), sp^3d^2 outer.

CFT

- Octahedral: t_{2g} neeche, e_g upar.
- $\Delta > P \Rightarrow$ low spin.
- $\Delta_t = 4/9\ \Delta_o$.
- I^- sabse weak … CO sabse strong.

ISOMERS & USES

- Linkage: NO_2^-/ONO^-, SCN^-.
- Cis-platin: cancer.
- EDTA: hardness, Pb poisoning.

Koi doubt? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.