

LIVE

# COORDINATION COMPOUNDS

## CRYSTAL FIELD THEORY

for JEE-MAIN

One Shot

By VJ Sir

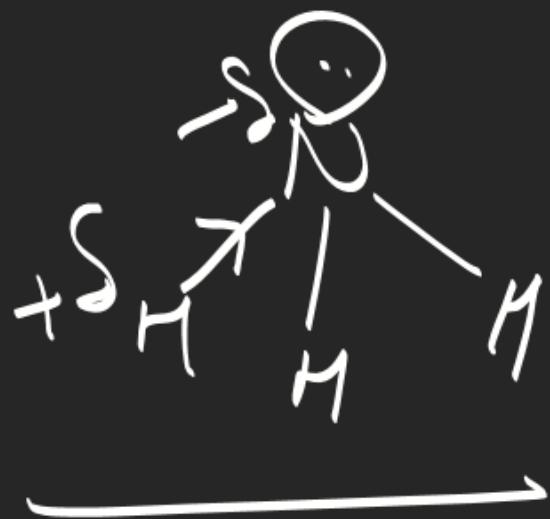
7:30 PM Tonight 🔥

Apni Kaksha





# COORDINATION CHEMISTRY



C · F · T

① Van Vleck and Bethe

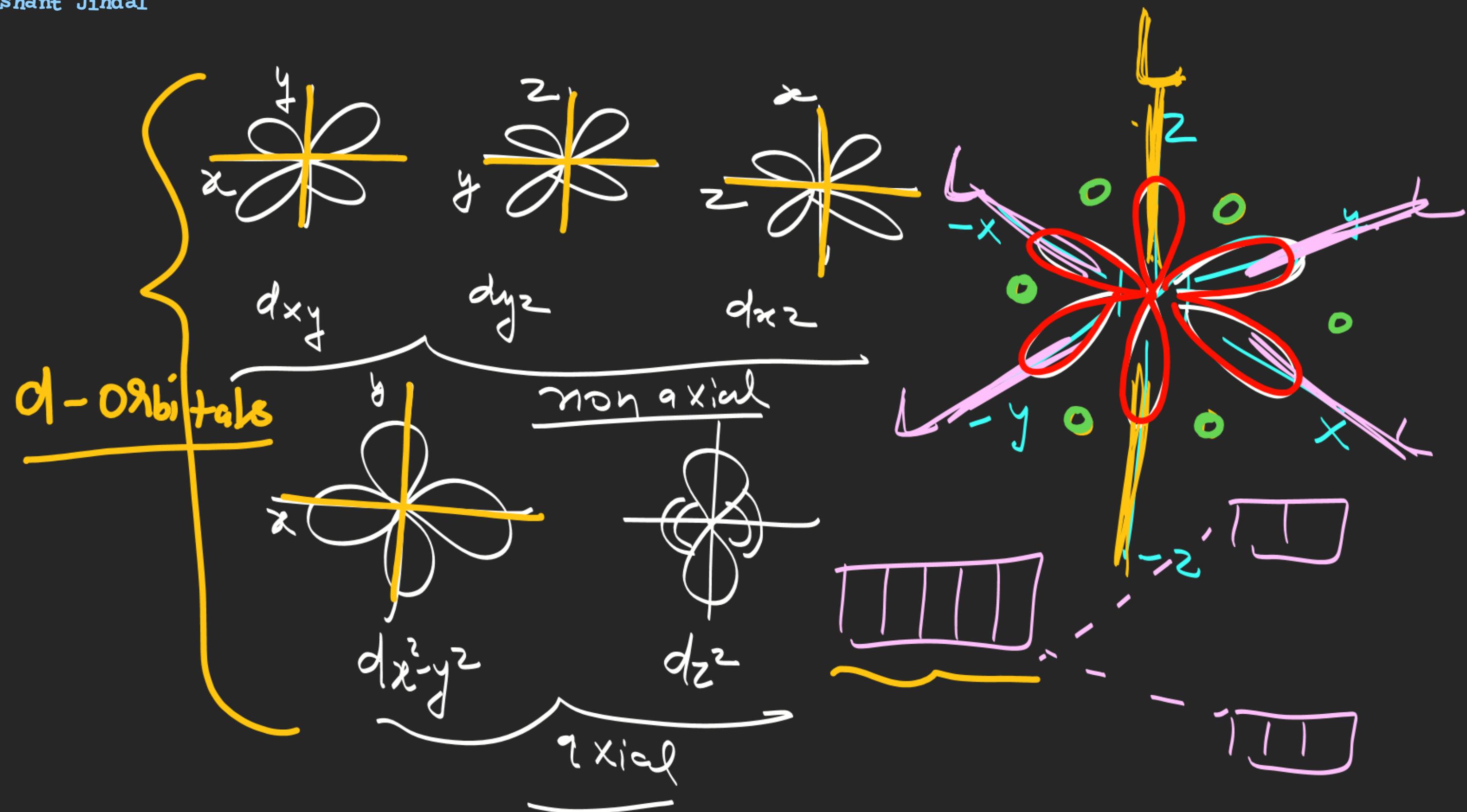


② -ive ligand  $\rightarrow$  a C<sup>+</sup> as point charge  
neutral ligand acts as dipole

③ acc. to C · F · T pure electrostatic  
 attraction present between metal  
 cation and ligand. but it is not true  
due to synergic bonding

.

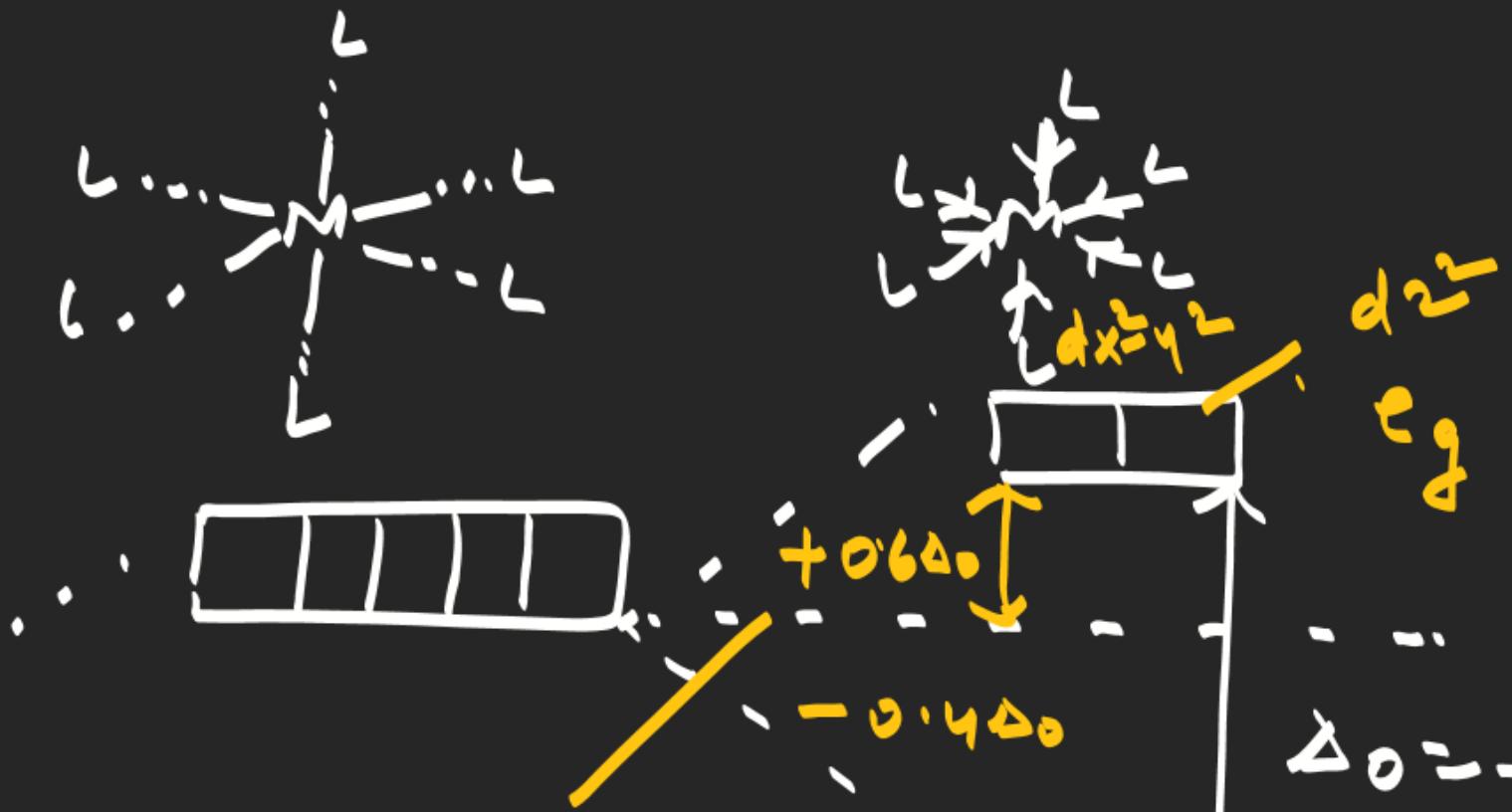




## Octahedral splitting



five degenerate  
orbital of  
free metal  
cation

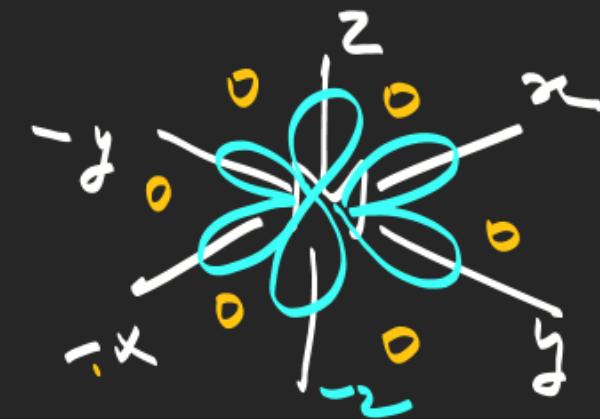


Baovi  
Centre

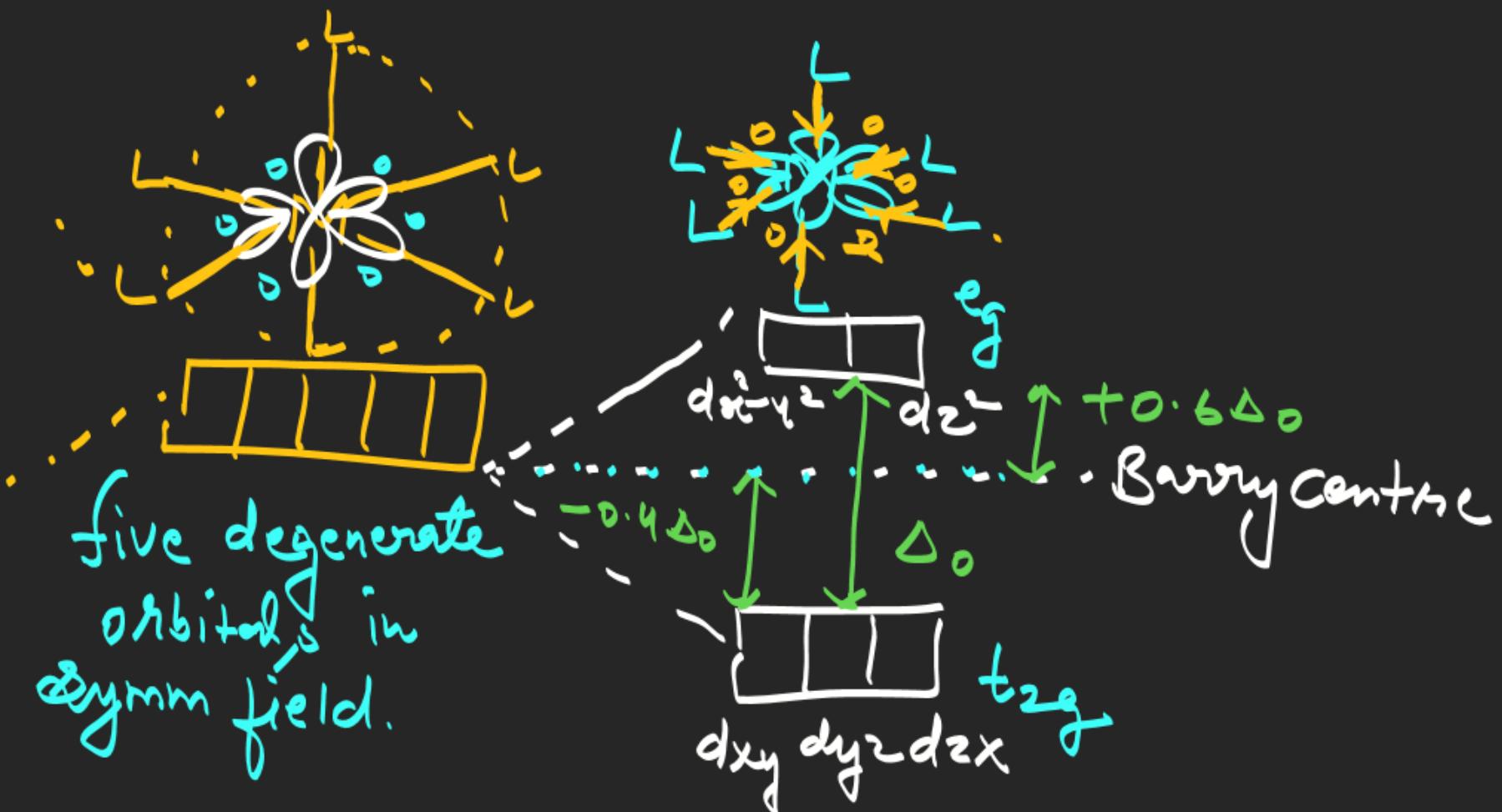
$t_{2g}$   
 $d_{xy} \ d_{yz} \ d_{zx}$

- - - octahedral  
 $\Delta_0 = \text{splitting}$

# Octahedral splitting



five degenerate orbital  
of free metal cation



$\Delta_0 = C \cdot F \cdot S \cdot E$  for octahedral

$C \cdot F \cdot S \cdot E = \text{Crystal field splitting energy}$

S.F.L

$$\underline{\Delta_0 > P}$$

↑L	↑L
----	----

W.F.L

↑L	↑L	↑L
----	----	----

↑L	↑L
----	----

 $d^1 \text{ to } d^{10}$ 

$$\underline{\Delta_0 < P}$$

 $d^4 \text{ to } d^7$ S.F.L

↑L	↑L	↑L
----	----	----

low spin  
high spinW.F.L

for octahedral

P = Pairing energy  
 req-energy for pairing

high spin  $\Rightarrow$  number of u.p.e  $\uparrow$ low spin  $\Rightarrow$  number of u.p.e  $\downarrow$  $d^1 \text{ to } d^3 \Rightarrow$  no low spin / no high spin $d^8 \text{ to } d^{10} \Rightarrow$  $d^4 \text{ to } d^7 \xrightarrow{\text{S.F.L}} \text{low spin}$  $\xrightarrow{\text{W.F.L}} \text{high spin}$

S.F.L



$$\Delta_0 > P$$

$d^1$  to  $d^3$  = no low spin  
no high spin



P = Pairing energy

W.F.L



$$\Delta_0 < P$$



high spin complex = no d up.e ↑

low spin complex = number of u.p.e ↓

$$\text{Fe} = \underline{3d^6 4s^2}$$

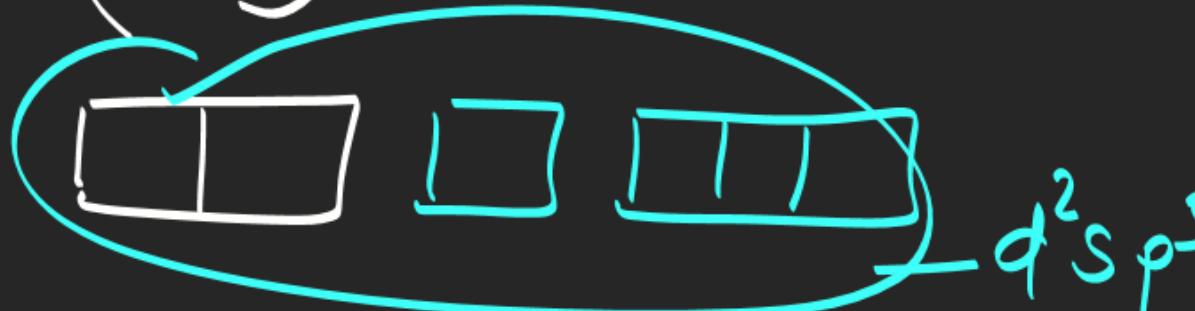
$$\text{Fe}^{+2} = \underline{3d^6}$$

$$\text{Sc}^{+3} = \underline{3d^0}$$

$$\underline{3d^1 4s^2}$$

$$\underline{3d^2 4s^2}$$

Sc Ti V Cr Mn Fe


 $\text{CN}^-$  (S.F.L)


S.F.L



$$4t - \alpha + 6(-1) = 0$$

$$\chi = +2$$

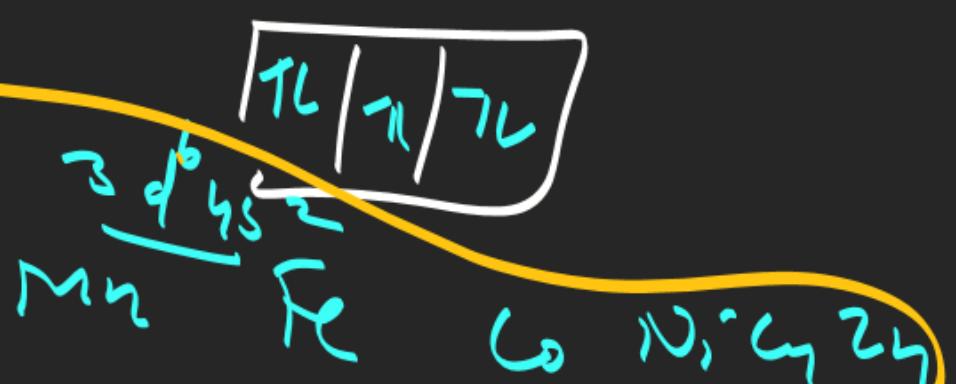
Key point

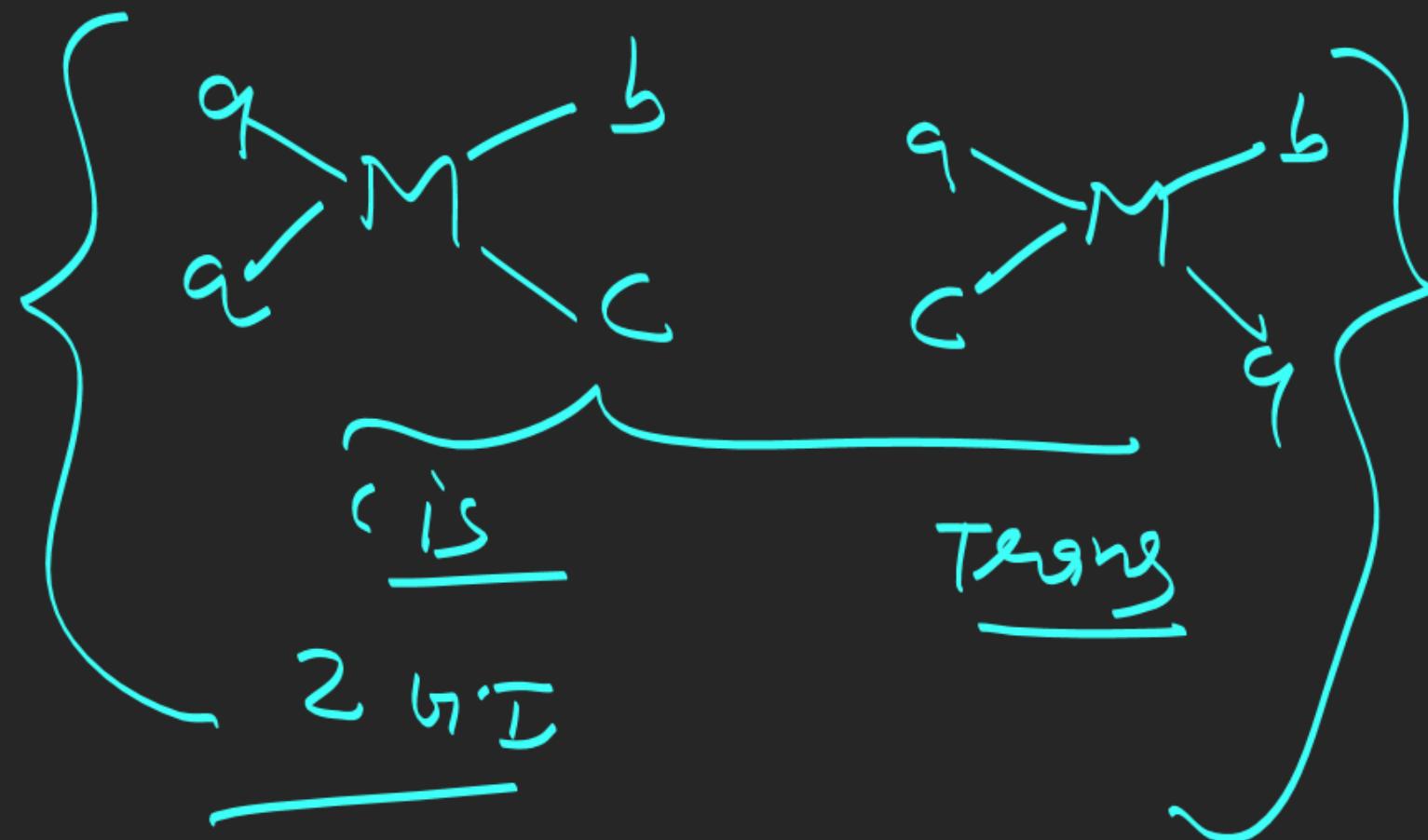
$d^2s^2p^3 \Rightarrow \}$  inner

$d^3s^2p^3 \Rightarrow \}$  inner

$s^2p^3d^2 \Rightarrow \}$  outer

Diq  
 $m=0$   
low spin  
inner orbital



M<sub>abc</sub>[M<sub>abc(d)</sub>]

$$\left[ \text{Fe}^{+3} \right]^{-3}$$

$$\text{Fe}^{+3} = 3d^5$$

$$f^\Theta = w \cdot F \cdot L$$

$\begin{array}{|c|c|} \hline 1 & 1 \\ \hline \end{array}$

$\begin{array}{|c|c|c|} \hline 1 & 1 & 1 \\ \hline \end{array}$



$SP^3d^2$

OCT.  
Para

$M = 5.92$

Outer orbital

high spin

u.p.e

1

2

3

4

5

$\mu$

1.73

2.83

3.87

4.90

5.92

~~d<sup>5</sup>s<sup>2</sup>p<sup>3</sup>d~~

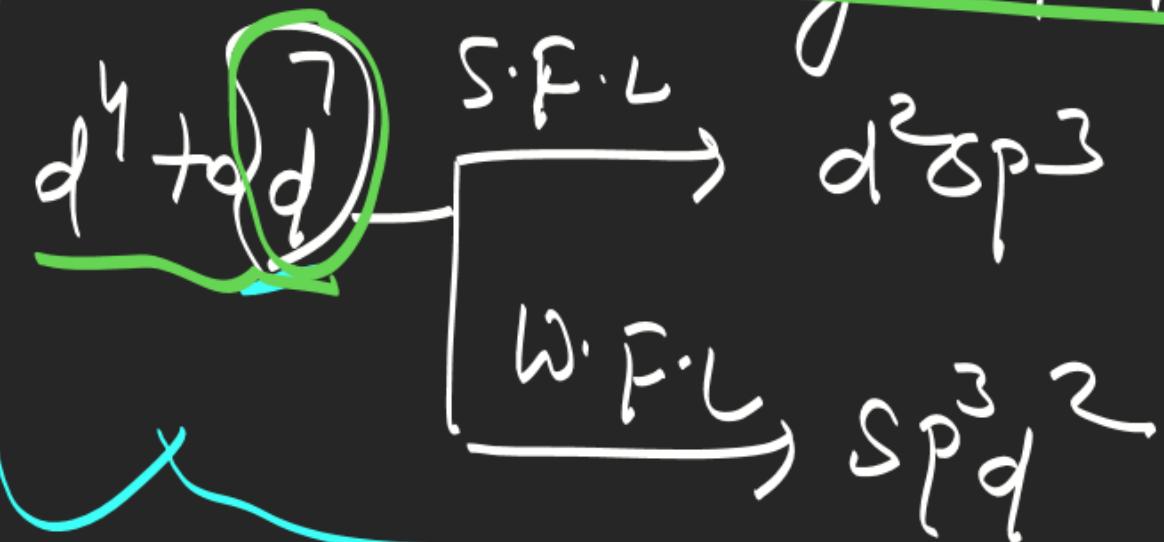
for C:N = 6 (Octahedron)

Keypoint



~~d<sup>1</sup> to d<sup>3</sup>~~ — always ~~d<sup>2</sup>s<sup>2</sup>p<sup>3</sup>~~ inner

~~d<sup>8</sup> to d<sup>10</sup>~~ — always ~~s<sup>2</sup>p<sup>3</sup>d<sup>2</sup>~~ outer



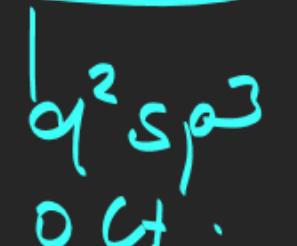
$$x + 6(-1) = -4 \left[ \text{Co}(\text{NO}_2)_6 \right]^{-4}$$

$$x = +2$$

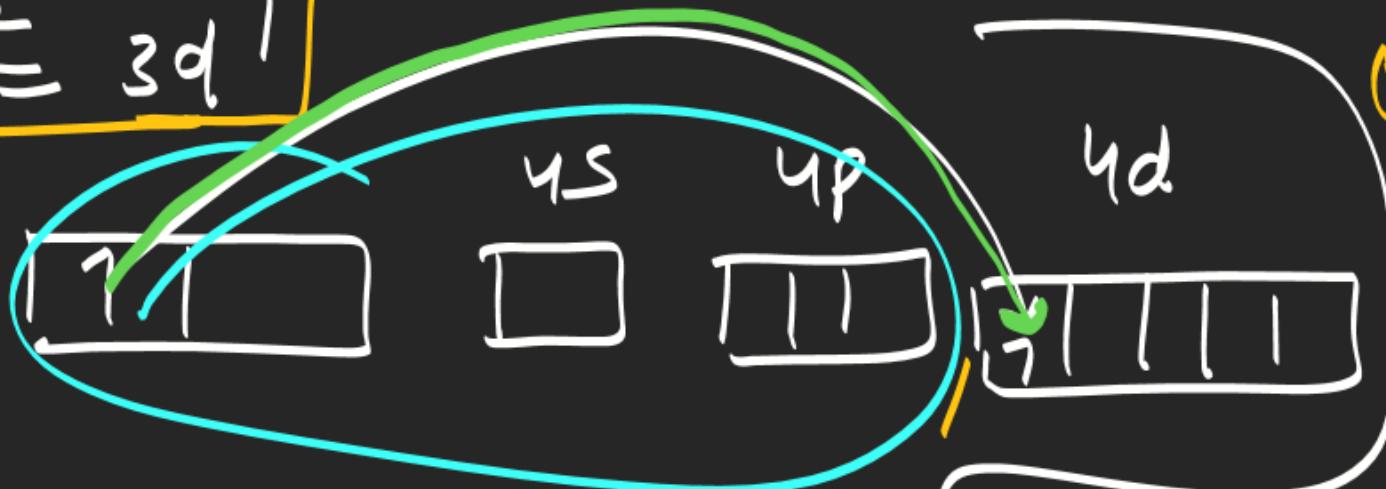
$$\text{Co} = 3d^7 \frac{1}{2} s^2$$

$$\text{Co}^{+2} \approx 3d^7$$

$\text{Co}^{+2} \approx \text{S.F.L}$  surrounded  
then U.P.C present  
in 4d orbital rather than  $\underline{\underline{3d}}$



$M = 1.73$   
inner  
low spin



### Condition of transference

- ① Complex should have only one U.P.C
- ② Complex should have only S.F.L
- ③ Complex should have possibility of inner orbital complex compound.



When  $\text{Co}^{+2}$  surrounded by 6 S.F.L then

it always form  $d^2\text{sp}^3$  hybrid (inner orbital complex) compound  
and in such types complex

4-p-e present in 4d orbital (higher energy)  
rather than 3d orbital.

4-p-e present in 4d orbital (higher energy level)  
so easily remove and they act as R-A

# COORDINATION CHEMISTRY

$$C.N = 4$$

Square planar

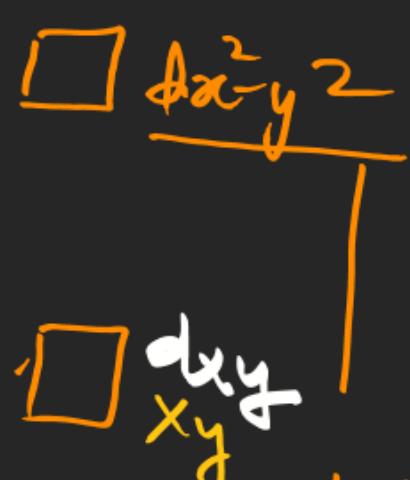
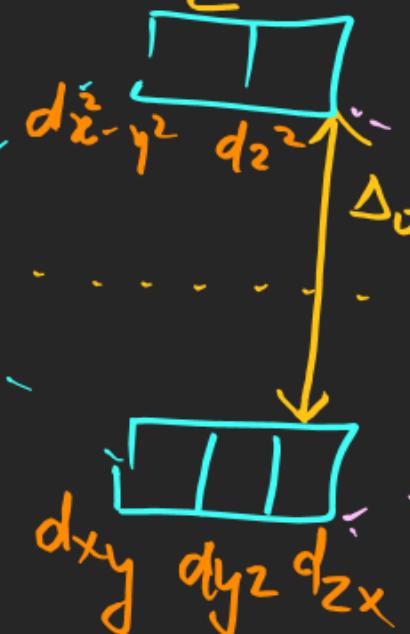
Tetrahedral

Square planar splitting

five degenerate  
orbital



$$\begin{aligned} & -d_{x^2-y^2} \\ & -d_{xy} \\ & -d_{z^2} \\ & = d_{yz} \end{aligned}$$



$$\Delta_{SP}$$

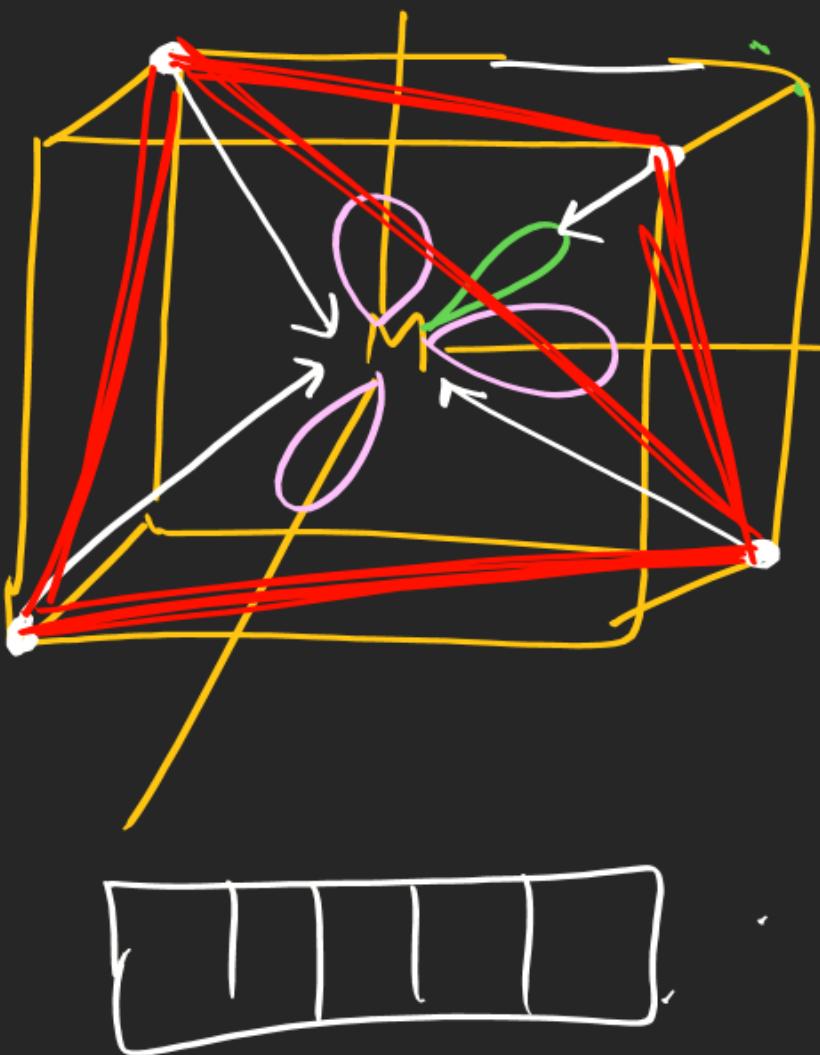
(Tetrahedral distortion)

tetrahedral split

$$\Delta_{SP} = 1.3 \Delta_t$$

$$\Delta_{SP} > \Delta_o > \Delta_t$$

$$\Delta_t = \frac{4}{9} \times \Delta_o$$

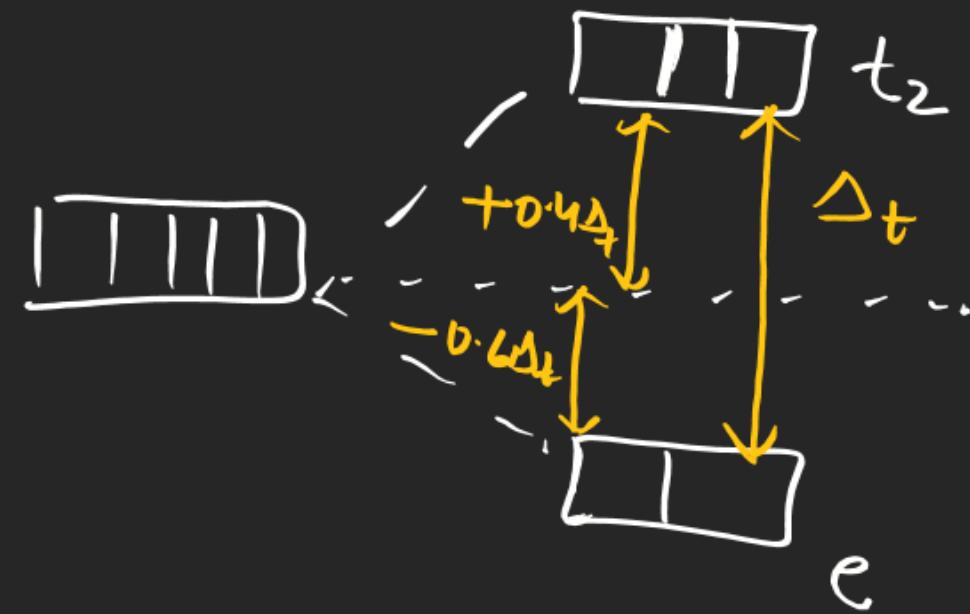


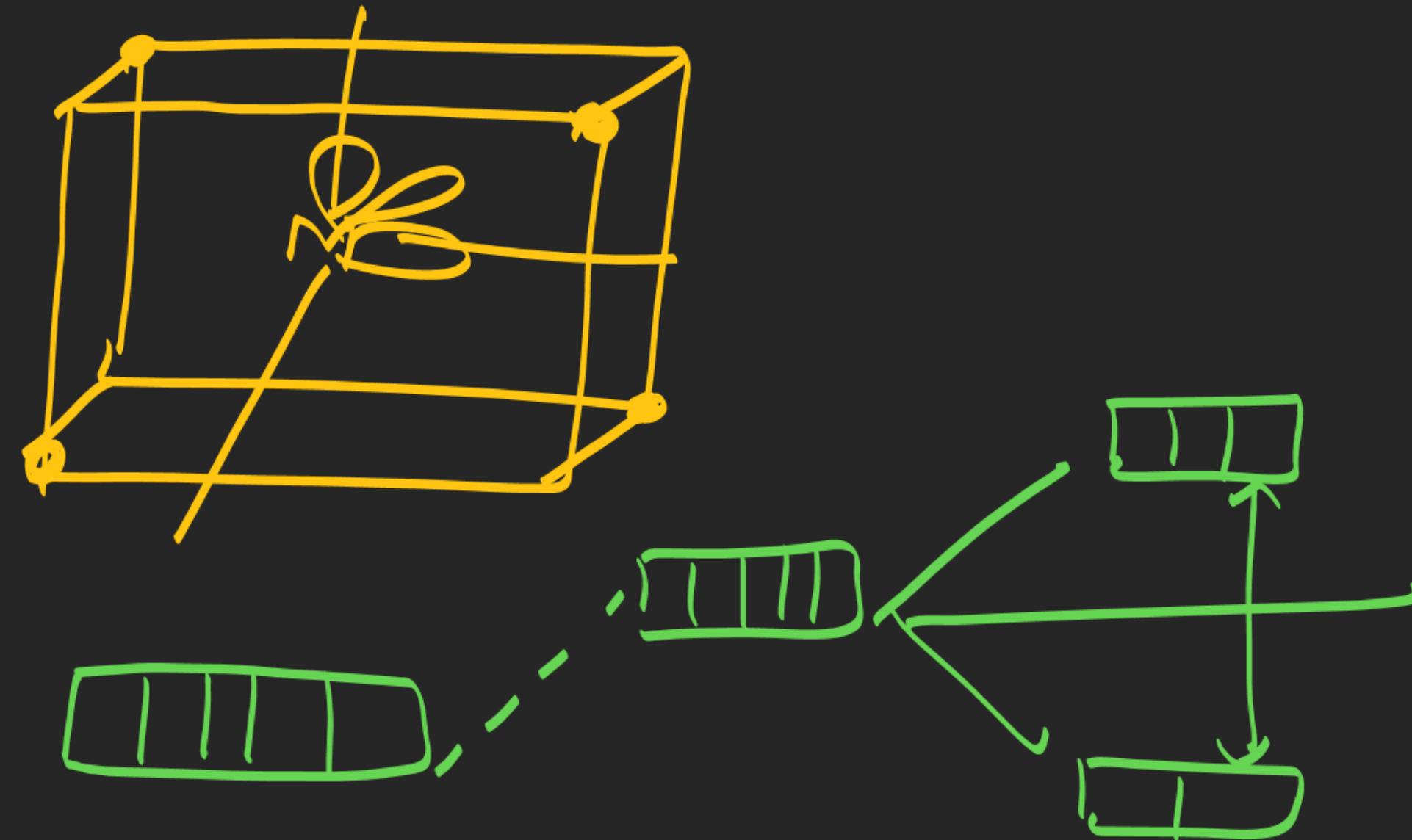
In Cube

axial orbital  $\Rightarrow$  centre of face

non axial orbital

$\Rightarrow$  centre edges





Square planar  $C \cdot N = 4$

$$\Delta_{sp} > \rho$$

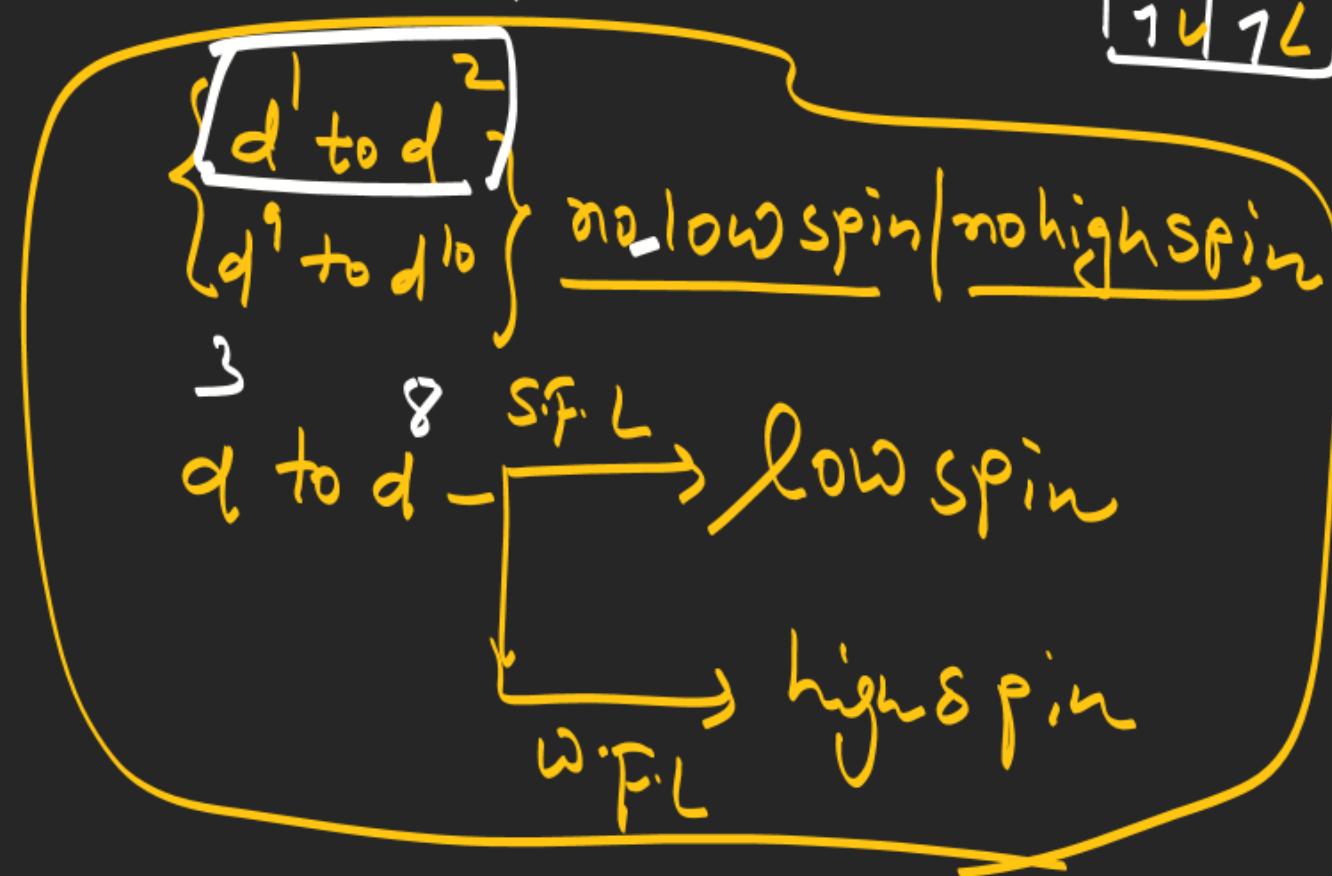


$$\Delta_t < \rho$$



for  $C \cdot N = 4$

<https://t.me/VJSIRofficial>



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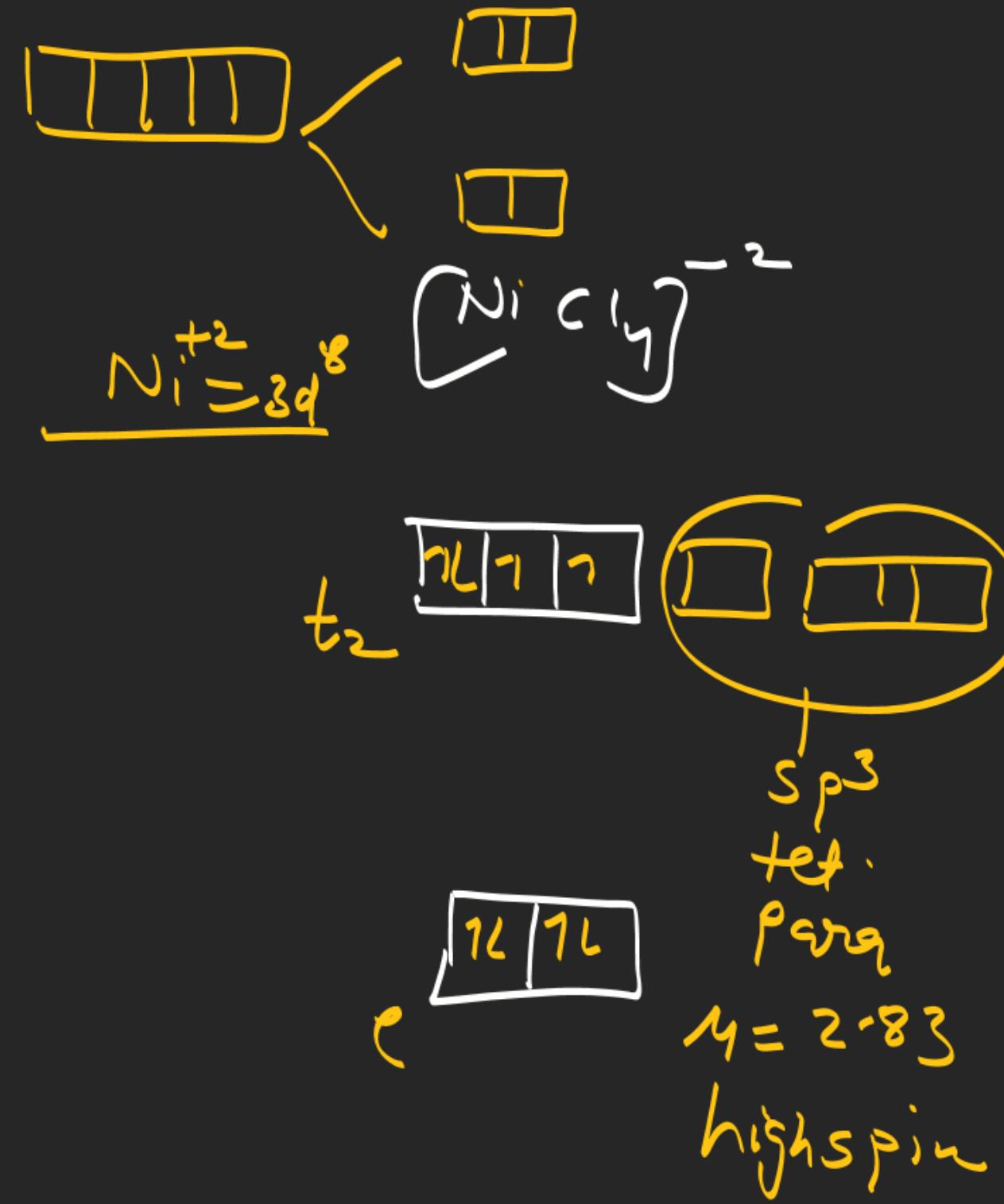
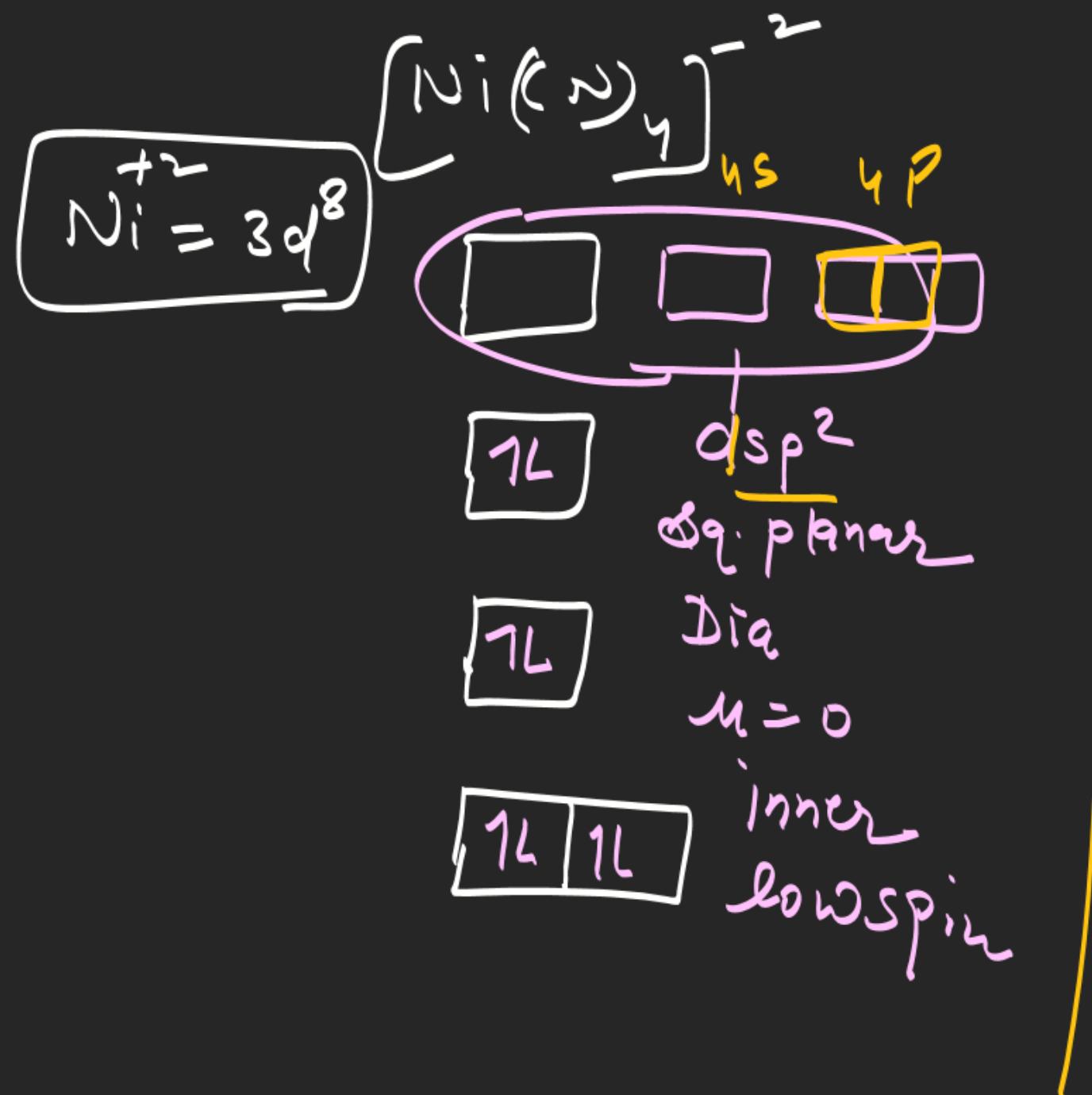
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$$\text{for } \text{C.N.} = 4 \quad \text{Zn}^{+2} = 3d^{10}$$

$d^{10}$  — always  
= irr. nature of ligand

Multiply



for C.N. = 4

Metal cation

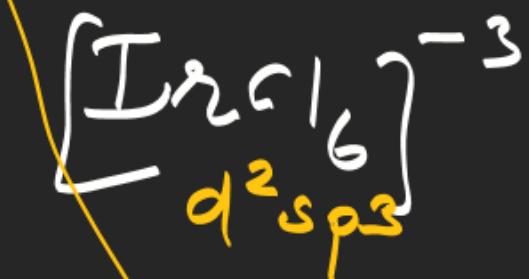
if I T.S series

4s.F.L

sq. planar

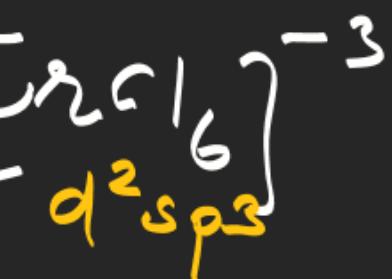
4w.F.L

tet.



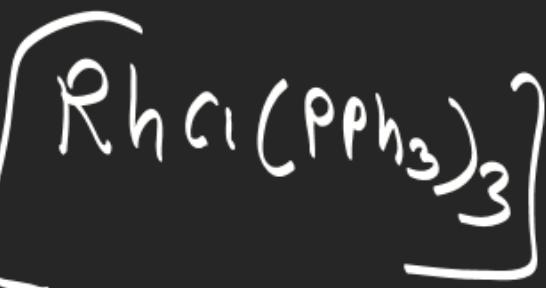
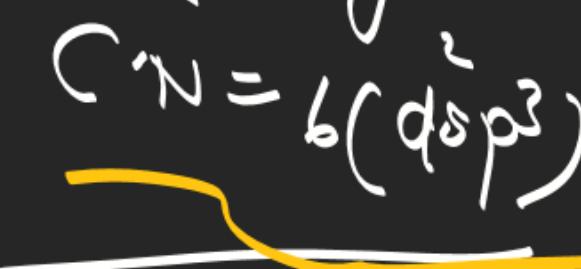
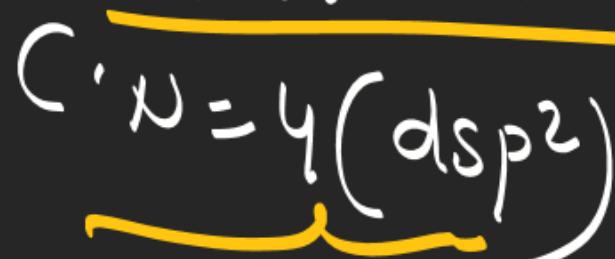
$\text{dsp}^2$

Will Kinson cat.



$\text{d}^2\text{sp}^3$

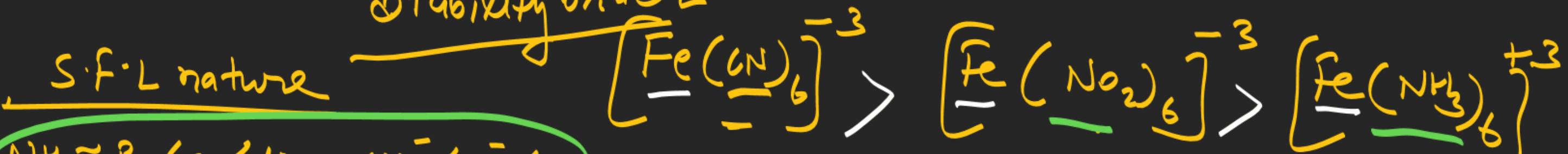
Note  $\Rightarrow$  II and III T.S series element  
always show large splitting  
irr. nature of ligand.



# factors affecting C.F.S.E value

① nature of ligand →

Stability order



$\text{NH}_3 \approx \text{Py} < \text{en} < \text{dipy} < \text{NO}_2 < \text{C}_6\text{H}_5\text{C}_6\text{H}_4\text{CO}$

Charge on metal cation same

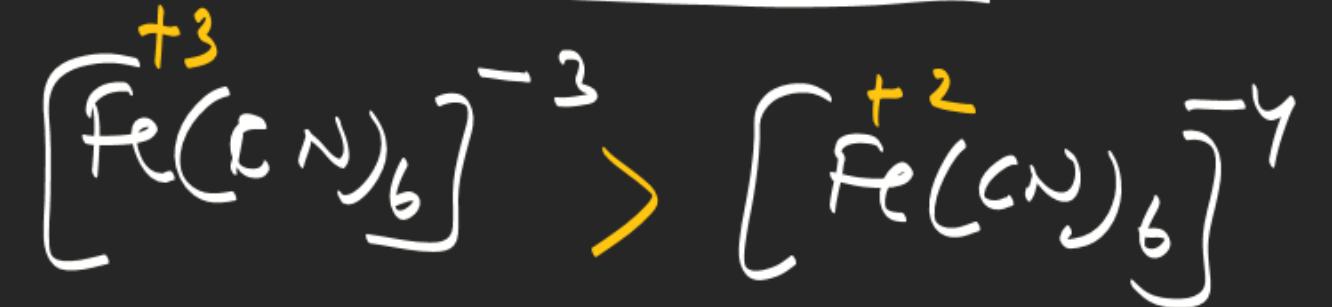
Type of metal cation same ( $Z_{\text{eff}}$ )

No of ligand same

then stability decided by nature of ligand

$S.F.L \uparrow$  stability  $\uparrow$

② Charge on metal cation



nature of ligand same

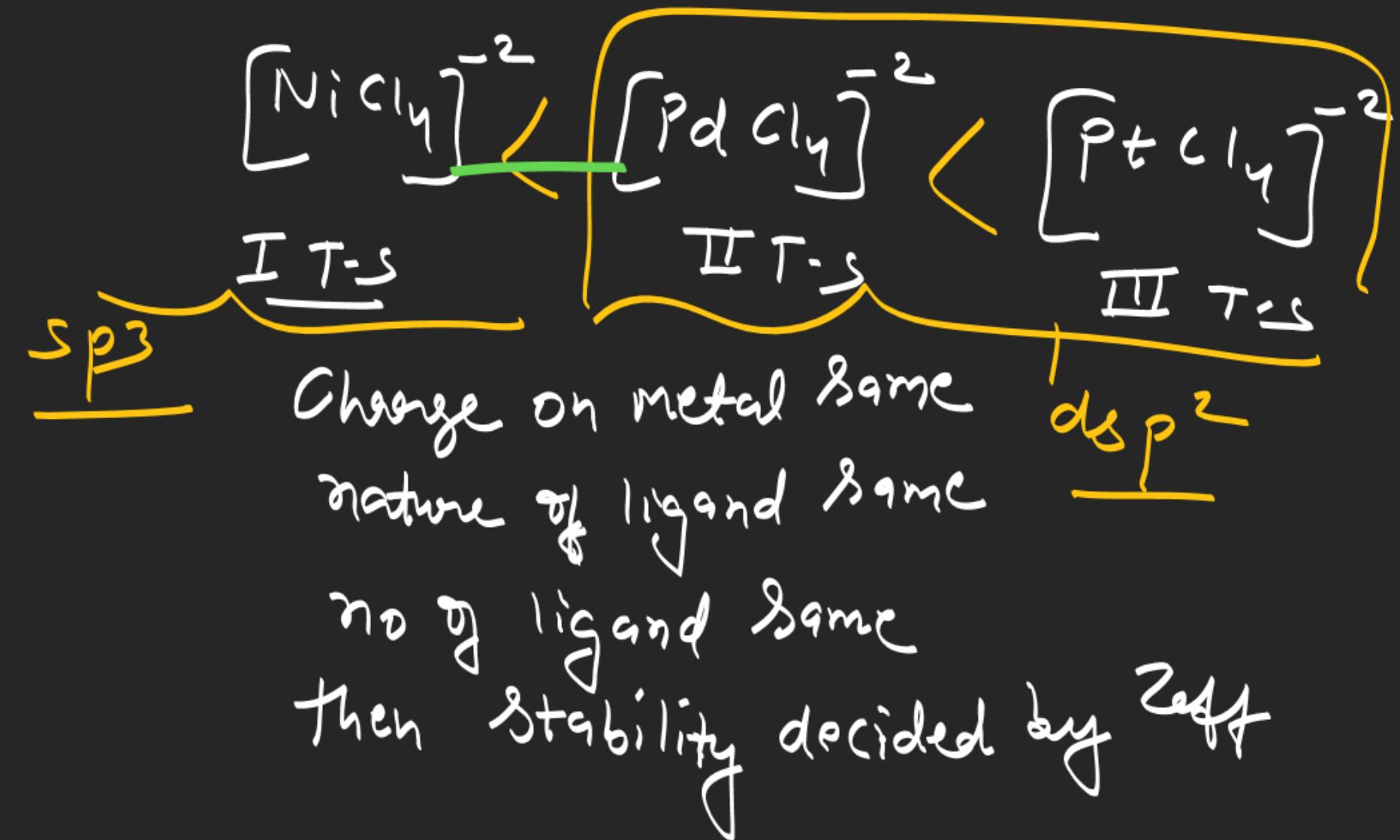
no of ligand same

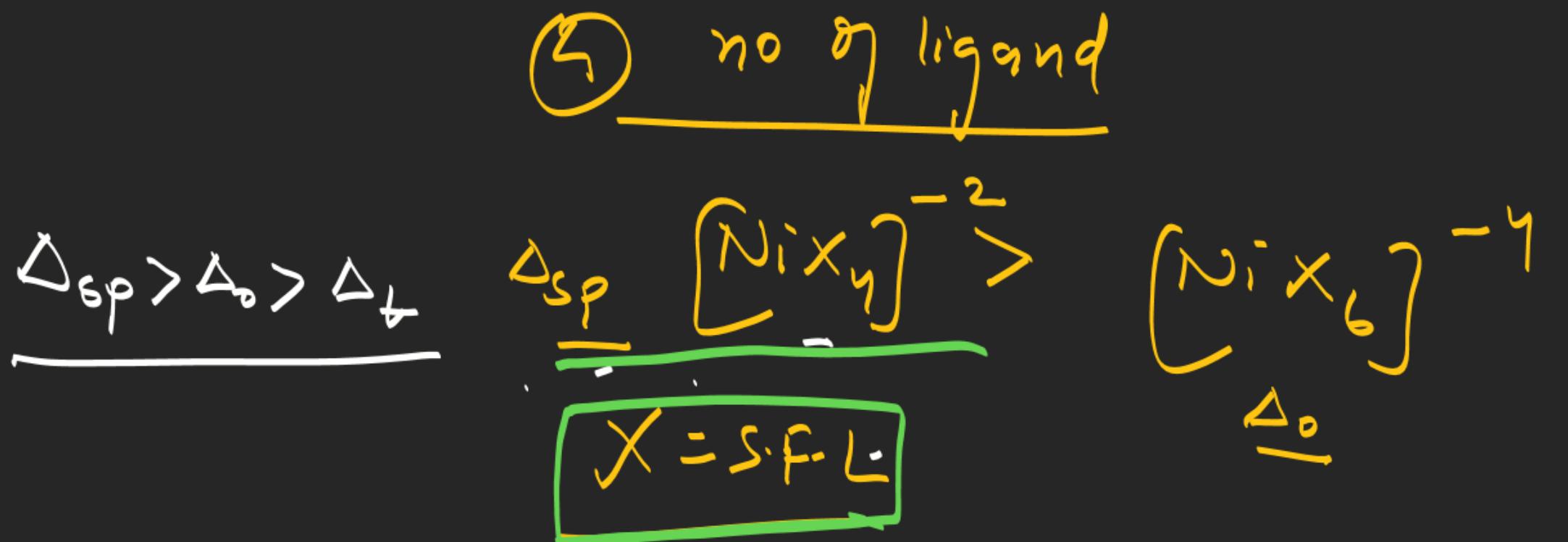
type of metal same

then stability decided by Charge on metal cation

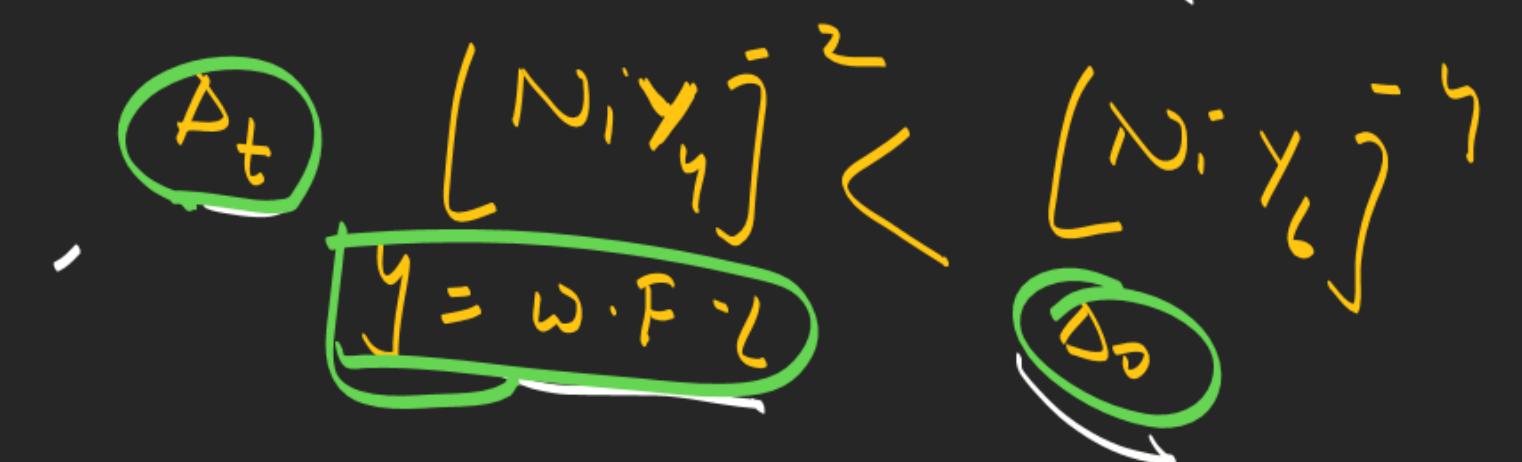
charge on cation  $\uparrow$  stability  $\uparrow$

## $Z_{eff}$ on metal cation



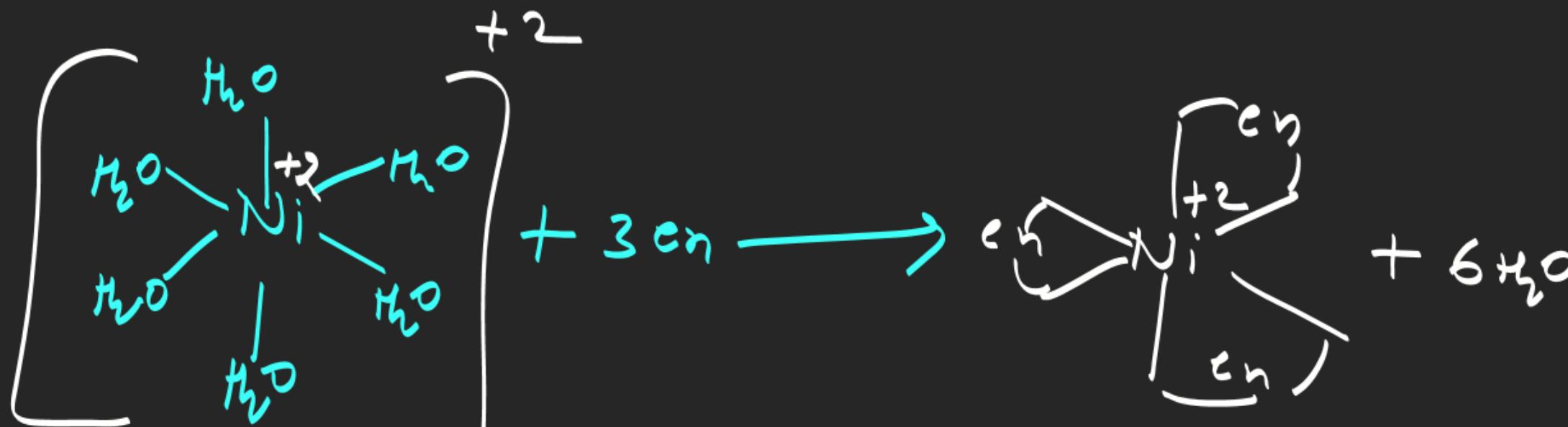


$X$  and  $y$   
neg. ligand

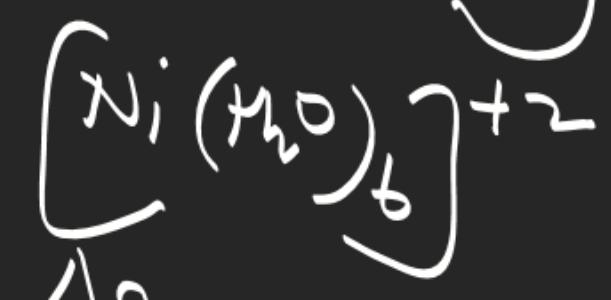


$$\Delta_{\text{sp}} > \Delta_o > \Delta_t$$

## Chelation

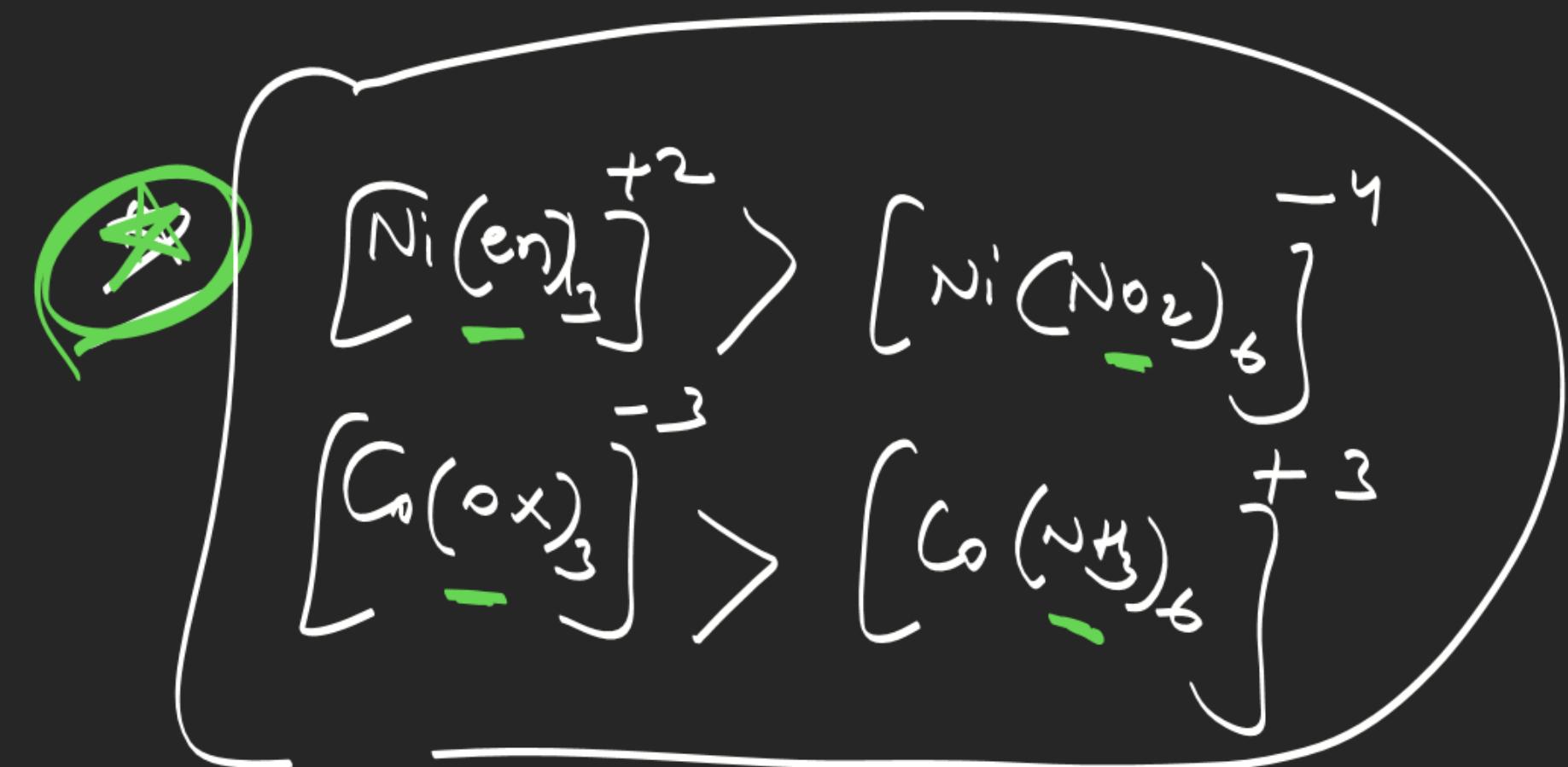
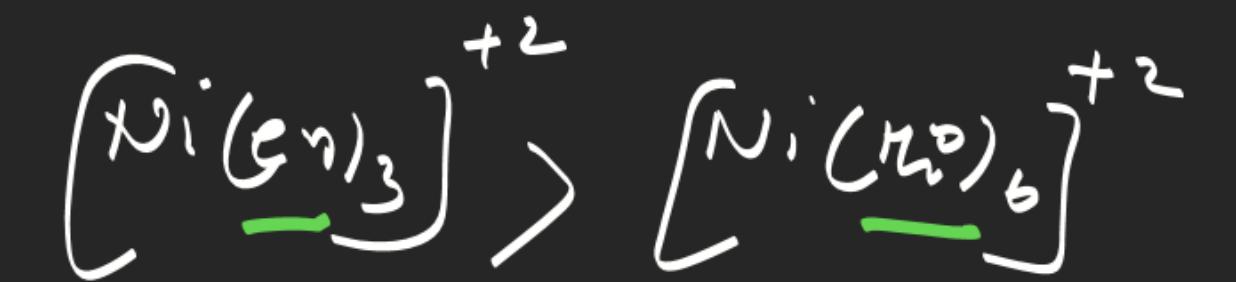


$$\Delta G = \Delta H - T\Delta S$$

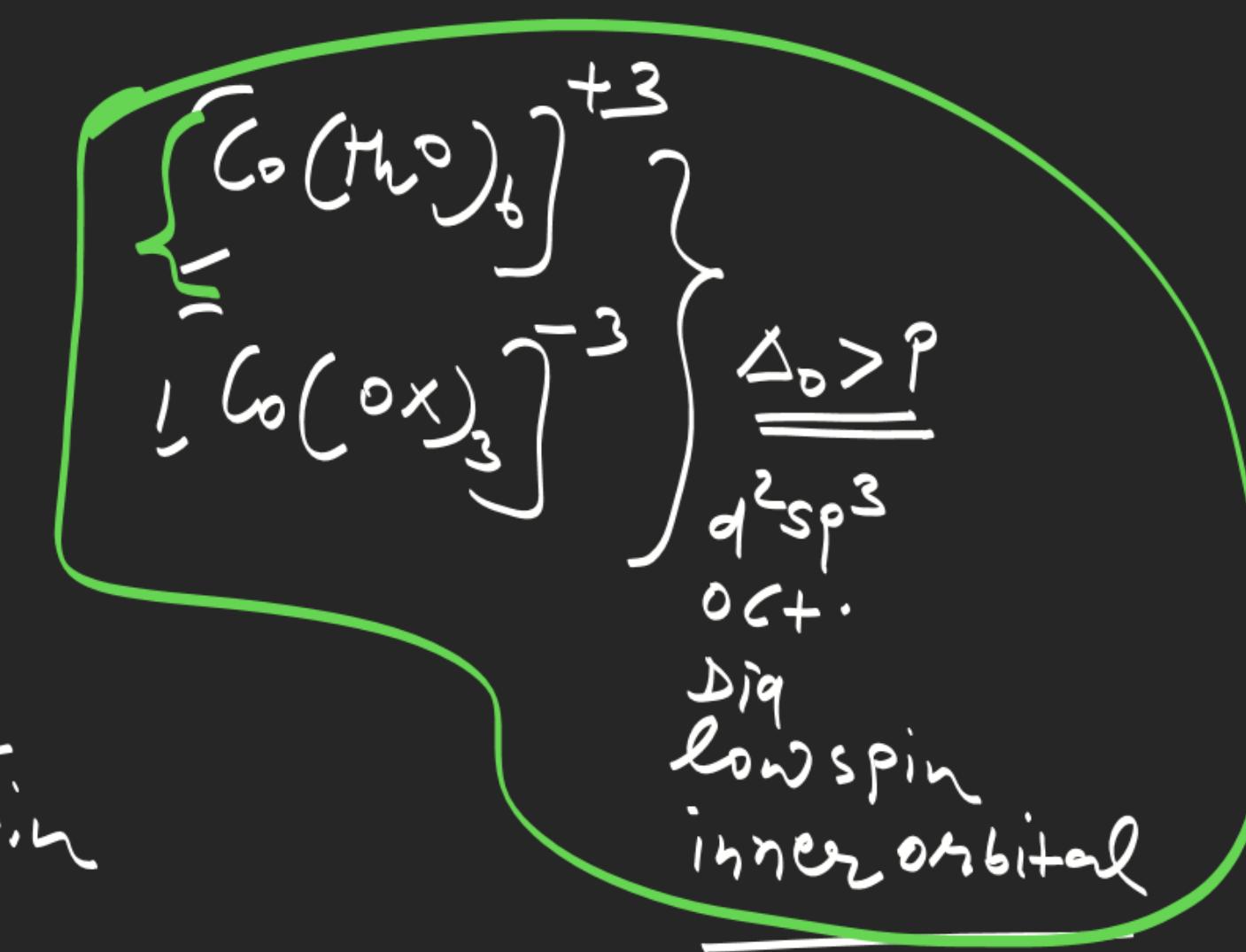
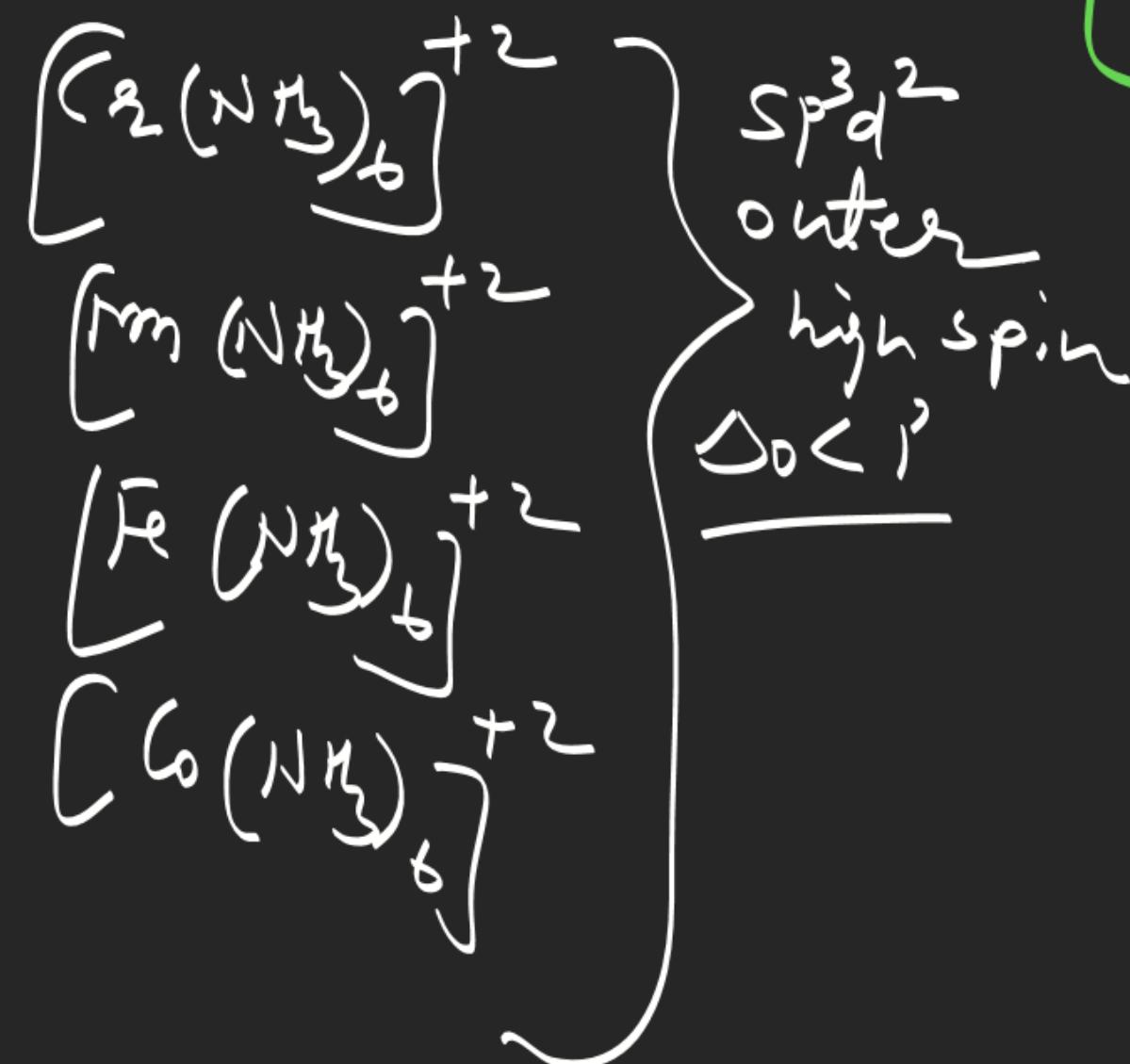


$$= 7 - 4$$

positive

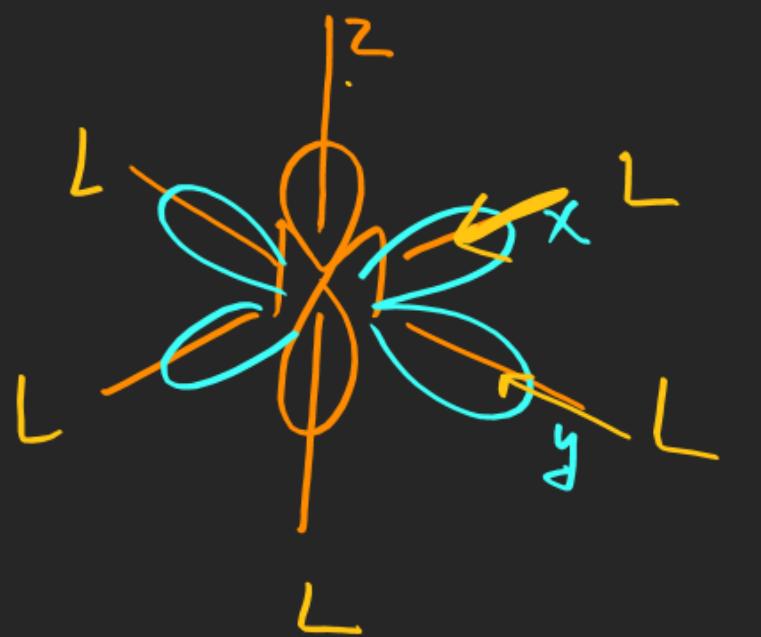


8mp



$$\underline{dz^2}$$

$$\underline{dx^2 - y^2}$$



# COORDINATION CHEMISTRY

★ Calculation of C.F.S.E

$$\boxed{C.F.S.E = -0.4 \Delta_0 x + 0.6 \Delta_0 y + m p}$$

x = no of  $e^-$  in  $t_{2g}$

y = no of  $e^-$  in  $t_{2g}$

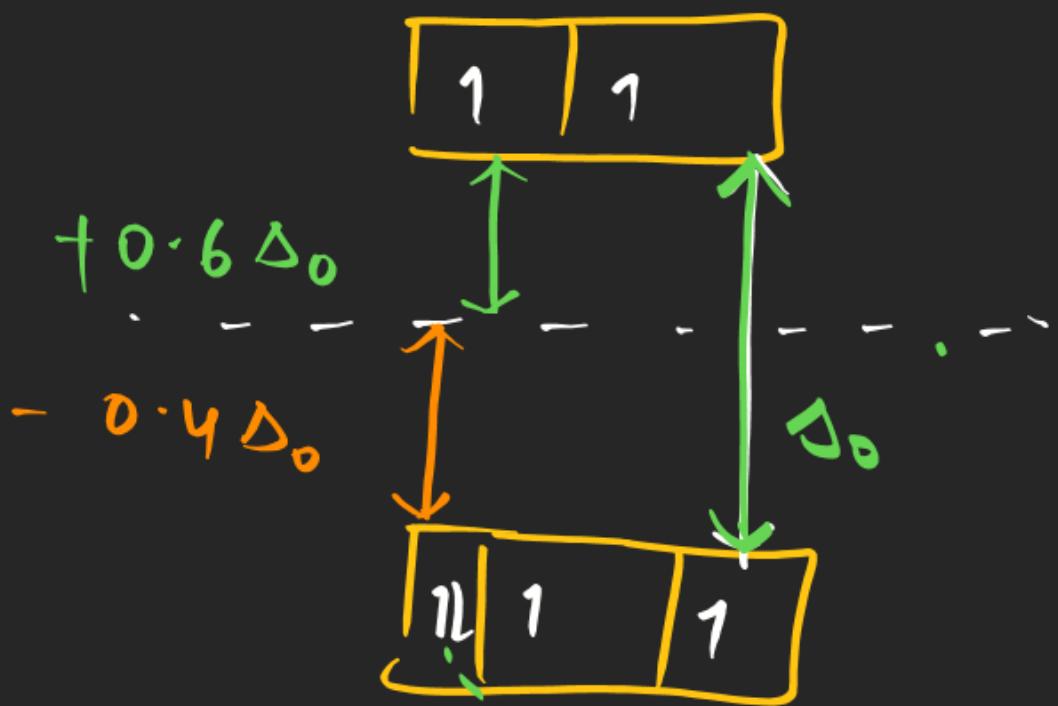
m = pairs of  $e^-$

$$\left[ \underline{\text{CoF}_6} \right]^{-3}$$

Calculate C.F.S.E

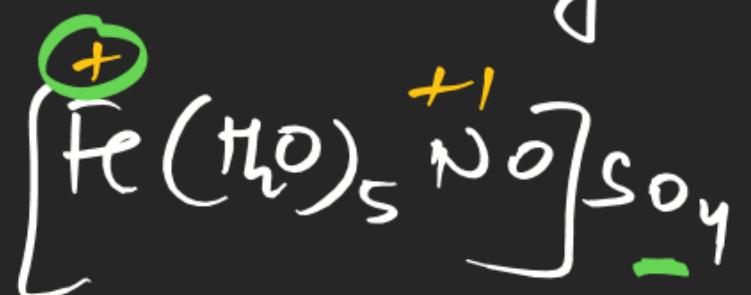
$$\underline{C_0}^{+3} = \underline{3d}^6$$

$$\underline{D_0} = 10 D_L$$



$$\begin{aligned}
 &= -0.4 \times 4 D_0 + 0.6 \times 2 D_0 + 1 P \\
 &= -1.6 D_0 + 1.2 D_0 + 1 P \\
 &= -0.4 D_0 + 1 P
 \end{aligned}$$

Q What is the hyd. of Brown Ring complex



NO acts as five ligand and it is decided by its magnetic moment in solid state

$$\text{Fe}^+ = 3d^6 4s^1$$

$$\text{Fe} = 3d^6$$



$$\text{Fe}^+ = 3d^6 4s^1$$



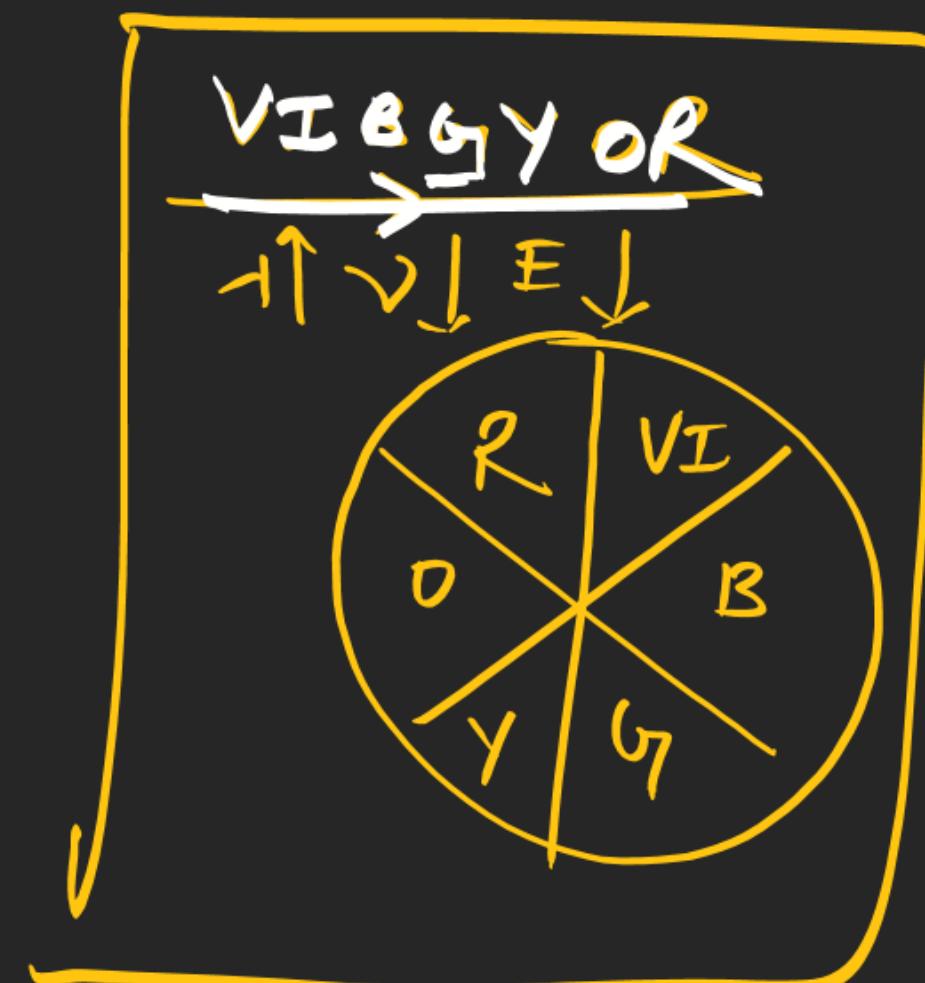
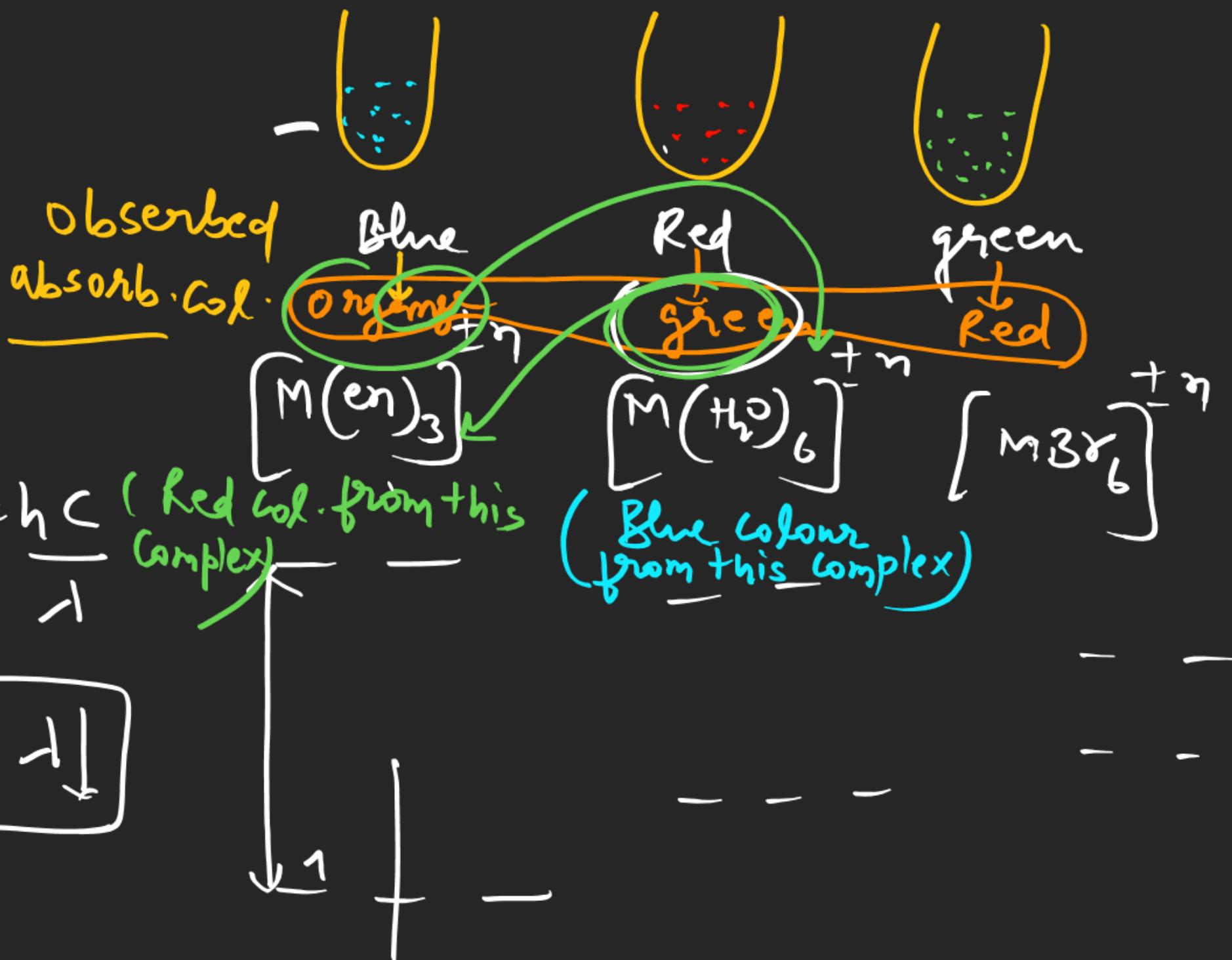
$\text{sp}^3\text{d}^2$  outer orbital  
Oct. -  
para

$$\mu = 3.87 \text{ B.M}$$

## \* Colour in complex Compound

{ d<sup>1</sup> to d<sup>9</sup> → Colourful  
but [FeF<sub>6</sub>]<sup>-3</sup> → Colourless  
d<sup>0</sup> and d<sup>10</sup> ⇒ Colourless

\* d<sup>n</sup> and d<sup>10-n</sup> ⇒ Same colour  
d<sup>3</sup> and d<sup>7</sup>



## Keypoint



Key point

S·F·L ↑

↓

Order of S·F·L nature

$$L_1 > L_2 > L_3 > L_4$$

Order of absorption of 1

$$L_1 < L_2 < L_3 < L_4$$

PYS IIT-JEE advanced one

CuSO<sub>4</sub>·5H<sub>2</sub>O is blue  
Which of the following  
Colour absorbed by  
this complex.

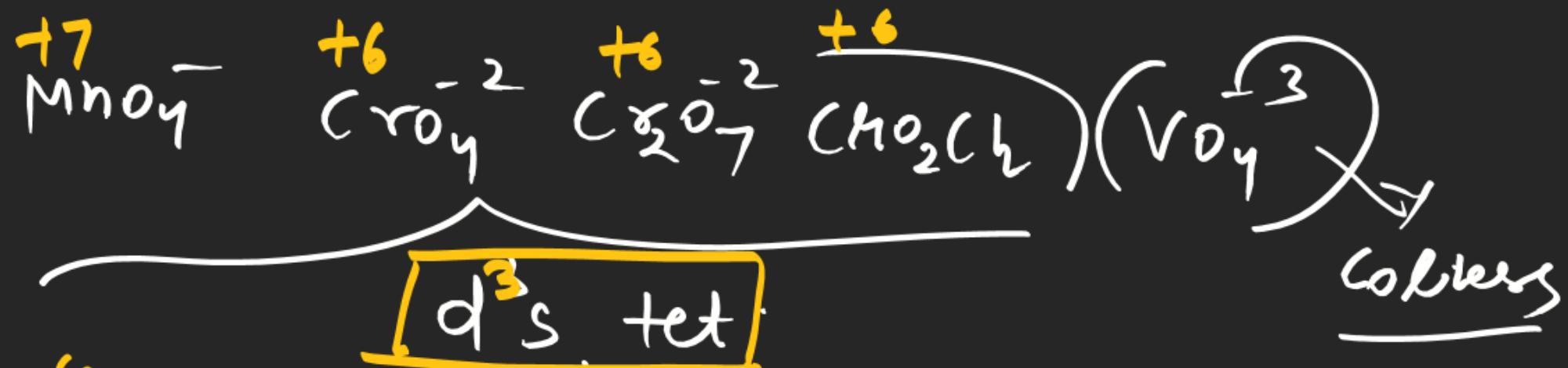
- ① green
- ~~② orange - Red~~
- ③ violet
- ④ blue

one

Colour of aq.  $\text{CrCl}_2$  is green.

Which of the following  
Colour absorbed by  
this complex.

Ans = Red



4 oxygen (W.F.L) hence splitting  
tetrahedral colorful due to charge

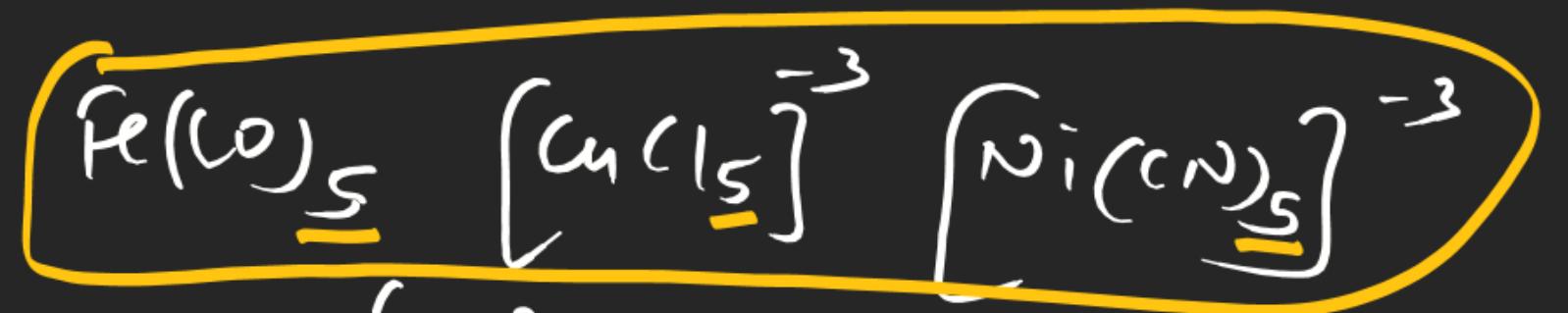


tet, Dia     $d^3 s$

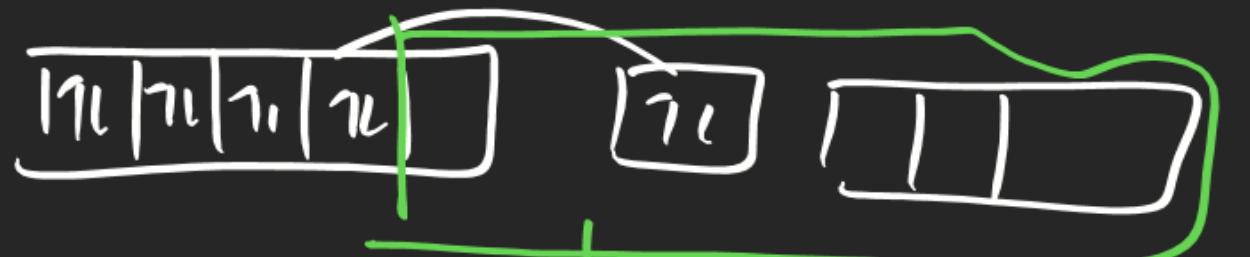


Charge transfer  $L \rightarrow M$

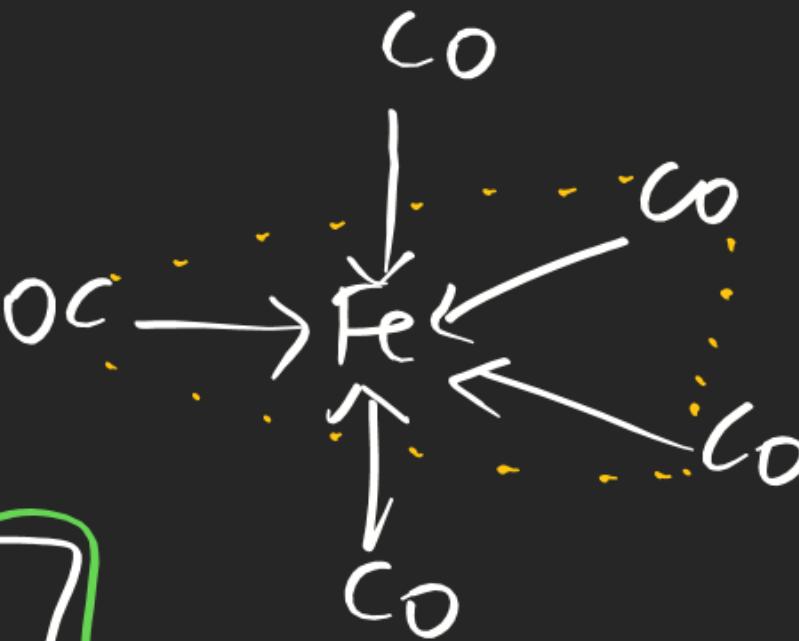
Cobalt



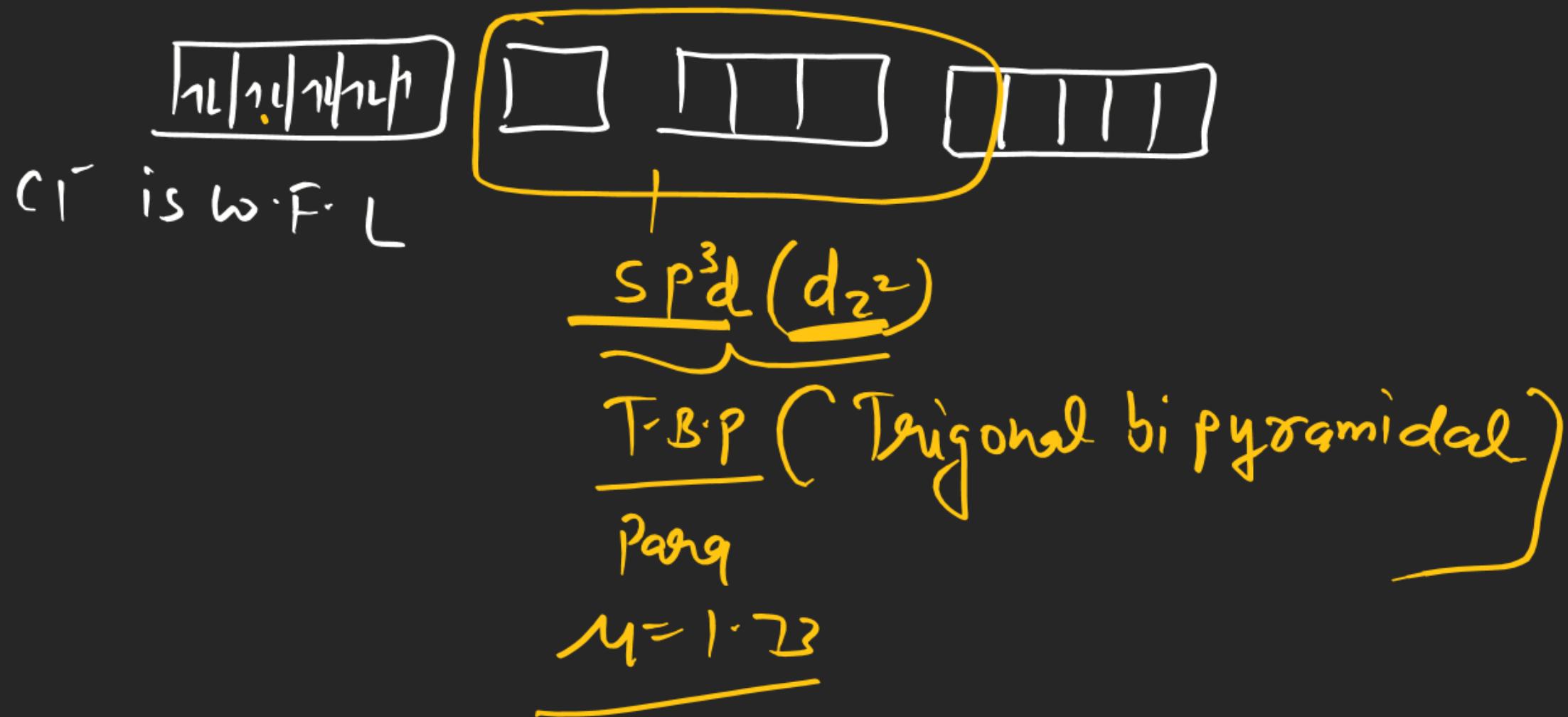
CO is S.F.L hence  
it will pair up 4-p.e

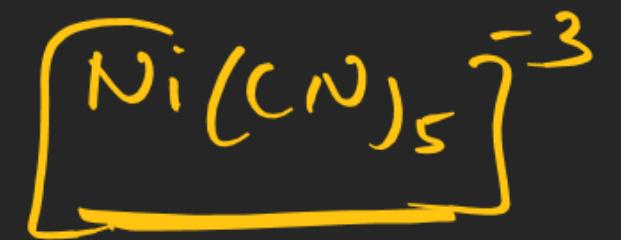


$d^5 s^1 p^3$  ( $d^2$ )  
 T.B.P  
 Diq, low spin



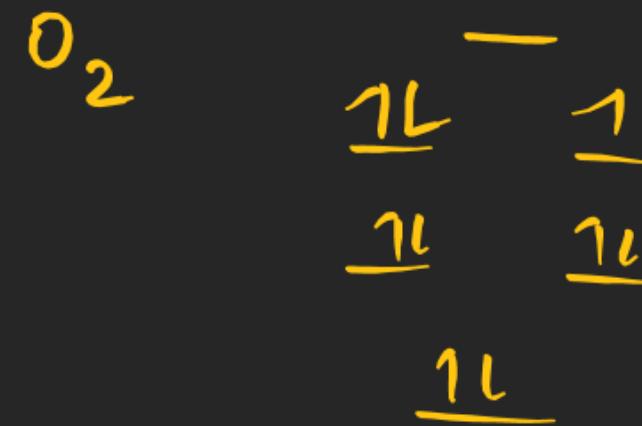
$$\frac{[\text{CuCl}_5]^{-3}}{\text{Cu}^{+2}} = 3\text{d}^9$$





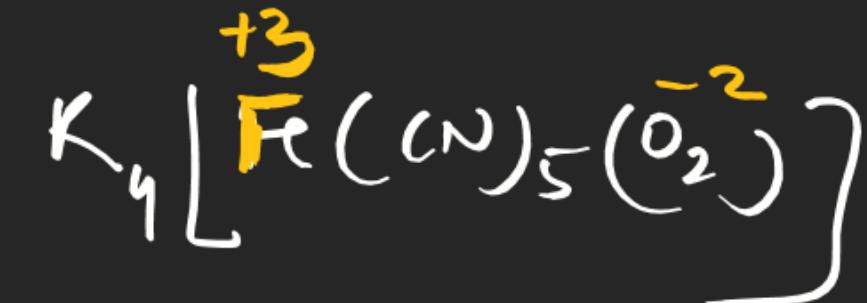
CN is S.F.L hence it will pair up 4.p.e

$d\delta p^3 [dx^2-y^2]$   
Square pyramidal



$O_2^- \rightarrow$  Peroxide  
 $O_2^- =$  Superoxide

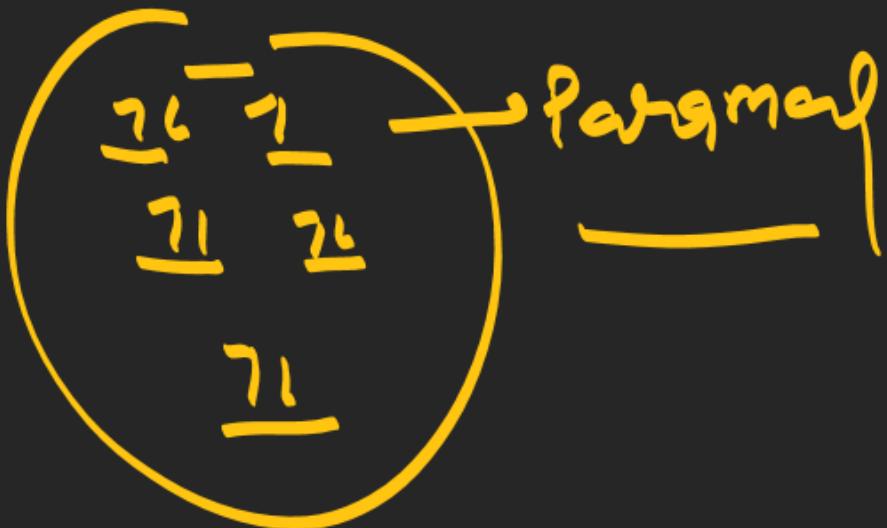
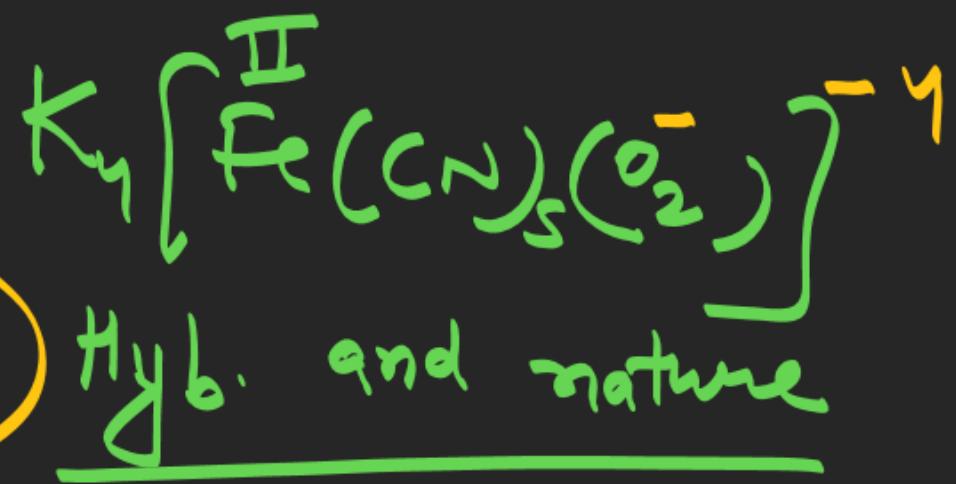
one

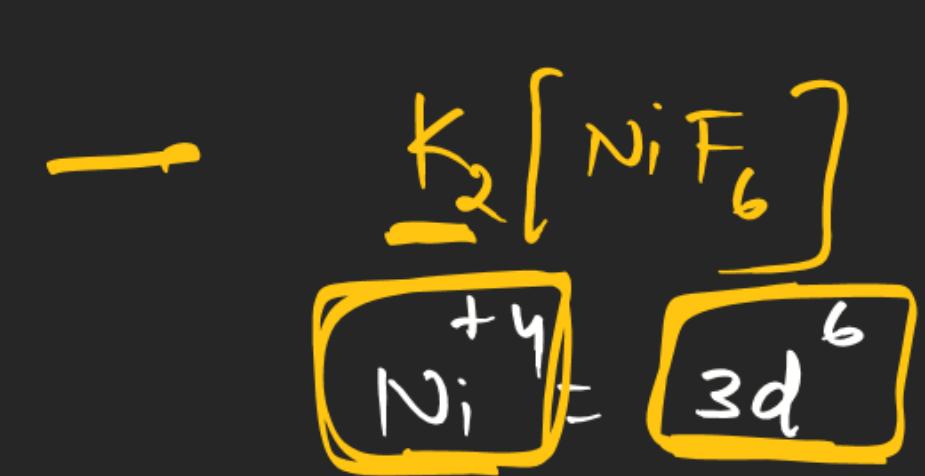


$d^2sp^3$   
Oct.

Paramagnetic  
 $\mu = 1.73$

$$\text{Fe}^{+2} = 3d^6$$





$$\begin{aligned}\text{Ni}^{+4} &= 3\text{d}^8 \underline{\text{s}^2} \\ &= \underline{3\text{d}^6}\end{aligned}$$

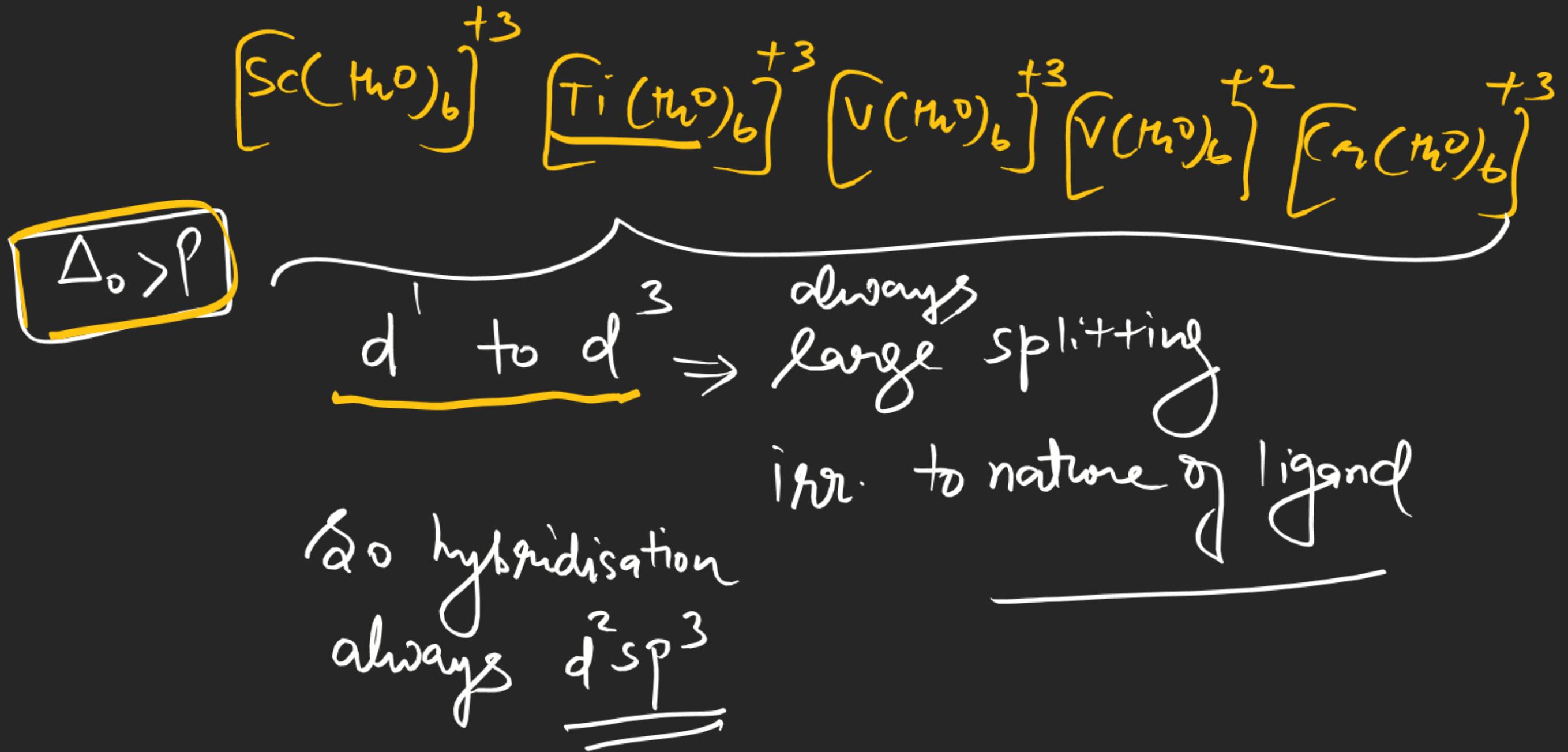
due to higher charge on Ni, large splitting

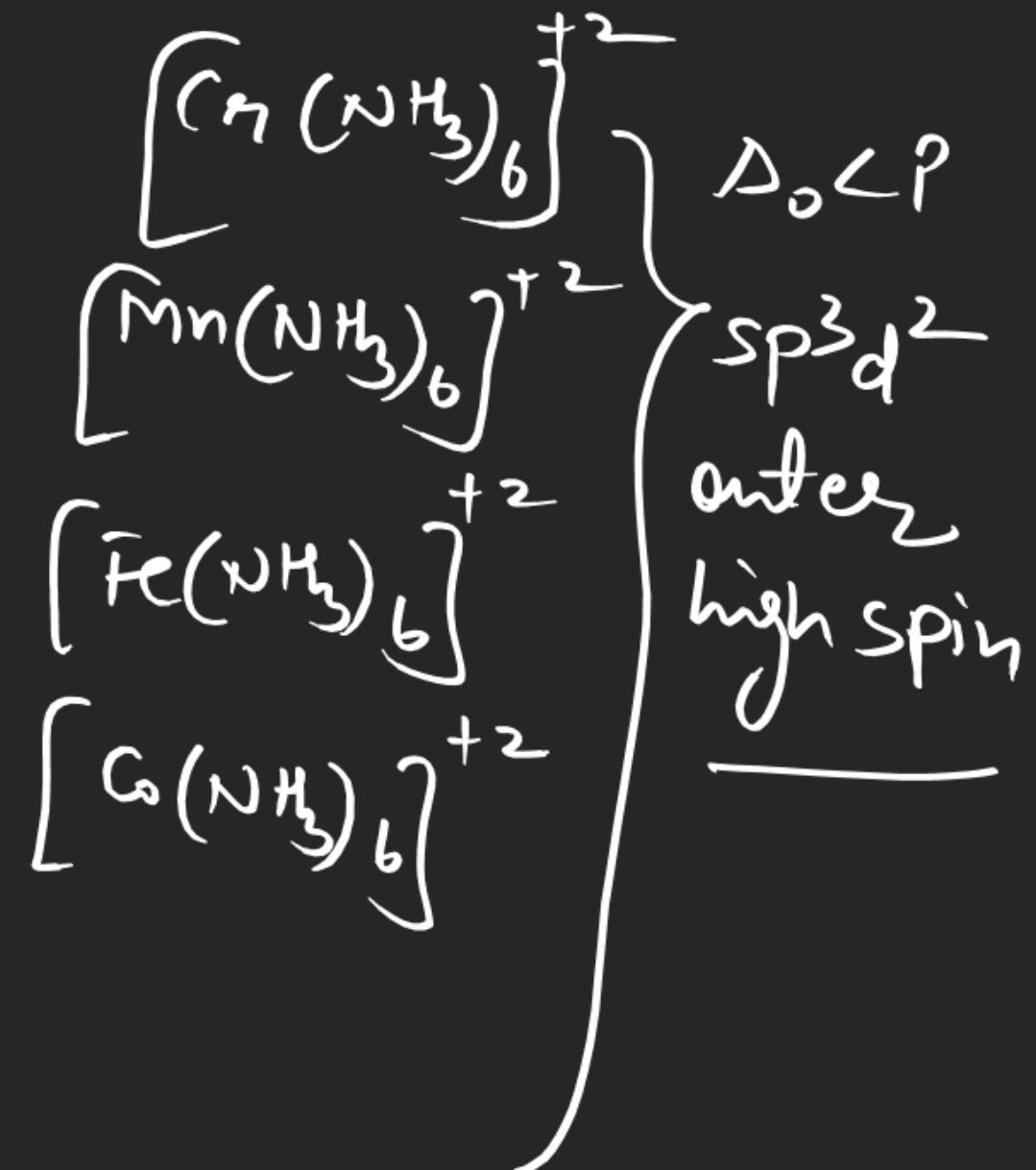
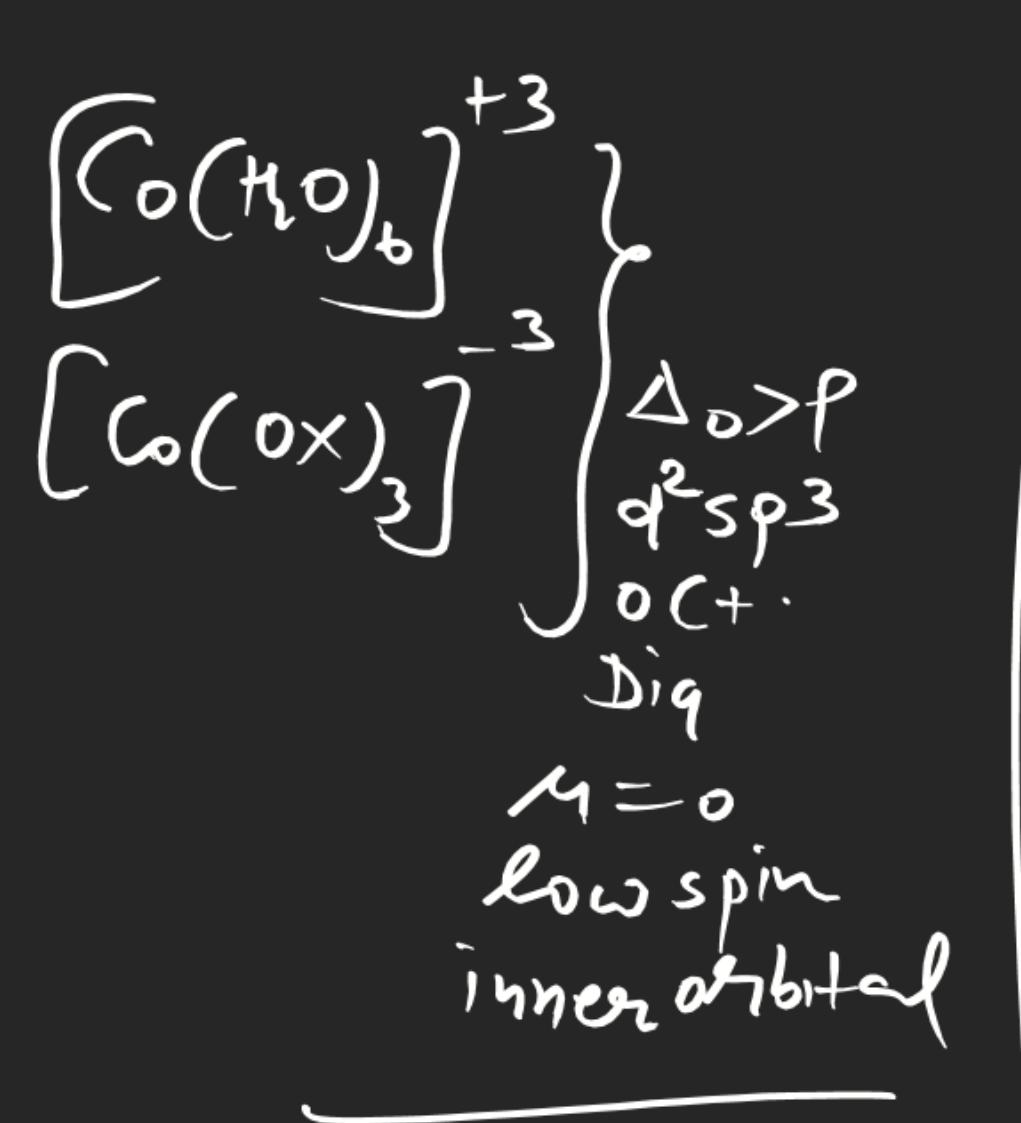
$$\Delta_o > P$$



$\text{d}^2 \text{s}^2 \text{p}^3$   
Oct.

Dia  
Magnetic





$\text{Fe}(\omega)_5$  follow 18 e<sup>-</sup> Rule

$\text{Fe}(\omega)_5$

(Spin only mag. moment)

$$\mu = \sqrt{n(n+2)} B.M$$

$$\gamma = \frac{4 \cdot p \cdot e}{}$$

$$\underline{\text{Fe}} = \boxed{3d^6 4s^2}$$

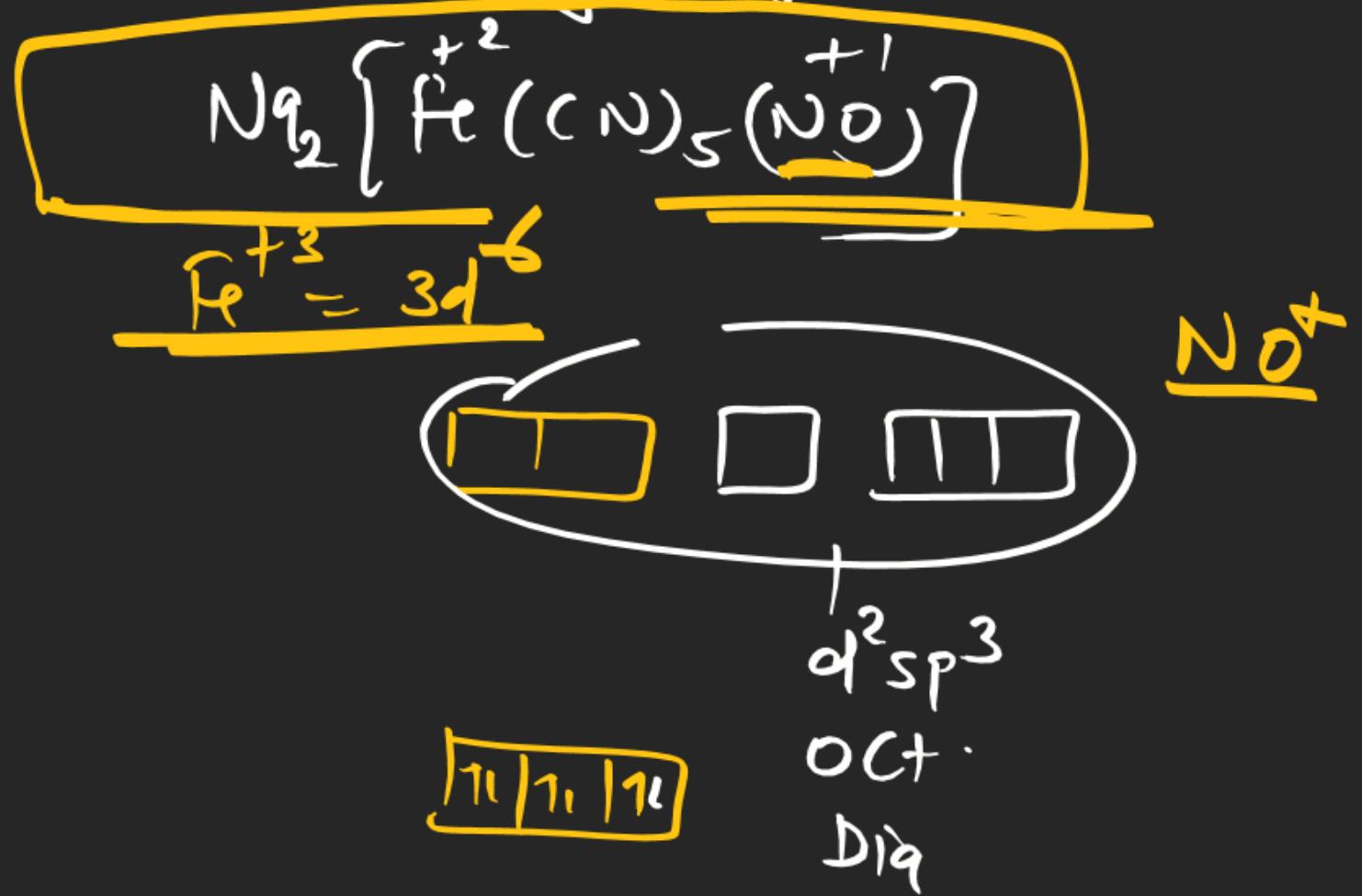
$$C_O = \frac{8}{2 \times 5} = \underline{\underline{10}}$$

$$\underline{\underline{8}} + \underline{\underline{10}} = \underline{\underline{18}}$$

$$\underline{\underline{\text{Ni}(\omega)_4}} = 10_i = \boxed{3d^8 4s^2}$$

$$4 C_O = \frac{4 \times 2}{18}$$

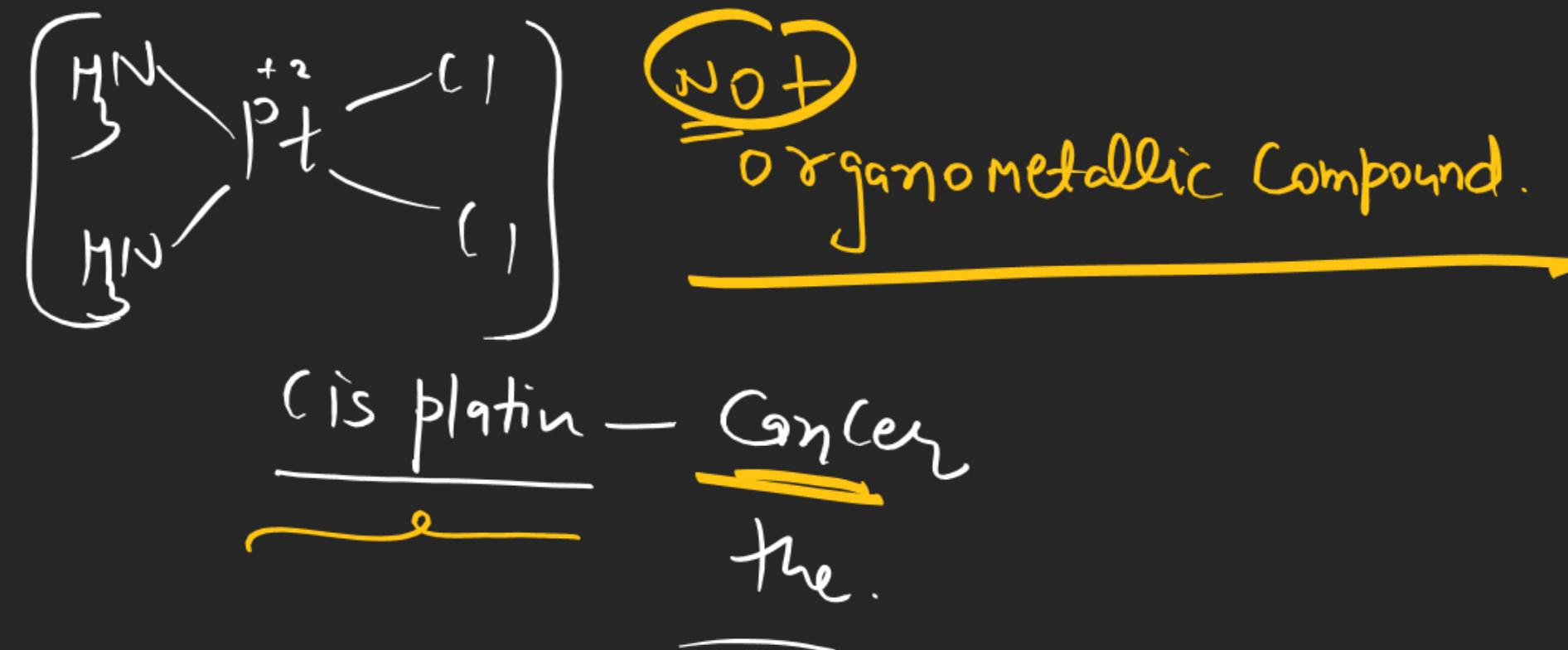
What is the hyb. of Sodium nitroprusside



$M = 0$   
inner orbital  
low spin

# COORDINATION COMPOUNDS

2. The compound that inhibits the growth of tumors is :



# COORDINATION COMPOUNDS

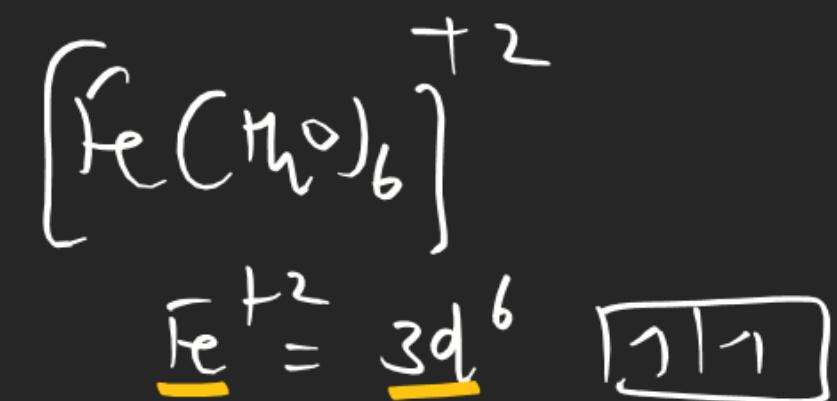
3. The calculated spin-only magnetic moments (BM) of the anionic and cationic species of  $[\text{Fe}(\text{H}_2\text{O})_6]^{+2}$  and  $[\text{Fe}(\text{CN})_6]^{-4}$ , respectively, are:

(A) 0 and 4.9

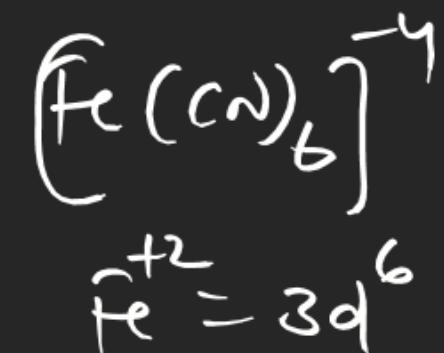
(B) 2.84 and 5.92

~~(C) 4.9 and 0~~

(D) 0 and 5.92

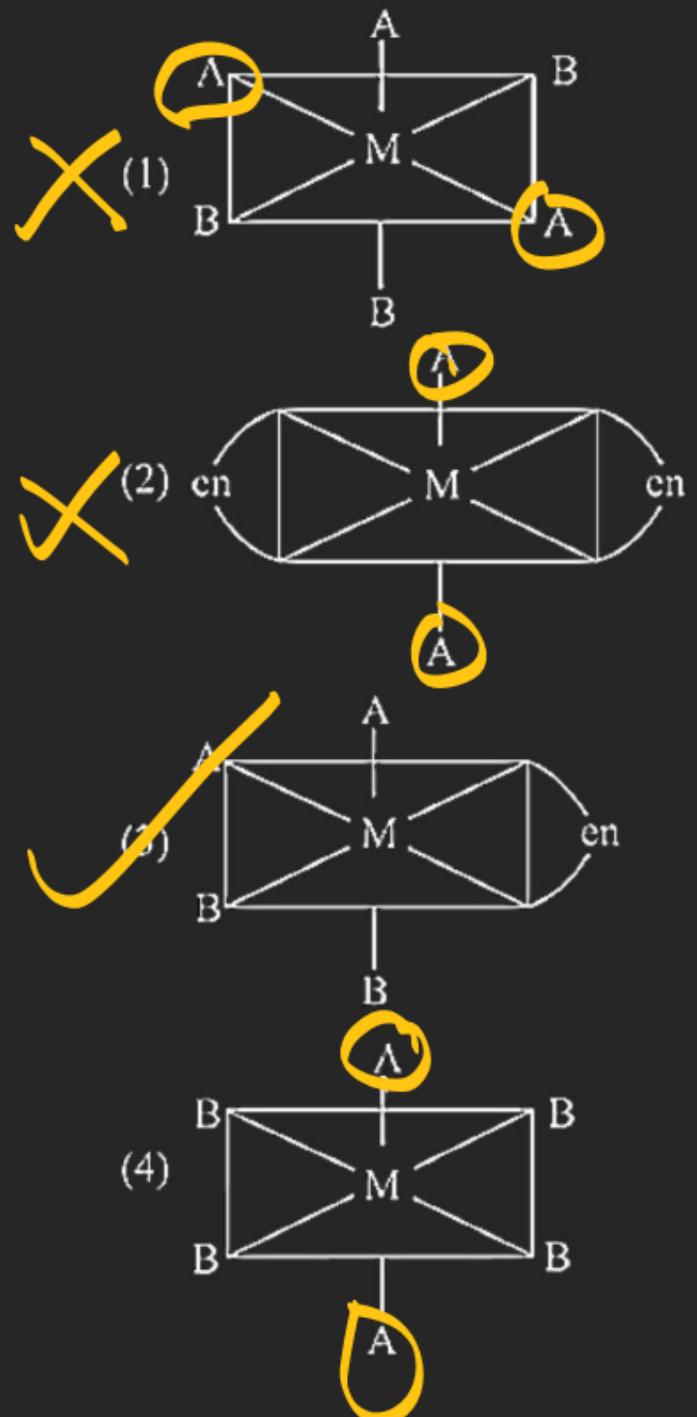


4.90



# COORDINATION COMPOUNDS

4. The one that will show optical activity is: (en = ethane 1, 2-diamine)



# COORDINATION COMPOUNDS

5. The degenerate orbitals of  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$  are:

(A)  $d_{xz}$  and  $d_{yz}$

(B)  $d_{yz}$  and  $d_{z^2}$

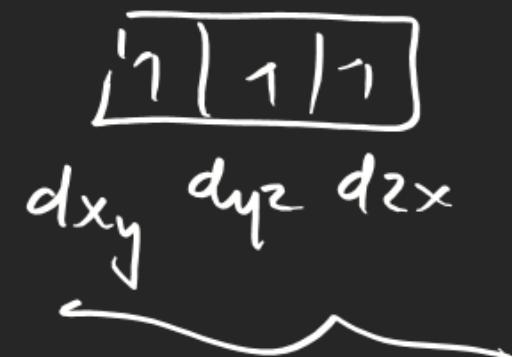
(C)  $d_{z^2}$  and  $d_{xz}$

(D)  $d_{x^2-y^2}$  and  $d_{xy}$

$$(g = 3d^3)$$



$d_{x^2-y^2} \quad d_{z^2}$



$d_{xy} \quad d_{yz} \quad d_{zx}$

# COORDINATION COMPOUNDS

**6. The correct statements among I to III are:**

# COORDINATION COMPOUNDS

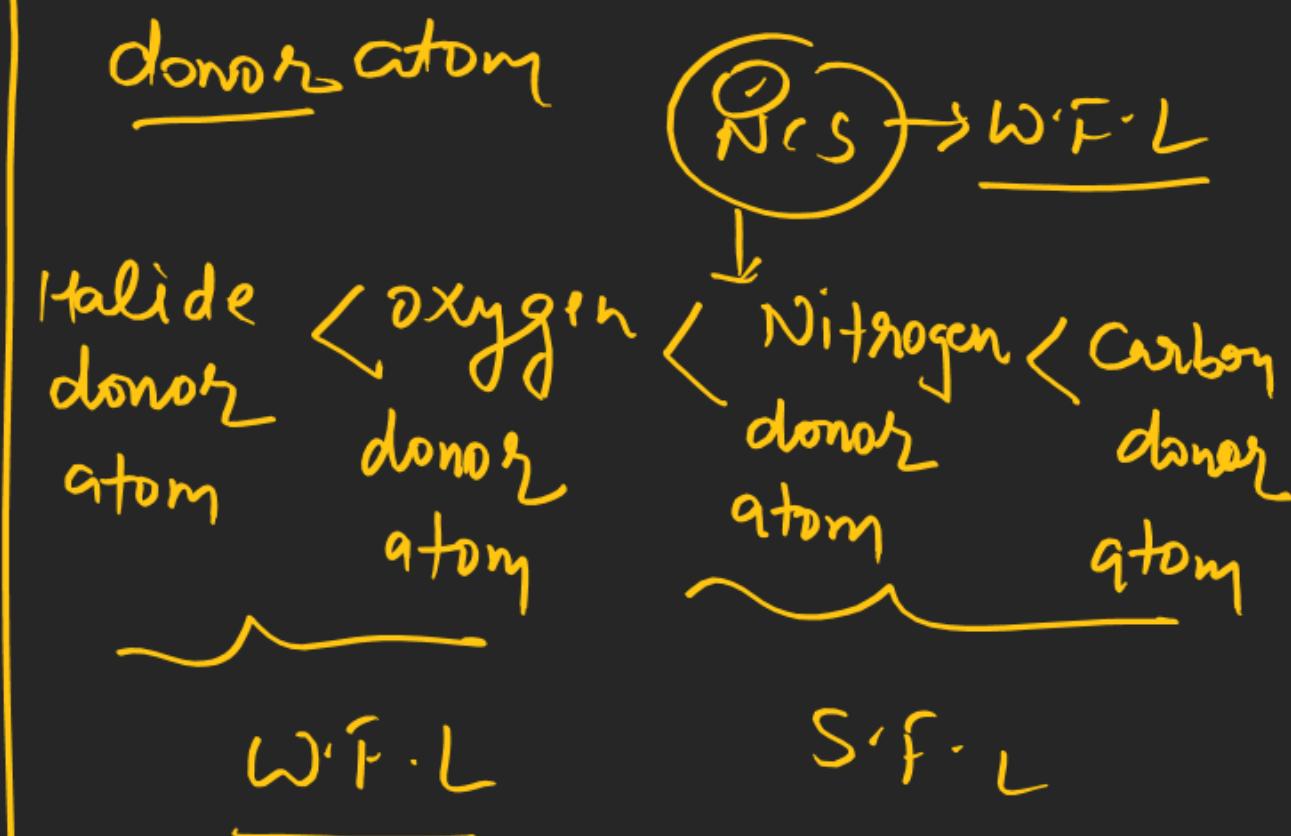
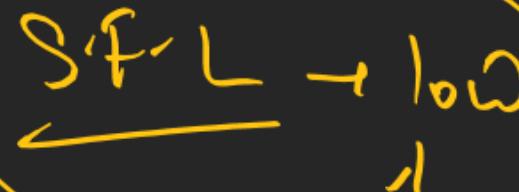
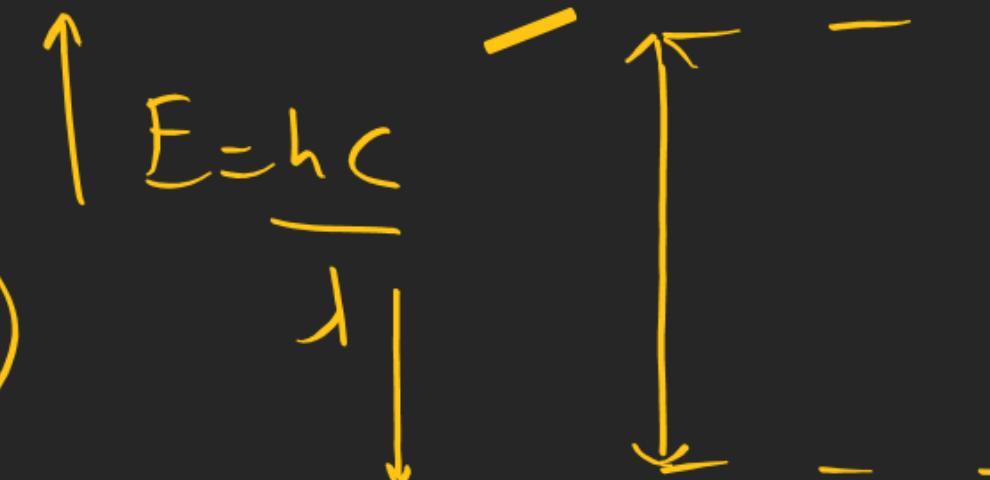
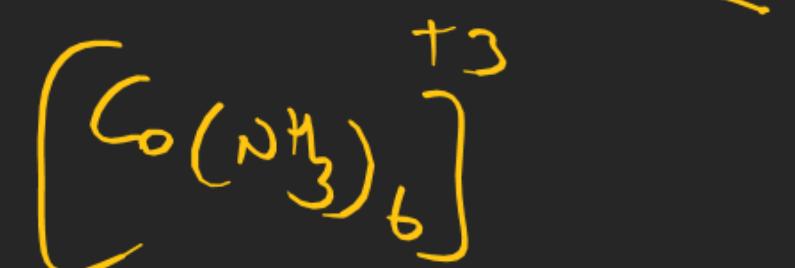
8. Three complexes,  $[\text{CoCl}(\text{NH}_3)_5]^{2+}$  (I),  $[\text{Co}(\text{NH}_3)_5\text{H}_2\text{O}]^{3+}$  (II) and  $[\text{Co}(\text{NH}_3)_6]^{3+}$  (III) absorb light in the visible region. The correct order of the wavelength of light absorbed by them is :

(A) (III) > (I) > (II)

(C) (II) > (I) > (III)

(B) (III) > (II) > (I)

~~(D) (I) > (II) > (III)~~

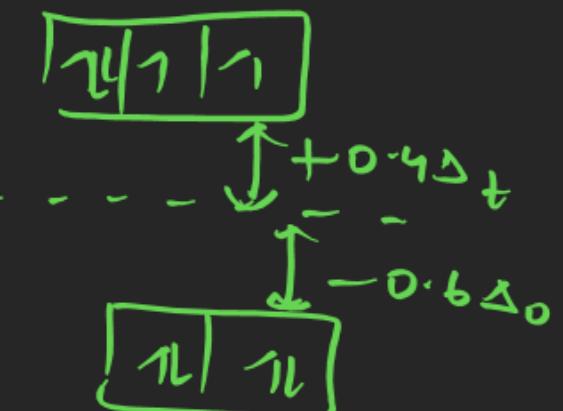


# COORDINATION COMPOUNDS

9. The crystal field stabilization energy (CFSE) of  $[\text{Fe}(\text{H}_2\text{O})_6]\text{Cl}_2$  and  $\text{K}_2[\text{NiCl}_4]$ , respectively are :

- (A)  $-0.6\Delta_0$  and  $-0.8\Delta_t$   
 (C)  $-2.4\Delta_0$  and  $-1.2\Delta_t$

- (B)  $-0.4\Delta_0$  and  $-0.8\Delta_t$   
 (D)  $-0.4\Delta_0$  and  $-1.2\Delta_t$



$$\text{C.F.S.E.} = -0.4\Delta_0 x + 0.6\Delta_0 y + m p$$

$$= -0.4 \times 4\Delta_0 + 0.6 \times 2\Delta_0$$

$$= -1.6\Delta_0 + 1.2\Delta_0$$

$$= -0.4\Delta_0$$

x = no  $\pi e^-$  in t<sub>2g</sub>

y = no  $\pi e^-$  in e<sub>g</sub>

m = no  $\eta e^-$  pairs

$$\text{Fe}^{+2} = 3d^6$$

$$+0.4 \times 4 - 0.6 \times 4$$

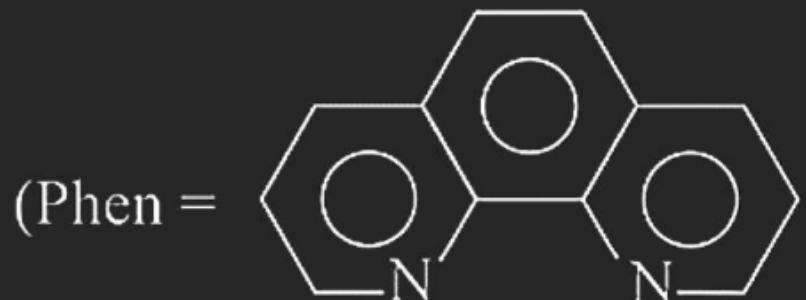
$$+1.6 - 2.4$$



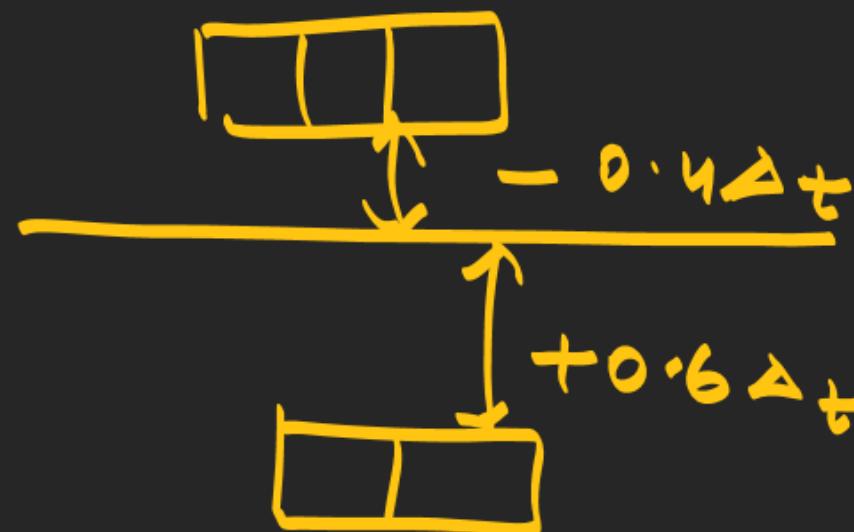
$$2.4 \\ 1.6 \\ 0.8$$

# COORDINATION COMPOUNDS

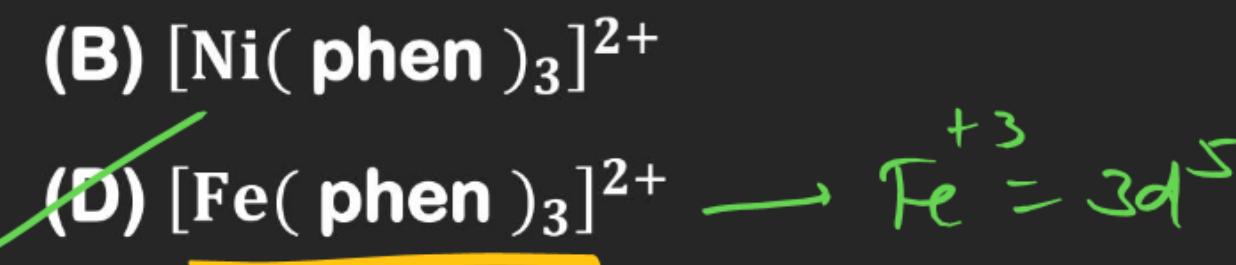
10. The complex ion that will lose its crystal field stabilization energy upon oxidation of its metal to +3 state is :



and  
ignore pairing energy)



- (A)  $[\text{Co}(\text{phen})_3]^{2+}$   
 (C)  $[\text{Zn}(\text{phen})_3]^{2+}$

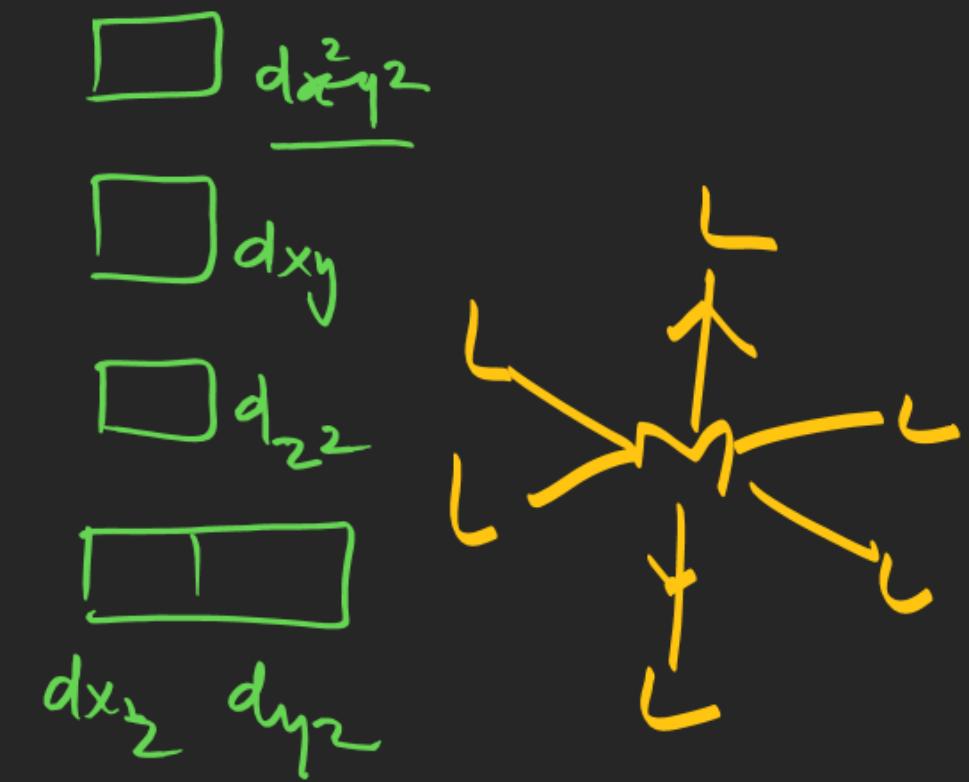
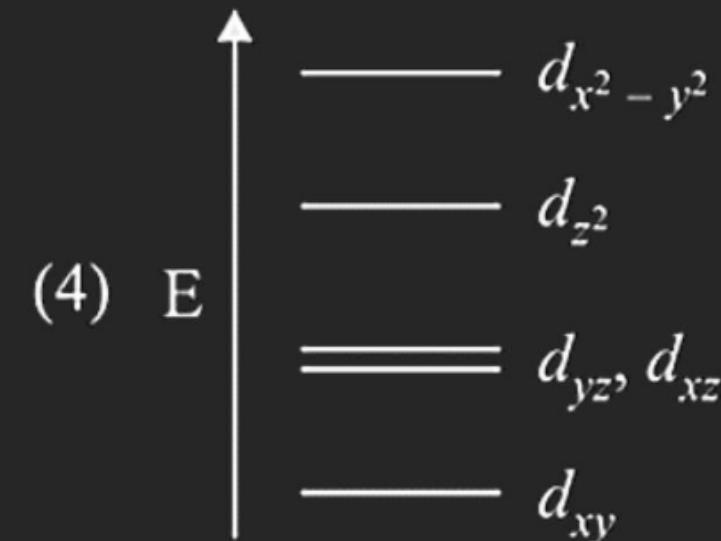
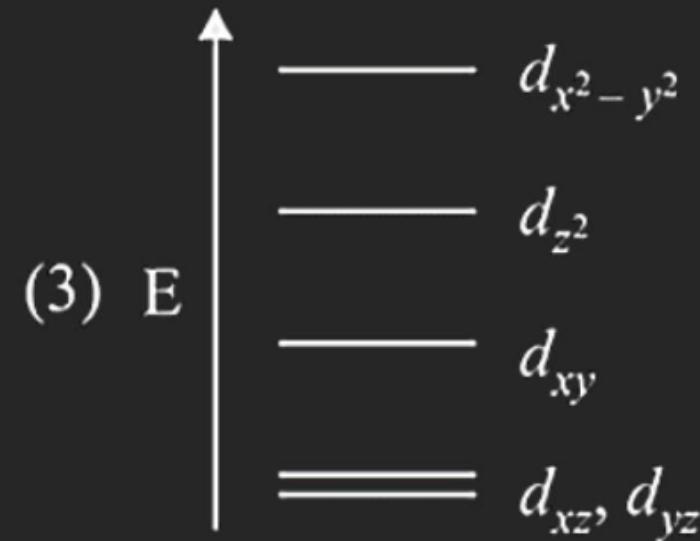
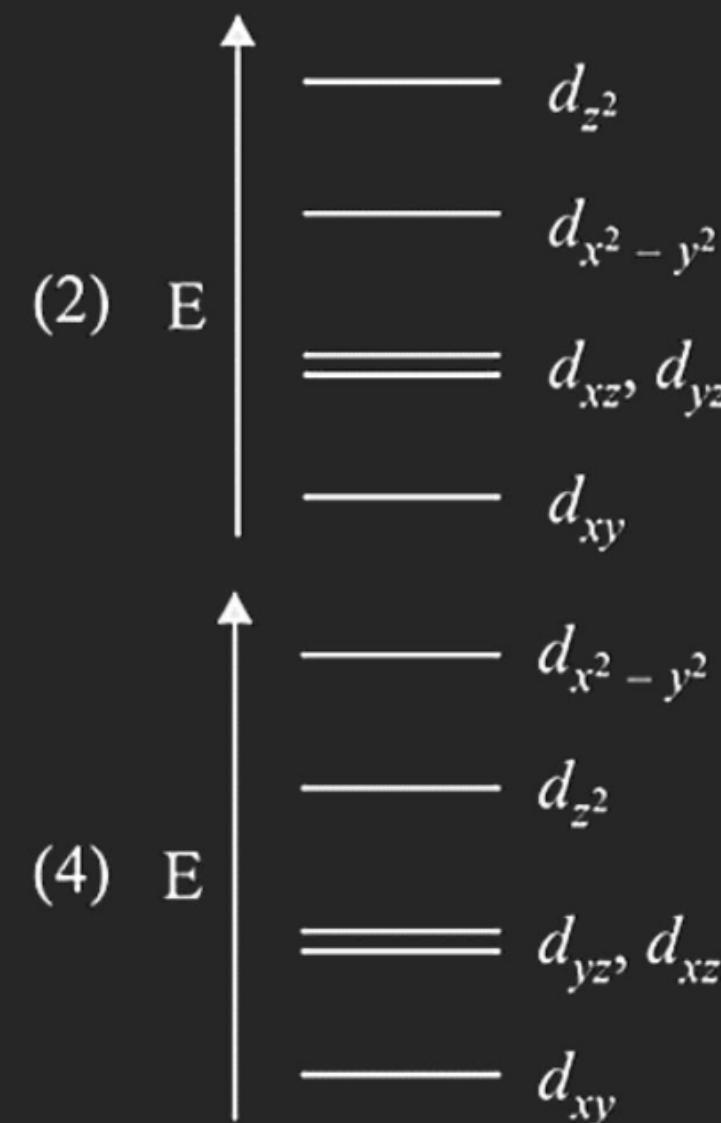
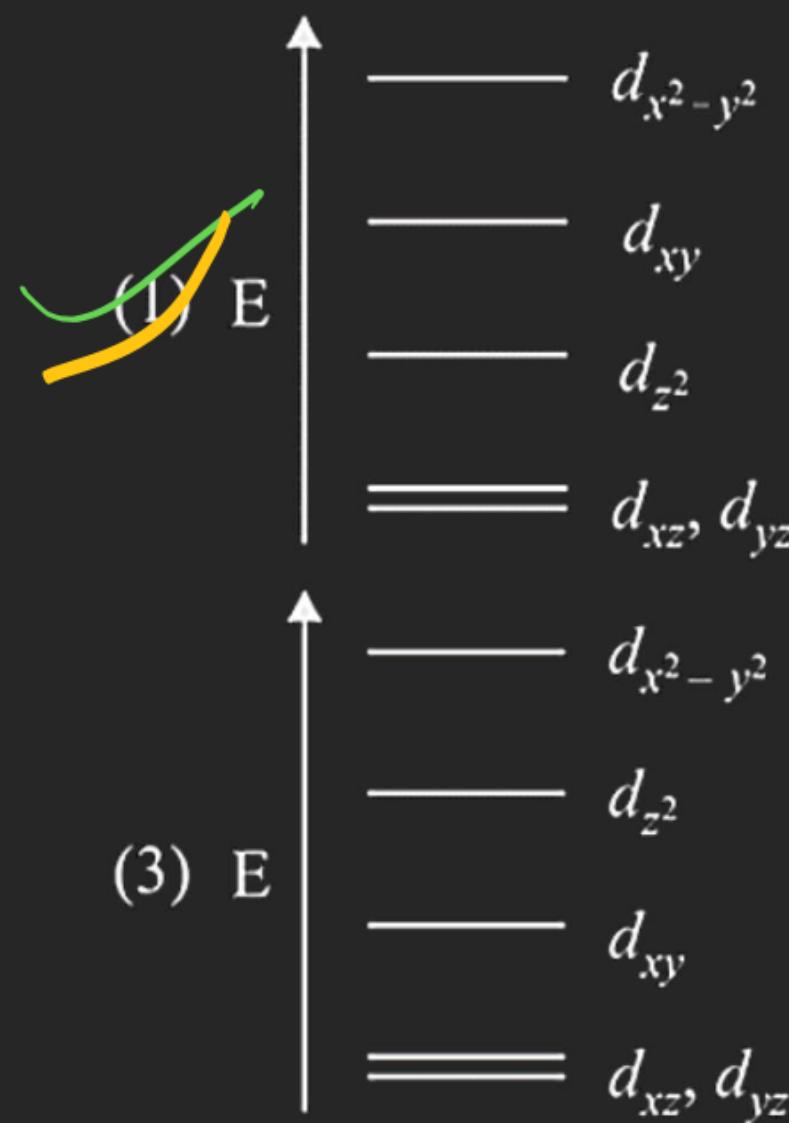


17/1

17/1

# COORDINATION COMPOUNDS

11. Complete removal of both the axial ligands (along the z-axis) from an octahedral complex leads to which of the following splitting patterns? (relative orbital energies not on scale)



# COORDINATION COMPOUNDS

12. The compound used in the treatment of lead poisoning is :

(A) D-penicillamine

(B) desferrioxime B

(C) Cis-platin

(D) EDTA]

