

Class 12th

→ d f Block
→ Coordination comp
4-5
Tg

Complete

INORGANIC
CHEMISTRY

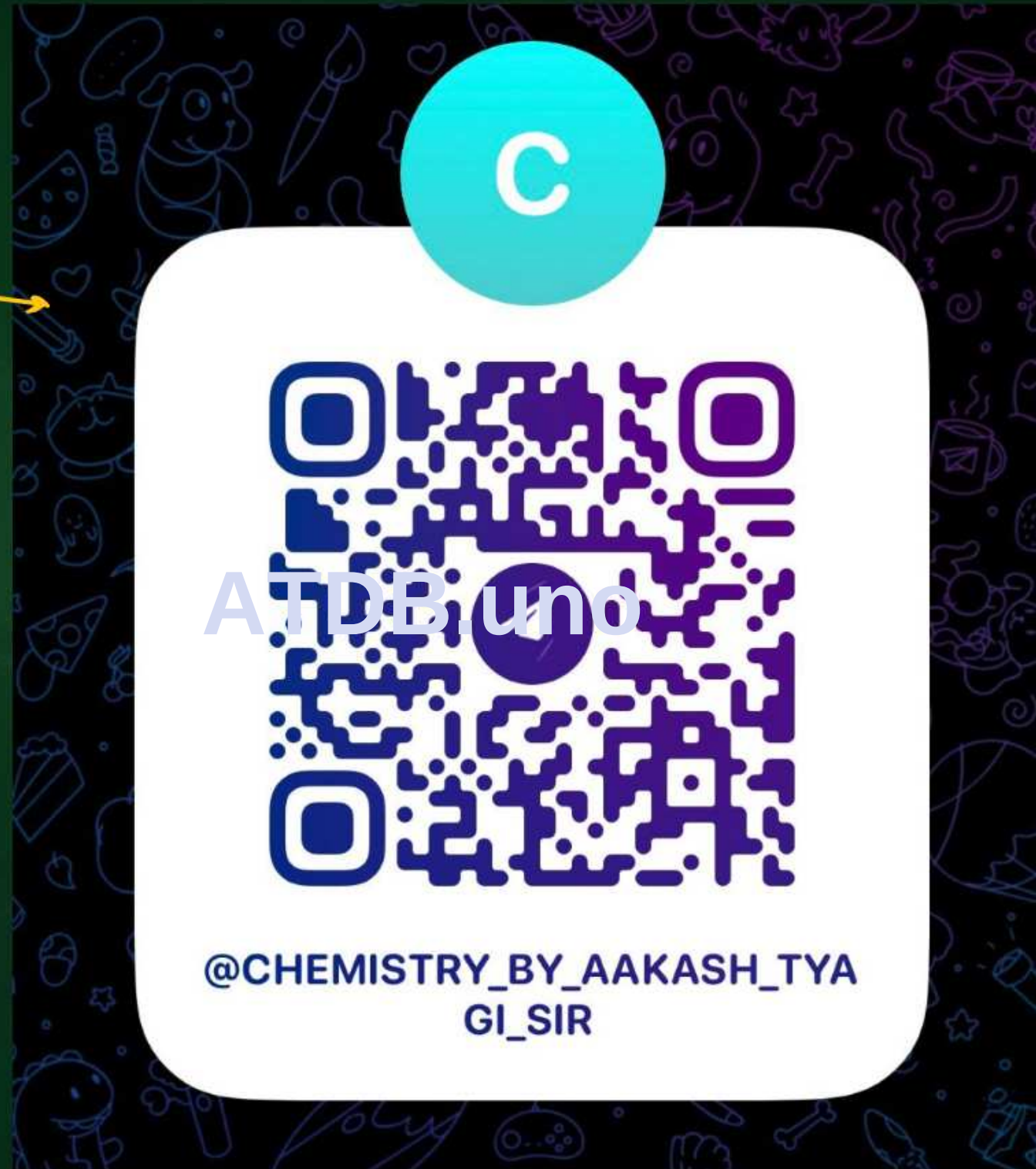
ATDB.uno

In Detail





Notes
Imp. Ques.



Break
15 min
↓
2:40
class will
Resume

1 → 1s

2 → 2s

3 → 3s

4 → 4s

5 → 5s

6 → 6s

7 → 7s

Li

Na

K

Rb

Cs

Fr

Be

Mg

Ca

Sr

Ba

Ra

S-block

d-Block

→ 40 elements

90% Ques

sky

T

V

chromepati

Mn

3d

4d

5d

6d

21 Sc

22 Ti

23 V

24 Cr

25 Mn

26 Fe

27 Co

28 Ni

29 Cu

30 Zn

39 Y

40 Zr

41 Nb

42 Mo

43 Tc

44 Ru

45 Rh

46 Pd

47 Ag

48 Cd

57 La

72 Hf

73 Ta

74 W

75 Re

76 Os

77 Ir

78 Pt

79 Au

80 Hg

89 Ac

104 Rf

105 Db

106 Sg

107 Bh

108 Hs

109 Mt

110 Ds

111 Rg

112 Cn

d-block

Ru belongs to which d-series?

(A) 3d

(B) 4d

(C) 2d

(D) 5d

12



Tricritical configuration of axes



4f Lanthanide
5f Actinide



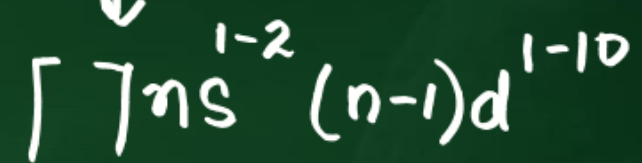
(APM) A/B/C/D

Que which of the following shows exceptional behavior in electronic Config?

- (A) Zn, Cr
- (B) Cu, Fe
- (C) Cu, Cr
- (D) None of these

General E.C of d-block

★★



ATDB.uno



d Block Elements



- **d-block** → Elements in d-block represent change or transition in properties from most electropositive s-block elements to most electronegative p-block elements. Therefore, these elements are called “**Transition elements**”.
- **Transition Elements** → Elements whose outermost shell is partially filled d orbitals either in ground state or in ionic form are only called as Transition Elements, that's why Zn, Cd, Hg are not transition metals or called as Pseudo Transition metals.

Account for the following:

Zn, Cd, Hg are considered as d-block elements but not as transition elements. (1/5, 2020)

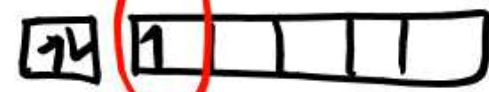
This is due to the reason that they do not have partially filled d-orbitals in their ground or ionic state.

APM ❤️



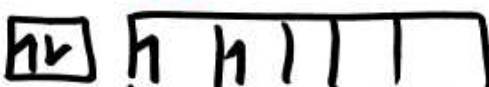
Diagram illustrating covalent bonding: Two atoms, each with one valence electron (represented by a box with '1'), are shown. An arrow points from the pair of electrons to the text "covalent Bonding".

- 3d

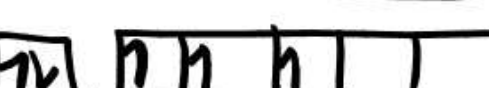


Unpaired

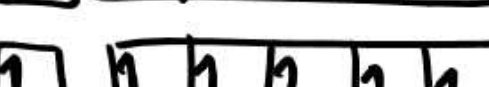
1 ✓



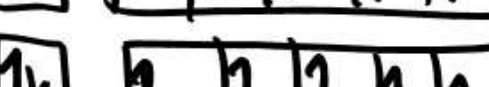
ATD



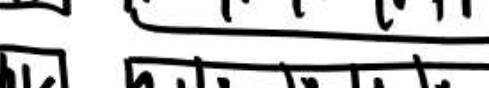
2



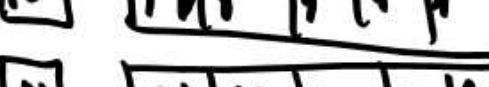
3 ✓



6 ✓



5 ✓



4 ✓



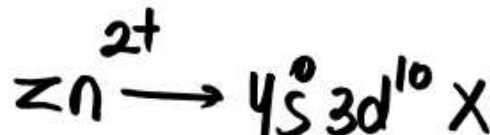
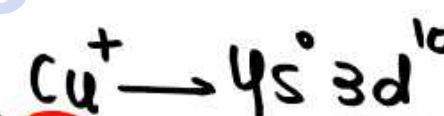
✓



2



Not a
Transition
element



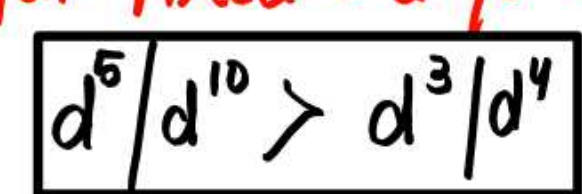
d-block



Fully filled $\rightarrow d^{10}$

Half filled $\rightarrow d^5$

ien. Filled $\rightarrow d^3/d$





	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
Z	39	40	41	42	43	44	45	46	47	48
5s	2	2	1	1	1	1	1	0	1	2
4d	1	2	4	5	6	7	8	10	10	10

ATDB.uno



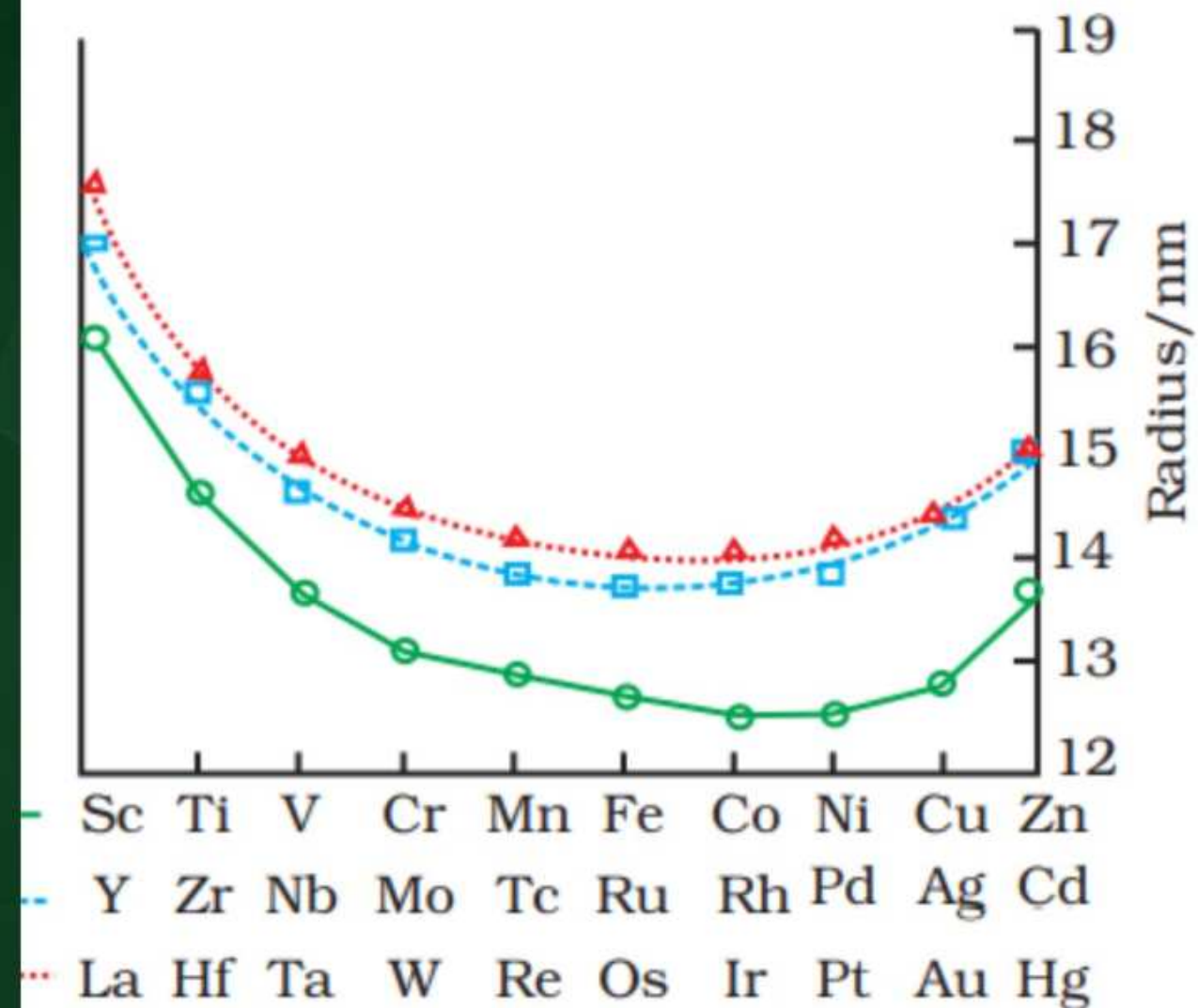
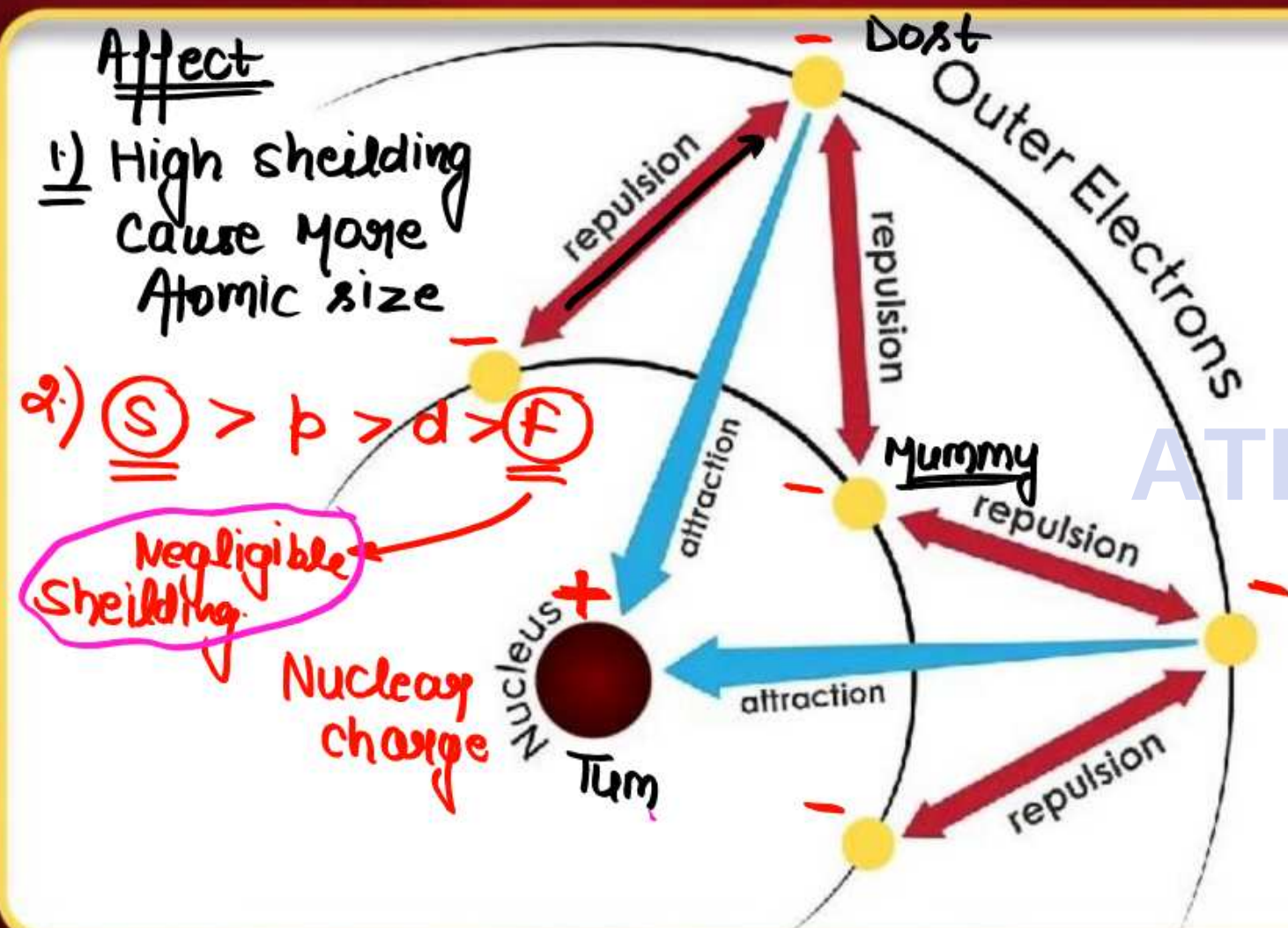
Metallic Character



- All the d-block elements are metals, have High M.P. and B.P. are good conductors of electricity, are hard ductile and Malleable (**Hg is an exception**).
→ Liq, at room Temp
- d-block elements shows both metallic and Covalent bonding.
Metallic → It is due to the presence of d-electrons in outermost shell
Covalent → It is due to the presence of partially filled d-orbital
APM ❤️
- More unpaired e in d orbitals → More Covalent/Metallic Bonding
↓
Hard will be the Metal
- **Cr, Mo and W** are very hard. due to large no. of unpaired e⁻
- **Zn, Cd, Hg** are very soft due to absence of unpaired e⁻ in d-orbitals.
- **Metallic character inc. down the group.**



SHIELDING EFFECT





Atomic Radii

★★

APM ♥



- Left → Right

As we move left to right in d-block, firstly size decreases due to increase nuclear charge but from midway when screening due (n – 1)d also increases the effect of inc. nuclear charge got overshadowed by screening effect and then further no change in atomic radii. *but at the end due to more s.f in Zn Atomic radii inc.*

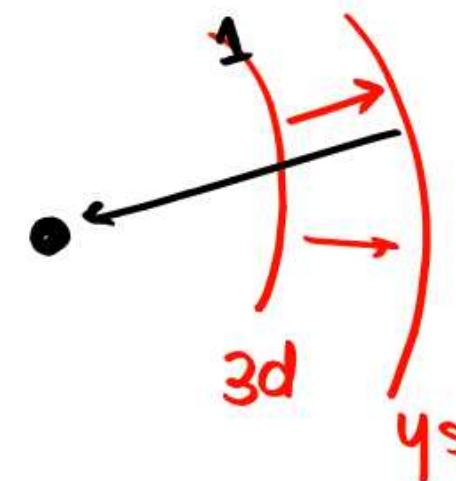
Ex. $4s^2 3d^1 > 4s^2 3d^2 > 4s^2 3d^3 > 4s^1 3d^5 \sim 4s^2 3d^5 \sim 4s^2 3d^6 \sim 4s^2 3d^7 \sim 4s^2 3d^8 \sim 4s^1 3d^{10} < 4s^2 3d^{10}$
Sc₂₁ > Ti₂₂ > V₂₃ > Cr₂₄ ~ Mn ~ Fe ~ Co ~ Ni ~ Cu < Zn

144	132	122	117	117	117	116	115	117	125
□	□	□	□	□	□	□	□	□	□
dec.				constant			Inc.		

Nuclear Charge > Screening

N.C = S.E

N.C < S.E





Lanthanide Contraction



Top → Bottom

The filling of 4f before 5d orbital results in a regular decrease in atomic radii called Lanthanoid contraction.

No. of shell inc.
Nuclear charge inc
Screening eff. inc
As a result size inc 3d → 4d

No. of shell inc. ✓
Nuclear charge inc. ✓
Negligible s & p
As a result atomic size remains cons. from 4d → 5d

3d
4s²3d¹

4d
5s²4d¹

5d
6s²4f¹⁴5d¹

6d

21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Mn	27 Co	28 Ni	29 Cu	30 Zn
39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd
57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg
89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn

f block

The net result of the lanthanoid contraction is that the second and the third d series exhibit similar radii (e.g., Zr 160 pm, Hf 159 pm) and have very similar physical and chemical properties. They are hard to separate.



2. two statements are given - one labelled as Assertion (A) and the other labelled as Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below. (2024)

~~(A)~~ Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

ATDB.uno

Assertion (A) : Separation of Zr and Hf is difficult.

Reason (R) : Zr and Hf have similar radii due to lanthanoid contraction.

Melting/Boiling Point

As we move Left → Right,
M.P. / B.P. first inc. and then decreases this is due to the fact that initially unpaired e⁻ in d-orbitals inc. Therefore, more covalent/Metallic bonding Hence strong bond but then further pairing up of d-orbitals taking place. Hence less Metallic bonding & low M.P.

M.P / B.P ⇒ High ⇒ Large no of unpaired e⁻ ↓ High Bonding

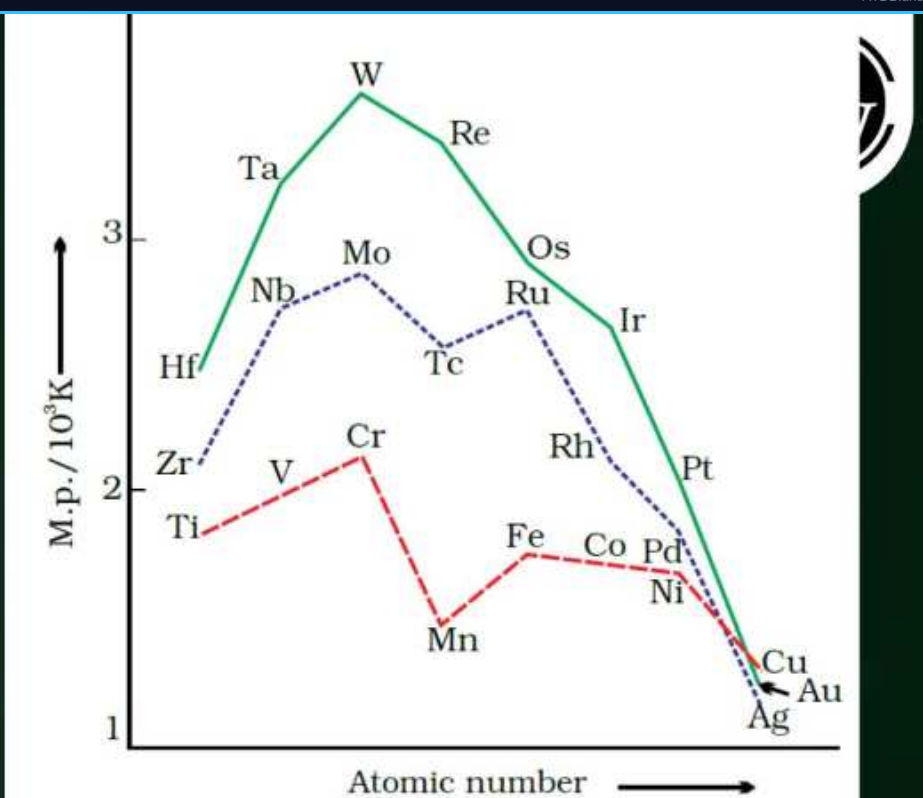


Fig. 4.1: Trends in melting points of transition elements

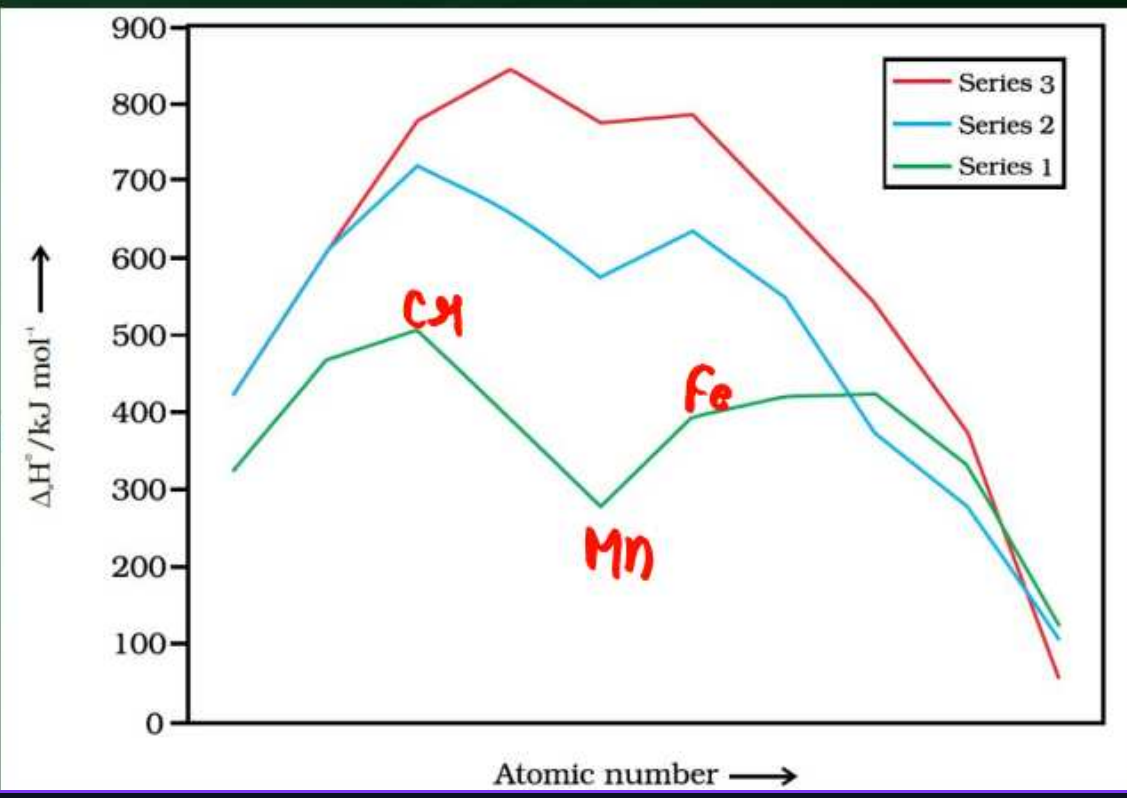
Enthalpy of Atomisation

In general, greater the number of valence electrons, stronger is the resultant bonding and Hence higher will be the enthalpy of atomization.

No. of unpaired e⁻ ⇒ High ⇒ High Bonding ⇒ High ΔH_{atom}



Due to its Half filled configuration it is Highly stable



Que which of the following
has least ΔH_{atom} ? PYQ 2024

(A) Mn

(B) Cr

(C) Sc

~~(D) Zn~~

ATDB.uno

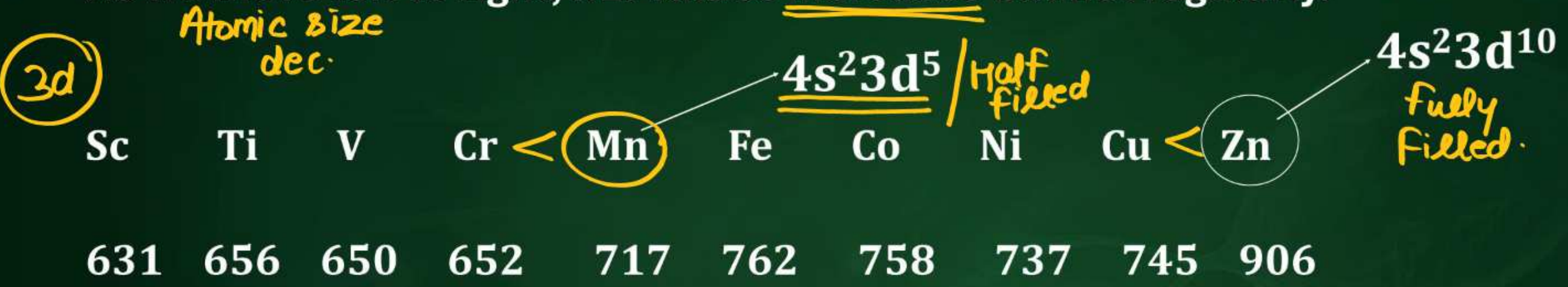




Ionization Energies



- As we move left to right, I.E. values increases but not regularly.

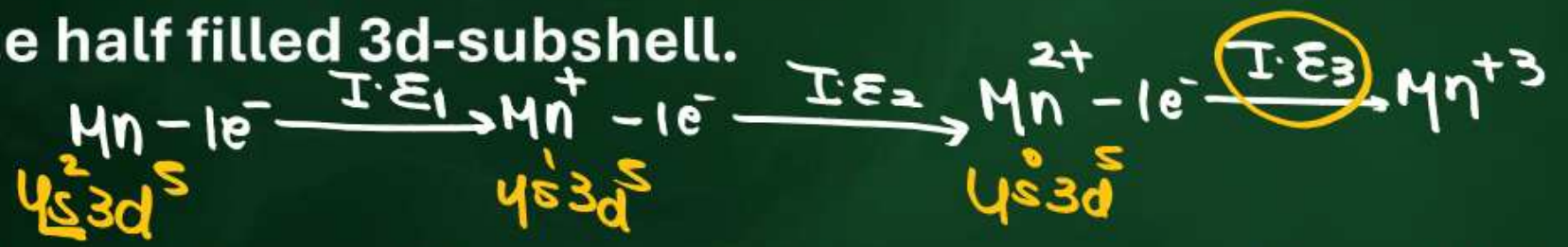


It can be as the minimum energy required to remove one e⁻ from outermost shell of an isolated gaseous atom.

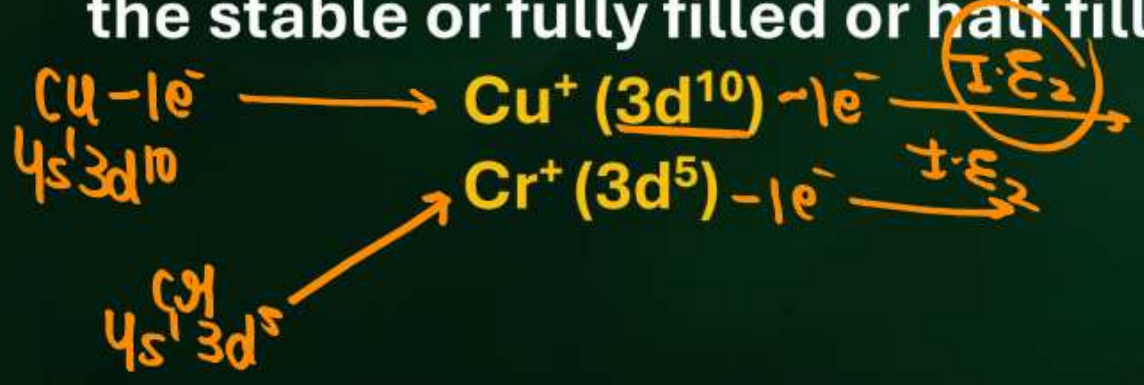
Stable & I.E

APM ❤️

Note : IIIrd I.E. of Mn is very high because third e⁻ is to be removed from a stable configuration (Mn²⁺, 3d⁵) i.e half filled 3d-subshell.



Note : IInd I.E. of Cu and Cr is very high as compared to neighbouring elements. This is because of the stable or fully filled or half filled configurations.



Top to Bottom-

From 4d to 5d or from 5d to 6d series where differentiating e⁻ enters into f-subshell which causes negligible screening effect (i.e Lanthanide contraction)
Hence due to More Nuclear charge I.E increases.

Size inc.
I.E dec

Size constant
Negligible S.E
High N.C
I.E inc

3d	21 Sc	22 Ti	23 V	24 Cr
4d	39 Y	40 Zr	41 Nb	42 Mo
5d	57 La	72 Hf	73 Ta	74 W
	89 Ac	104 Rf	105 Db	106 Sg

ATDB.uno





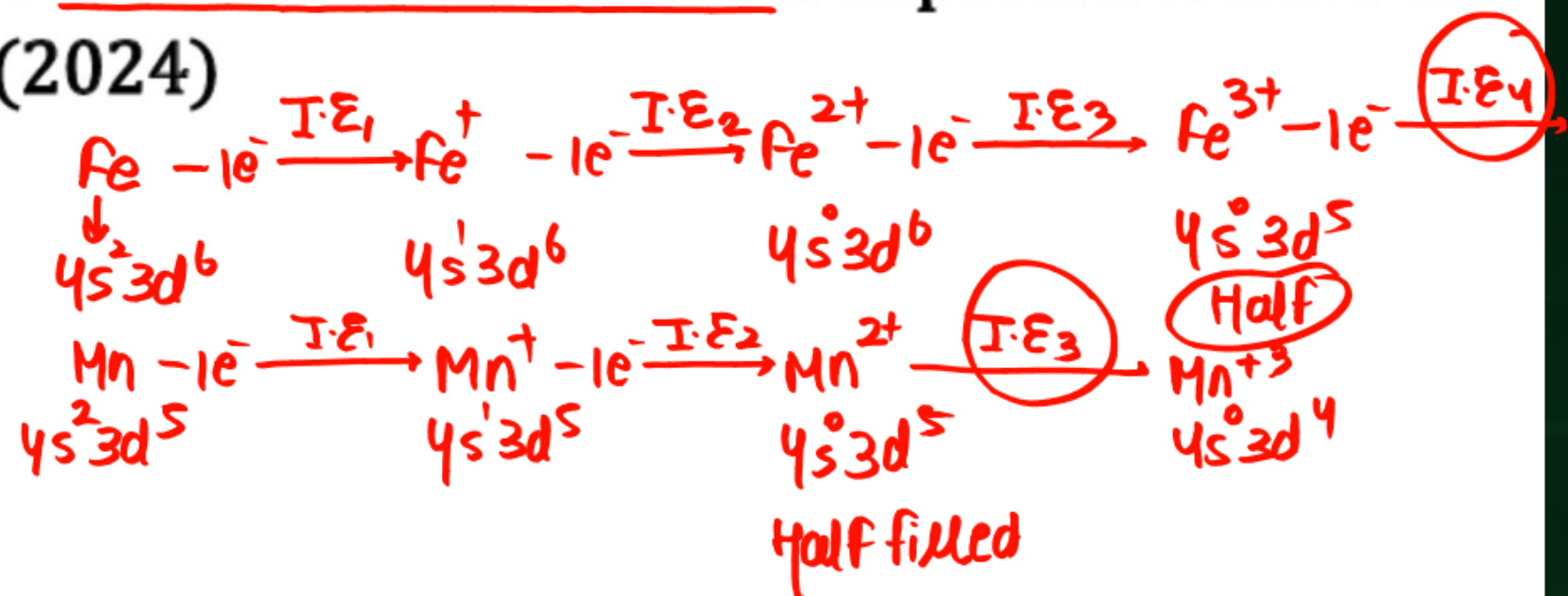
1. Which one of the following first row transition elements is expected to have the highest third ionization enthalpy ? (2024)

(A) Iron (Z = 26) X

☒ (B) Manganese (Z = 25)

(C) Chromium (Z = 24)

(D) Vanadium (Z = 23)



ATDB.uno



Why d-block elements shows variable Oxidation State

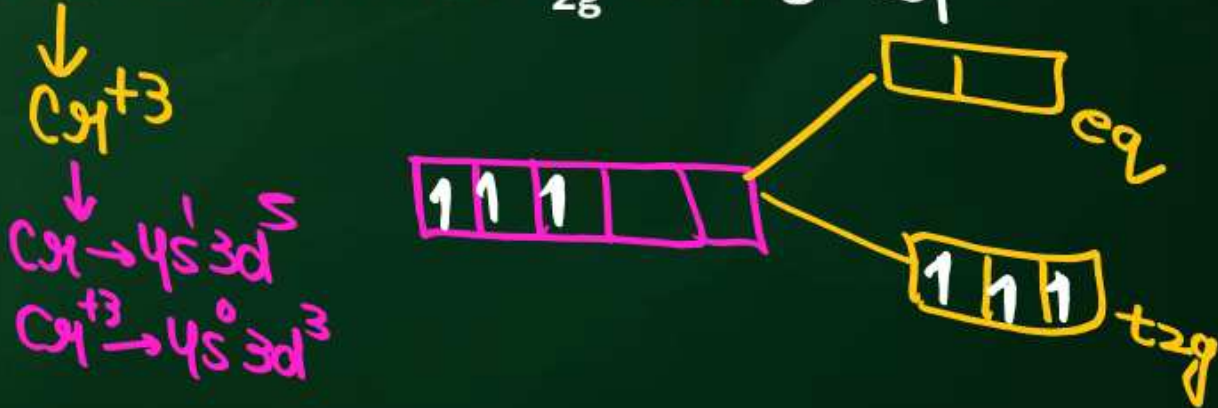
Transition elements shows variable oxidation states is due to the involvement of (n-1)d and outer ns electrons in Bonding as the energy of ns and (n-1)d subshell are nearly equal.

The lower oxidation state is generally shown when only ns elections participate in Bonding and higher oxidation states are exhibited when ns and (n-1)d electrons Both take part in Bonding.

$4s^2 3d^1$	$4s^2 3d^2$	$4s^2 3d^3$	$4s^1 3d^5$	$4s^2 3d^5$	$4s^2 3d^6$	$4s^2 3d^7$	$4s^2 3d^8$	$4s^1 3d^{10}$	$4s^2 3d^{10}$
Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
+3	+2 +3 +4	+2 +3 +4 +5	+2 +3 +4 +5 +6	+2 +3 +4 +5 +6 +7	+2 +3 +4 +6	+2 +3 +4	+2 +3 +4	+1 +2	+2
Bold → High stable									

Why some of the Oxi. State are more stable

- 1) Due to half filled d^5 config. Fe^{3+} , Mn^{2+}
- 2) Due to fully filled d^{10} config. Zn^{2+}
- 3) Due to inert electronic config. Cr^{+6} , Mn^{+7}
- 4) Due to half filled t_{2g} config. Cr^{+3}



Note PYQ

Sc & Zn doesn't show variable Oxidation State.



Oxidation state

- (i) Higher O.S (shown by fluorides (+4, +5, +6, +7, +8) and oxyfluoride)
- (ii) Common O.S (shown by chlorides (+2, +3) and sulphides)
- (iii) Lower O.S (shown by Metal carbonyl (Co) complex compound)

ATDB.uno



$$\text{Mn} + 4 \times 0 = -1$$

$$\text{Mn} + 4(-2) = -1$$

$$\text{Mn} - 8 = -1$$

$$\text{Mn} = -1 + 8$$

$$\boxed{\text{Mn} = +7}$$

Why Fluorine has ability to show higher oxidation state?

The ability of fluorine to stabilise the highest oxidation state is due to either higher lattice energy or higher bond enthalpy terms for the higher covalent compounds.

Why Oxygen has higher ability to stabilises higher oxidation state than fluorine?

This is due the reason that Oxygen can make multiple bonds to stabilise higher oxidation state while fluorine can't.

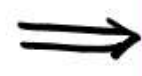


Standard reduction Potential



- Tendency of an element to get oxidized is called as Oxidation Potential. / *Loss of e⁻*
- Tendency of an element to get reduced is called as Reduction Potential. / *gain of e⁻*

D-Block Elements



Metals

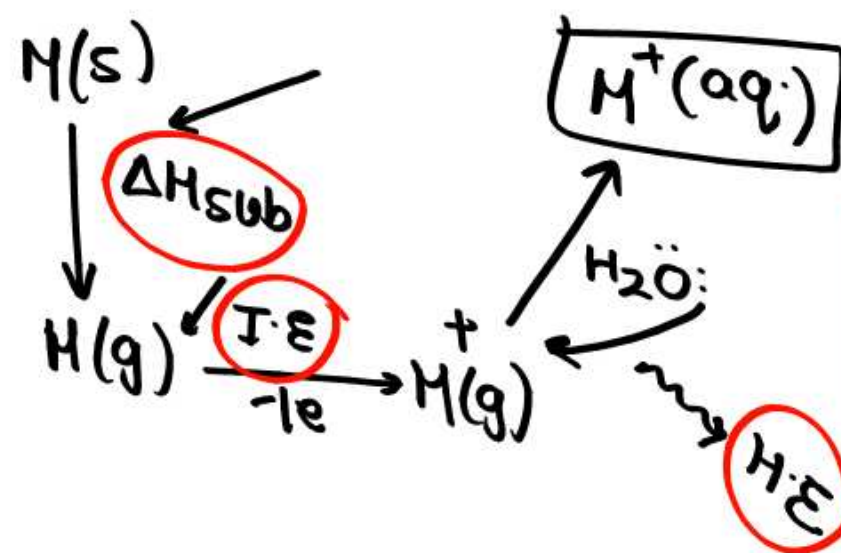


Oxidation

Red. Potential

$E_{Red} \Rightarrow$ Negative

This Reduction Potential is used to measure the stability of ions in aqueous form.



$\Delta H_T = \Delta H_{sub.} + I.E. - H.E.$

Process Forward



Stability

Low in Energy

Oxi.



T.E

Sub/I.E

H.E

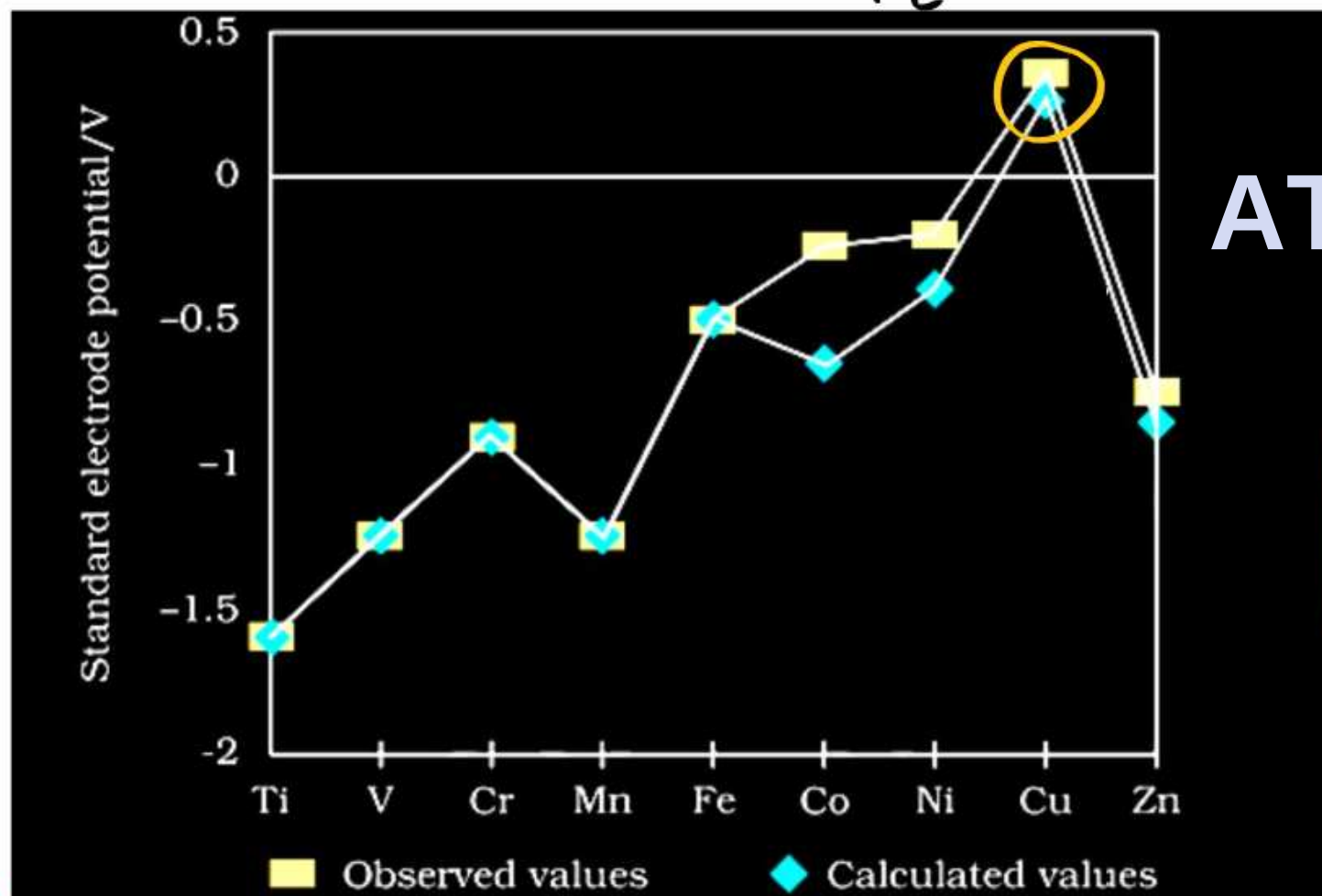
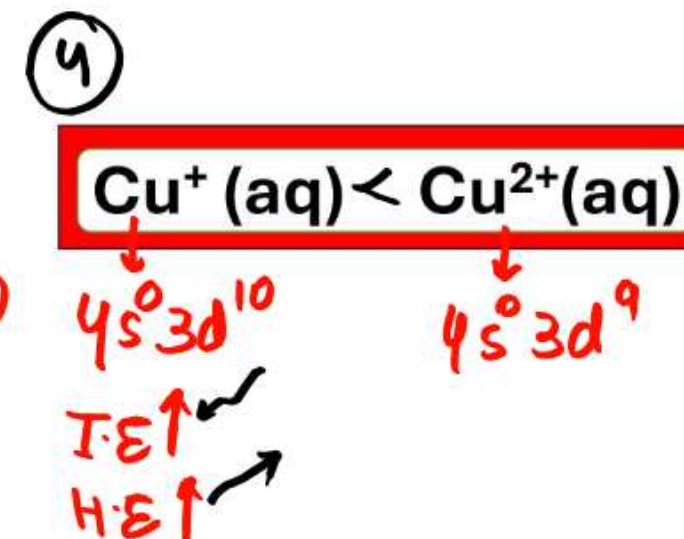
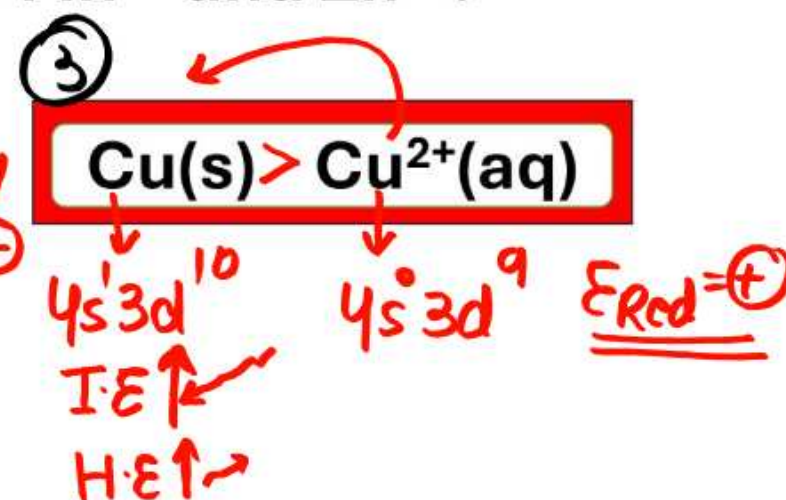
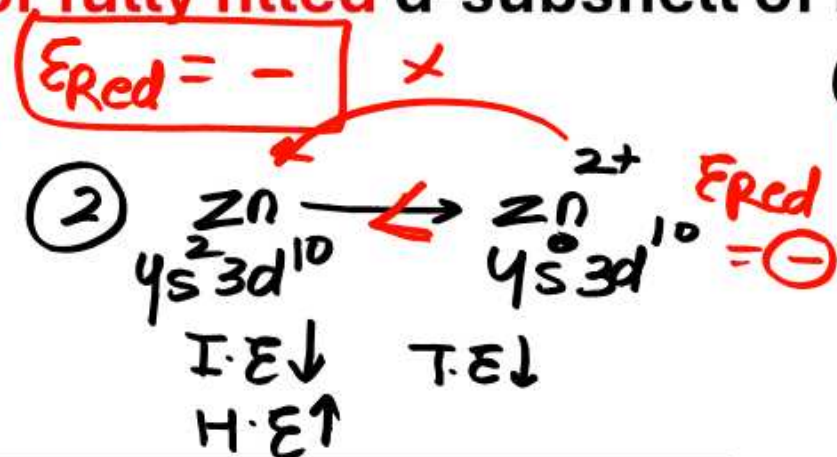
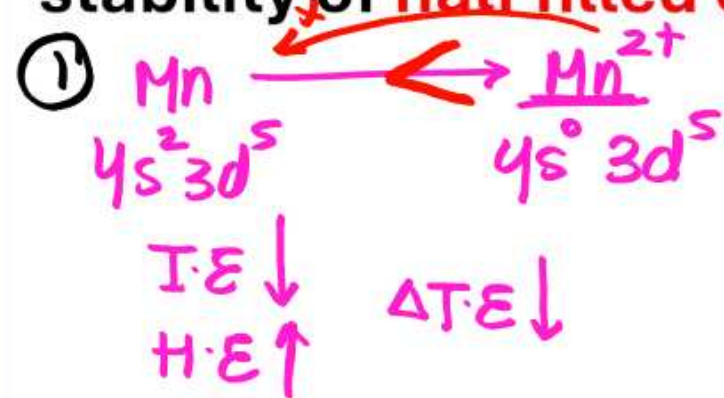
E_{Red}

$\downarrow (-)$



#

- The values of E^0 for **Mn, Zn and Ni** are more negative than expected. This is due to extra stability of **half filled or fully filled** d-subshell of Mn^{2+} and Zn^{2+} .



ATDB.uno

The high energy to transform $Cu(s)$ to $Cu^{2+}(aq)$ is not balanced/compensated by its hydration enthalpy.

The high energy to transform $Cu^+(aq)$ to $Cu^{2+}(aq)$ is balanced compensated by its hydration enthalpy.

Why Cu has $(+)$ E_{Red} potential while other d-block elements have $(-)$ E_{Red} potential.



4. The elements of 3d transition series are given as:

Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn

Answer the following:

(a) Copper has exceptionally positive

$E^\circ_{M^{2+}/M}$ value, why?

Ans

APM ❤️

(3 Marks) (2025)

Reducing agent
 ↓

Oxidation



(b) Which element is a strong reducing agent in +2 oxidation state and why?

Cu^{+3}

(c) Zn^{2+} salts are colourless. Why?

→ Due to absence of unpaired e^-

QUESTION



Why do the Transition elements exhibit higher enthalpies of atomization ?

Transition elements exhibit higher enthalpies of atomization due the presence of High no. of unpaired electrons which results in high bonding.

ATDB.uno

QUESTION



In the series Sc to Zn, the enthalpy of atomization of Zn is the lowest. Why ?

Since Zn has 0 unpaired electrons that's why it has lowest Enthalpy of atomisation.

ATDB.uno



Magnetic Properties



Paramagnetic Substances- A Paramagnetic substance is one which is weakly attracted into a magnetic field.

↳ Due to the presence of unpaired e^-

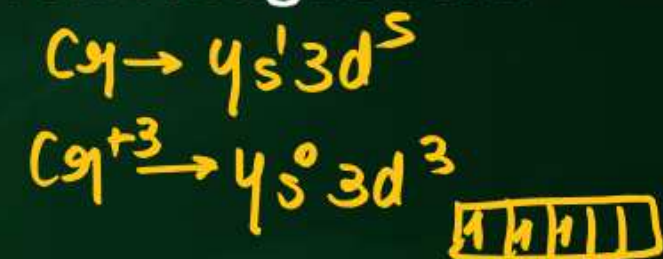
$$\mu = \sqrt{n(n+2)} \text{ Bohr Magnetons}$$

$n = \text{unpaired } e^-$

Diamagnetic Substances- A Diamagnetic substance is one which is repelled by a magnetic field.

↳ Due to absence of unpaired e^-

Substances which are attracted very strongly are said to be **ferromagnetic**. In fact, ferromagnetism is an extreme form of paramagnetism.



1. The magnetic moment is associated with its spin angular momentum and orbital angular momentum. Spin only magnetic moment value of Cr^{3+} ion (Atomic no. : Cr = 24) is _____.

(A) 2.87 B.M.

☒ (B) 3.87 B.M.

(C) 3.47 B.M.

(D) 3.57 B.M.

$\eta = 3$

(1 Marks) (2025)

$$\mu = \sqrt{3(3+2)}$$

$$\mu = \sqrt{15}$$

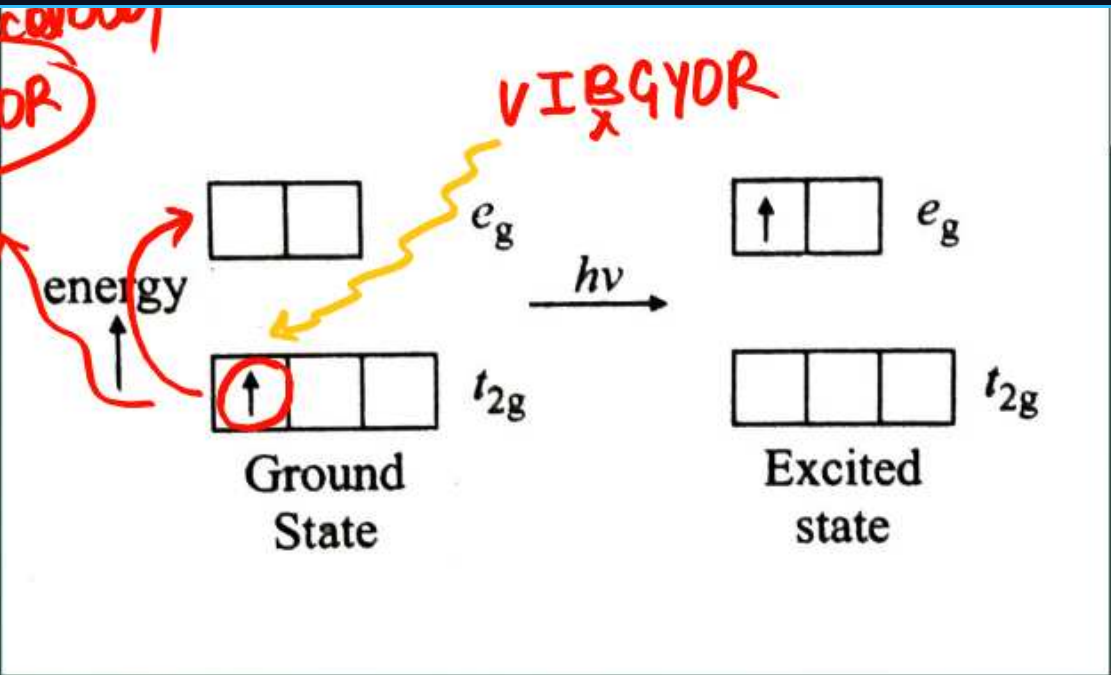


Colour

KAA

When an e⁻ from a lower energy d-orbital is excited to a higher energy d-orbital, the energy of excitation corresponds to a particular frequency of light absorbed And rest of the frequencies are passed giving complimentary colour.

This is called as d-d transition



Config.	Example	Colour
<u>3d⁰</u>	<u>Sc³⁺</u>	Colourless
<u>3d⁰</u>	Ti ⁴⁺	<u>Colourless</u>
3d ¹	Ti ³⁺	Purple
3d ¹	V ⁴⁺	Blue
3d ²	V ³⁺	Green
3d ³	V ²⁺	Voilet
3d ³	Cr ³⁺	Voilet
3d ⁴	Cr ²⁺	Blue

Config.	Example	Colour
3d ⁴	Cr ²⁺	Blue
3d ⁴	Mn ³⁺	violet
3d ⁵	Fe ³⁺	Yellow
3d ⁶	Fe ²⁺	Green
3d ⁷ /3d ⁶	CO ²⁺ /CO ³⁺	Blue pink
3d ⁸	Ni ²⁺	Green
3d ⁹	Cu ²⁺	Blue
3d ¹⁰	Zn ²⁺	Colurless

APM Trick on TOP

V^{2+}	→	voilet	very
Cr^{2+}	→	Blue	Beautiful
Mn^{2+}	→	Pink	pinky
Fe^{2+}	→	Green	q
Co^{2+}/Co^{3+}	→	Blue pink	Beautiful like pineapple
Ni^{2+}	→	Green	Hara h
Cu^{2+}	→	Blue	Balo ko
Zn^{2+}	→	Colourless	Colour apka

Sc	→	colourless	colourless
Ti^{3+}	→	Purple	Parlour jangi
V^{3+}	→	Green	Hara is
Cr^{3+}	→	Voilet	very
Mn^{3+}	→	Yellow	yummy



Tendency to form complexes

Formation of Interstitial compounds



•d-block elements have a marked ability to from complex compounds. This is due to their :-

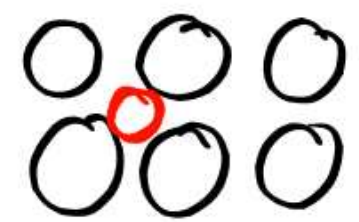
- 1. Small size
- 2. High nuclear charge
- 3. No. of vacant d-orbitals which can accommodate lone pair of ligands.

Ex. $\text{Fe}(\text{CO})_5$, $\text{Ni}(\text{CO})_4$, $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$

•Interstitial compounds are those which are formed when small atoms like H, C, B or N are trapped inside the crystal lattice of metal.

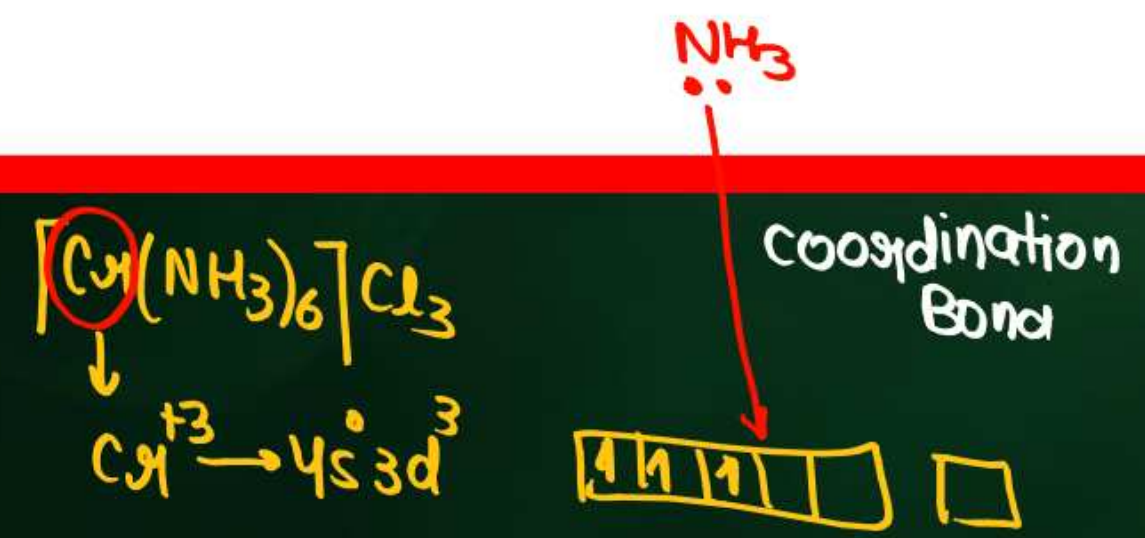
They are neither ionic nor covalent.

Ex. TiC , Mn_4N , Fe_3H , $\text{TiH}_{1.7}$ etc.



Charteristics :-

- 1. They have high M.P. that of pure metals.
- 2. They are very hard.
- 3. They are chemically inert





The incorrect statement about interstitial compounds is

- ~~(a)~~ they are chemically reactive.
- (b) they are very hard.
- (c) they retain metallic conductivity.
- (d) they have high melting point.

(2020)

ATDB.uno

Ye Question se darta h



Parr aaj to kr lega



Catalytic Properties



- The transition metals and their compounds are known for catalytic activity.
- Catalyst at a solid surface involve the formation of bonds between reactant molecules and atoms of the surface of the catalyst.



Since transition metal ions can change their oxidation state they become more effective or catalyst or they can utilize $(n - 1)d$ orbitals and use Multiple oxidation state in Bonding.

ATDB.uno

Catalyst	Process
Fe	Haber's process
Ni	Addition Reaction
V_2O_3	Contact process (H_2SO_4 formation)
Co salt	Bleaching power Decomposition

Catalyst	Used as
<u>Ziegler's Natta catalyst</u> <u>$\text{TiCl}_4^+ \text{Al}(\text{C}_2\text{H}_5)$</u>	Production of <u>polythene</u>
PdCl_2	In wacker process $\text{C}_2\text{H}_4 \rightarrow \text{CH}_3\text{CHO}$
Pt/Rh	Making of HNO_3 in Ostwald process

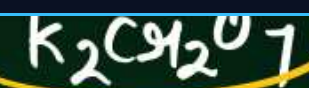


Important Compounds



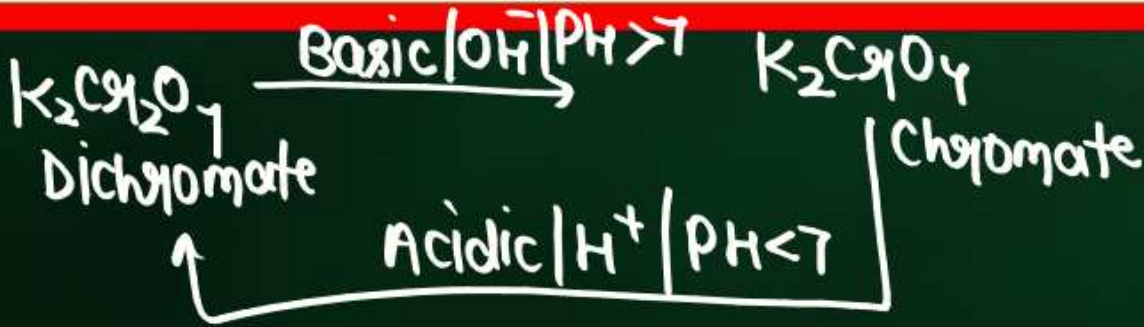
(A) Potassium Dichromate ($K_2Cr_2O_7$) :

Prep: Chromite ore



The chromate and dichromate are interconvertible in aqueous solution depending upon pH of the solution.

2024
PYQ



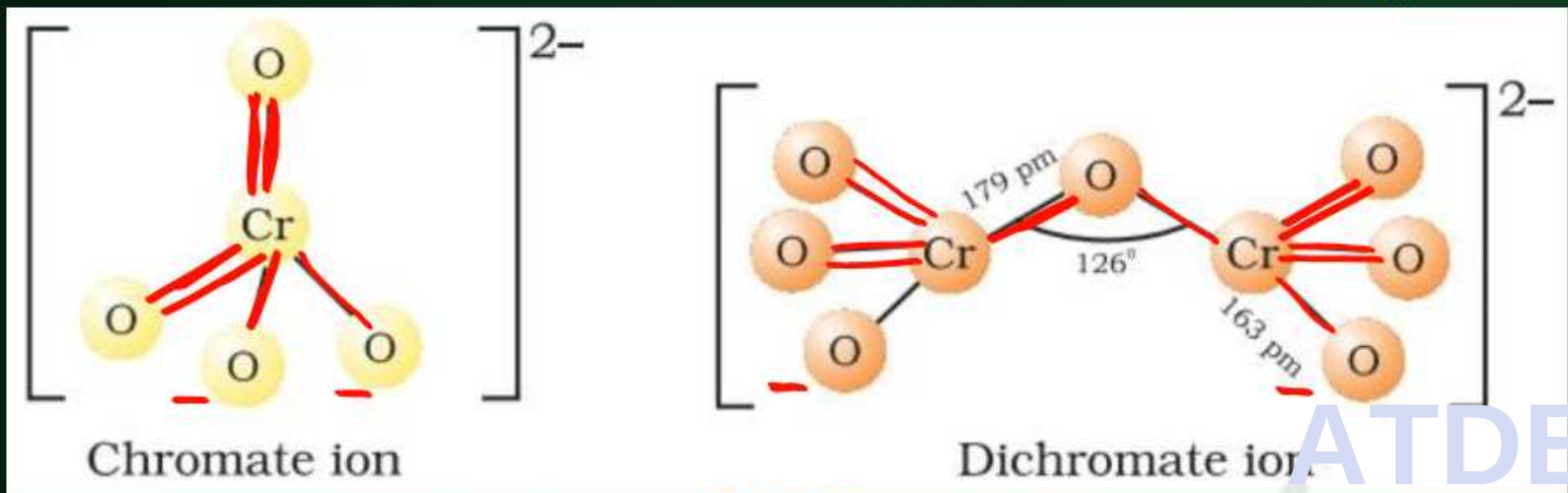


Structure of Chromate and Dichromate



Chromate/ CrO_4^{2-}

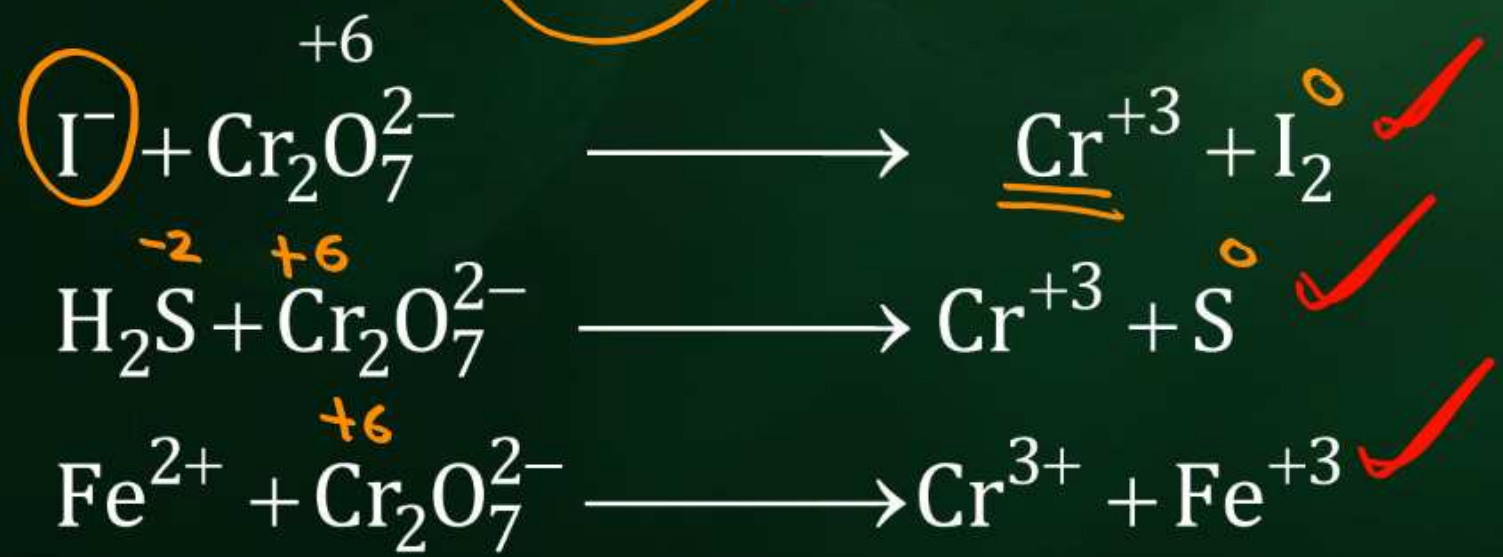
Dichromate/ $\text{Cr}_2\text{O}_7^{2-}$



CrO_4^{2-}
 $\downarrow$
 $\text{Cr} + 4 \times \text{O} = -2$
 $\text{Cr} + 4(-2) = -2$
 $\text{Cr} - 8 = -2$
 $\text{Cr} = -2 + 8$
 $\text{Cr} = +6$

APM ❤️

$\text{K}_2\text{Cr}_2\text{O}_7$ will oxidize Iodide to Iodine, Sulphides to Sulphur, Sn^{2+} to Sn^{4+} and Fe^{2+} to Fe^{3+}

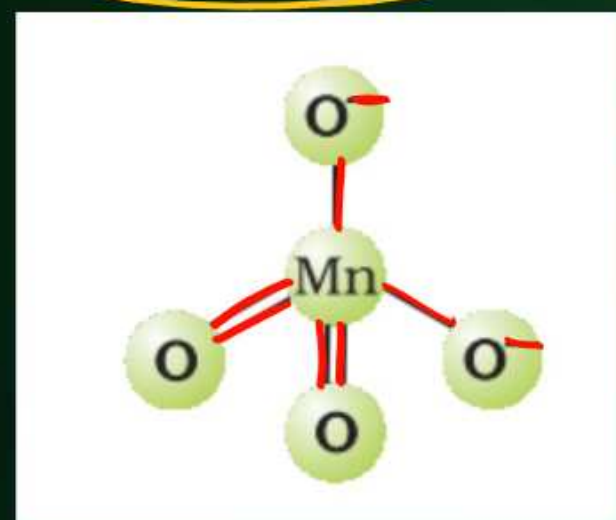


Note Cr^{+6} is less stable than Cr^{+3}
 $\text{Cr}^{+6} < \text{Cr}^{+3}$
↓
Oxidising agent
Reduction

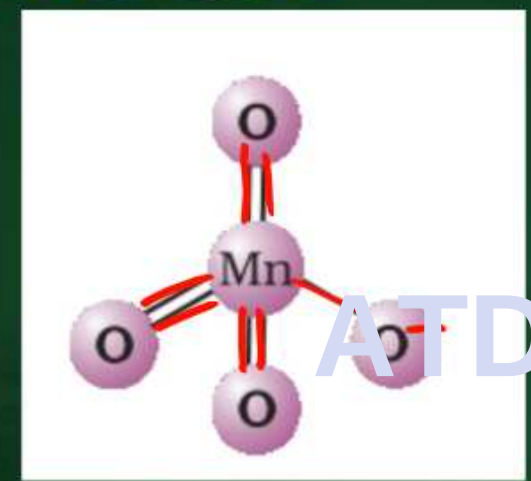


Manganate and Permanganate

(B) Manganate
(MnO_4^{2-})

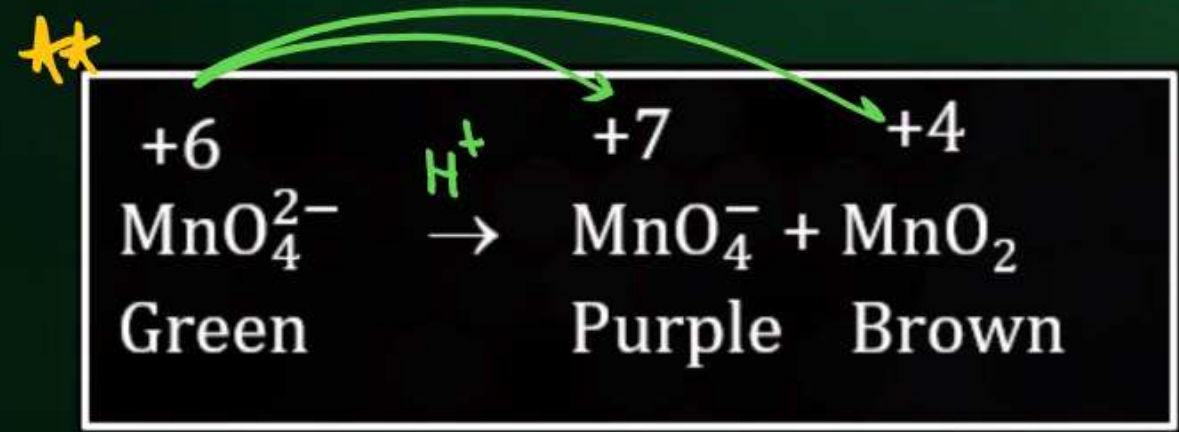


Permanganate
(MnO_4^-)



MnO_4^{2-}
 $\text{Mn} + 4 \times 0 = -2$
 $\text{Mn} + 4(-2) = -2$
 $\text{Mn} - 8 = -2$
 $\text{Mn} = -2 + 8$
 $\text{Mn} = +6$

MnO_4^{2-} is only stable in strong alkaline solution. If MnO_4^{2-} present is acidic/less basic/Neutral sol. It undergoes disproportionation.





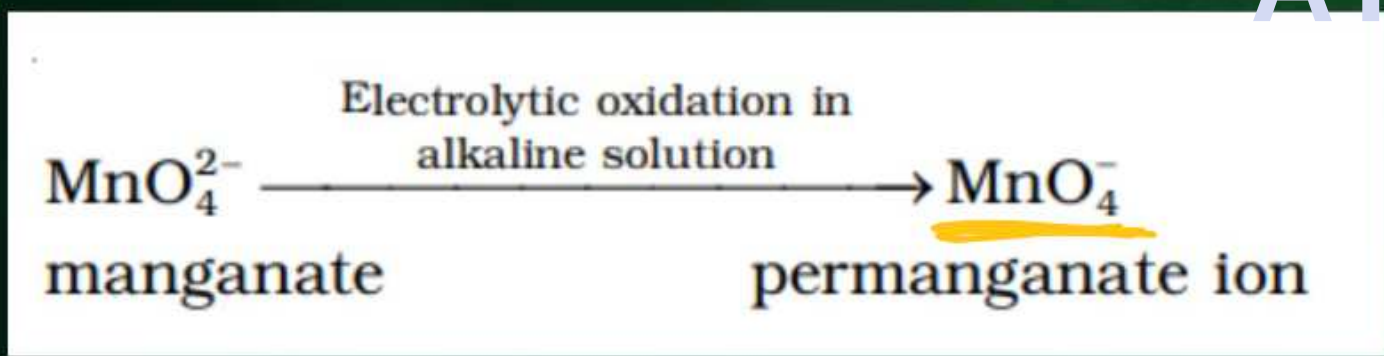
Preparation of Manganate



K_2MnO_4

Laboratory preparation of KMnO_4

ATDB.uno



Preparation of Permanganate





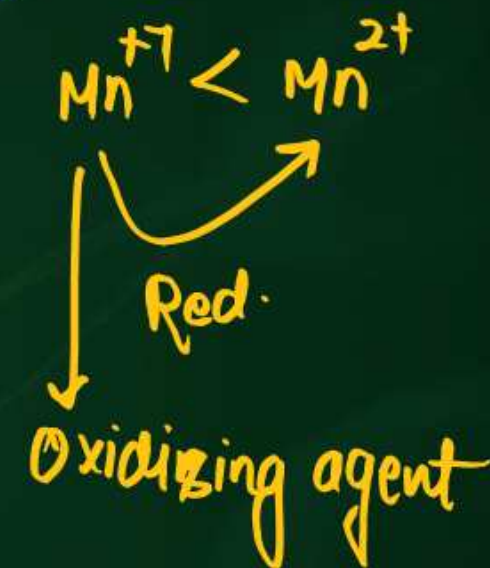
Oxidising Properties of MnO_4^- (In acidic Medium)



(1)	$\overset{+7}{\text{MnO}_4^-} + \text{Fe}^{+2} \rightarrow \text{Mn}^{2+} + \text{Fe}^{3+}$
(2)	$\overset{+7}{\text{MnO}_4^-} + \text{I}^- \rightarrow \text{Mn}^{2+} + \text{I}_2$
(3)	$\overset{+7}{\text{MnO}_4^-} + \text{H}_2\text{O}_2 \rightarrow \text{Mn}^{2+} + \text{O}_2$
(4)	$\overset{+7}{\text{MnO}_4^-} + \overset{+4}{\text{SO}_2} \rightarrow \text{Mn}^{2+} + \overset{+6}{\text{H}_2\text{SO}_4}$
(5)	$\text{MnO}_4^- + \text{NO}_2^- \rightarrow \text{Mn}^{2+} + \text{NO}_3^-$
(6)	$\text{MnO}_4^- + \text{C}_2\text{O}_4^{2-} \rightarrow \text{Mn}^{2+} + \text{CO}_2$
(7)	$\text{MnO}_4^- + \text{H}_2\text{S} \rightarrow \text{Mn}^{2+} + \text{S} \downarrow$
(8)	$\text{MnO}_4^- + \text{SO}_3^{2-} \rightarrow \text{Mn}^{2+} + \text{SO}_4^{2-}$

Oxidising Behaviour of Mn^{+7}

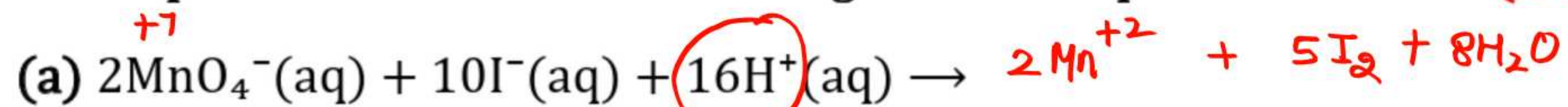
Mn^{+7} is less stable than Mn^{+2}





3. Complete and balance the following chemical equations:

(2 Marks) (2025)



ATDB.uno

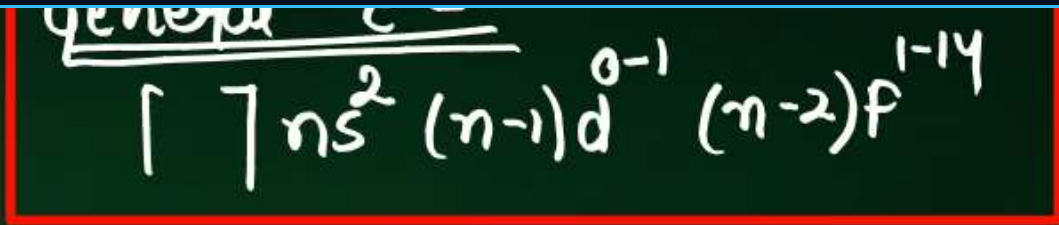
Ye Question se darta h



Parr aaj to kr lega



F-Block Elements



28 elements from 58 to 71 and from atomic no. 90 to 103, These elements are collectively called as f-block element as the last or differentiating electrons of these elements enters into f- orbital.

Electrons in f-orbital always present in Anti pen-ultimate shell ie. (n -2)f.

ATDB.uno

	58	59	60		62	63	64	65	66	67	68	69	70	71
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	140.12	140.91	144.24	(144.91)	150.36	151.97	157.25	158.93	162.50	164.93	167.26	168.93	173.04	174.97
	90	91	92											
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	232.04	231.04	238.03	(237.05)	(244.06)	(243.06)	(247.07)	(247.07)	(251.08)	(252.08)	(257.10)	(258.10)	(259.10)	(262.11)

Handwritten annotations:

- 4f (pointing to the first row of f-block elements)
- 5f (pointing to the second row of f-block elements)
- Cesium (pointing to element 55, just before the first f-block element)
- Lutetium (pointing to element 71, the last f-block element)
- Thorium (pointing to element 90, the first element of the second f-block)
- Lawrencium (pointing to element 103, the last element of the second f-block)

- Ce

→ Cerium
- Pr

→ Praseodymium
- Nd

→ Neodymium
- Pm

→ Presmuthium
- Sm

→ samarium
- Eu

→ europium
- Gd

→ Gadolinium
- Tb

→ Terbium
- Dy

→ Dysprosium
- Ho

→ Holium
- Er

→ Erbium
- Tm

→ Thulium
- Yb

→ Ytterbium
- Lu

→ lutetium

d'

- can → 58 → [Xe] 4f¹5d¹6s²
- Put → 59 → 4f³6s²
- Needle → 60 → 4f⁴6s²
- Properly in → 61 → 4f⁵6s²
- Slot → 62 → 4f⁶6s²
- Every → 63 → 4f⁷6s²
- Guy → 64 → 4f⁷5d¹6s²
- Tries → 65 → 4f⁹6s²
- Daily → 66 → 4f¹⁰6s²
- However → 67 → 4f¹¹6s²
- Every → 68 → 4f¹²6s²
- Time → 69 → 4f¹³6s²
- you → 70 → 4f¹⁴6s²
- Loose → 71 → 4f¹⁴5d¹6s²

[Xe] 6s² 5d¹ 4f¹

↓ ↓

5+2 4+3

↓ ↓

7 7

S=0

p=1

d=2

f=3

P

W

Electronic configurations

- Th → 90 → [Rn]6d²7s²
- Pa → 91 → [Rn]5f²6d¹7s²
- U → 92 → [Rn]5f³6d¹7s²
- Np → 93 → [Rn] 5f⁴6d¹7s²
- Pu → 94 → [Rn] 5f⁶7s²
- Am → 95 → [Rn] 5f⁷7s²
- Cm → 96 → [Rn] 5f⁷6d¹7s²
- Bk → 97 → [Rn]5f⁹7s²
- Cf → 98 → [Rn]5f¹⁰7s²
- Es → 99 → [Rn]5f¹¹7s²
- Fm → 100 → [Rn]5f¹²7s²
- Md → 101 → [Rn]5f¹³7s²
- No → 102 → [Rn]5f¹⁴7s²
- Lr → 103 → [Rn]5f¹⁴6d¹7s²

d²
d'
d'
d'

- Thorium → Th → Thor
- Protoactinium → Pa → Protect
- Uranium → U → Uranium
- Neptunium → NP → Neptune
- Plutonium → Pu → Pluto
- Americium → Am → American
- Curium → Cm → Computer/chemistry
- Berkelium → Bk → Book
- Californium → Cf → California explains
- Einsteinium → Es → Einstein
- Fermium → Fm → Fermi
- Mendelevium → Md → Maded
- Nobelium → No → Noble gas
- Lawrencium → Lr → Laws

✓

Actinides

[Rn] 7s² 6d¹ 5f

6+2
↓
8

5+3
↓
8

1 2 1 1 1

Ce
d'

Th
d²

P

W

Downloaded from ATDB.uno/StudyPrayas | Unauthorised redistribution is strictly prohibited.

ATDB.uno | 25 Mar 2026, 08:27 IST

ATDB.uno

Lanthanoids	Actinoids
Differentiating electron enters in 4f orbital	Differentiating electron enters in 5f orbital
Binding energy of 4f orbitals are higher	Binding energy of 5f orbitals are lower
They show less tendency to form complexes	They show greater tendency to form complexes
Besides +3 oxidation states lanthanoids show +2 and +4 oxidation states in few cases.	Besides +3 oxidation states actinoids show higher oxidation states such as +4, +5, +6 and +7



Why Actinoid contraction is greater than Lanthanide Contraction ?

Actinoid contraction is greater than Lanthanide contraction because the 5f electrons in Actinoid provides much poor shielding of nuclear charge as compared to 4f electrons of Lanthanide.



Lanthanides

↓
Rare Earth Metals

The best single use of the lanthanoids is for the production of alloy steels for plates and pipes.

A well known alloy is misch metal which consists of a lanthanoid metal (~ 95%) and iron (~ 5%) and traces of S, C, Ca and Al. A good deal of misch metal is used in Mg-based alloy to produce bullets, shell and lighter flint.



Actinides

↓
Radioactive elements





APM

ATDB.uno



Coordination ATDB.uno Compounds

CH-2

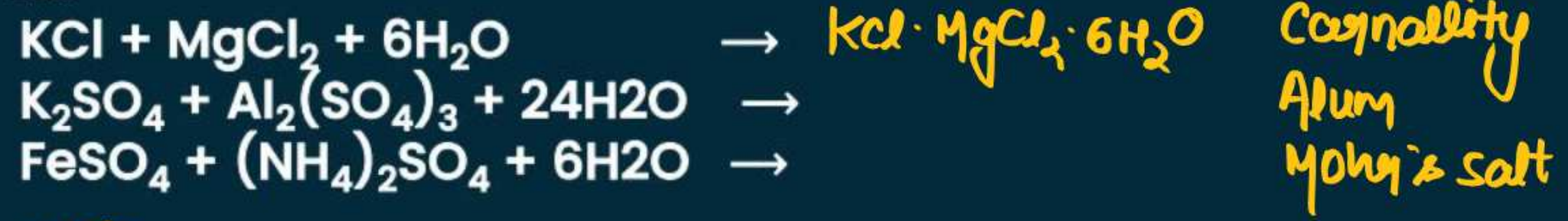
Board
supermacy < APM
supermacy

Molecular Or Addition Compounds



When solution containing two or more simple stable compounds in molecular proportions are allowed to evaporate, crystals of new substance are obtained. These substance are termed as molecular or Addition compounds.

Ex.



1 Double Salts Or Lattice Compounds

The addition comp. which are stable but broken down into individual constituents when dissolved in water. Their solutions have the same proportions as the mixture of individual comp. Ex. Mohr's salt
 $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$
 $\downarrow$
 $\text{Fe}^{2+} + 2\text{SO}_4^{2-} + 2\text{NH}_4^+ + 6\text{H}_2\text{O}$

2 Coordination Or Complex Compounds

The addition comp. in which some of the constituent ions or molecules retain their identity & when dissolved in water they do not break up completely into individual ions.
Ex- $\text{CuSO}_4 \cdot 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+} + \text{SO}_4^{2-}$

Important Terminology

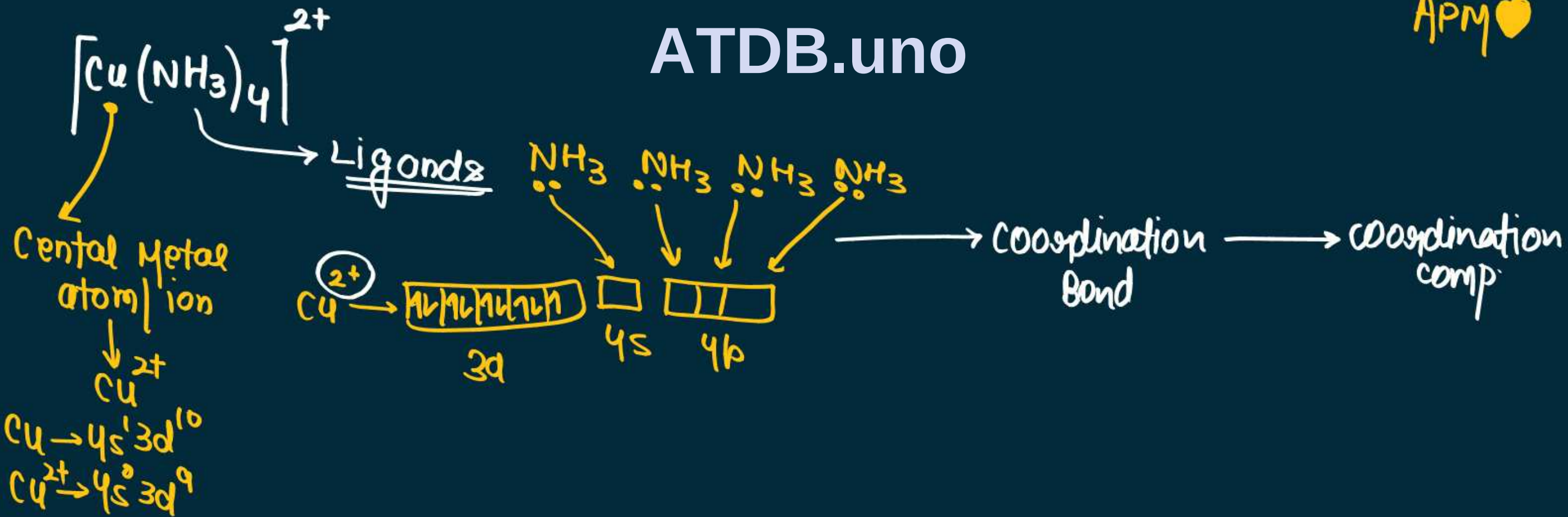


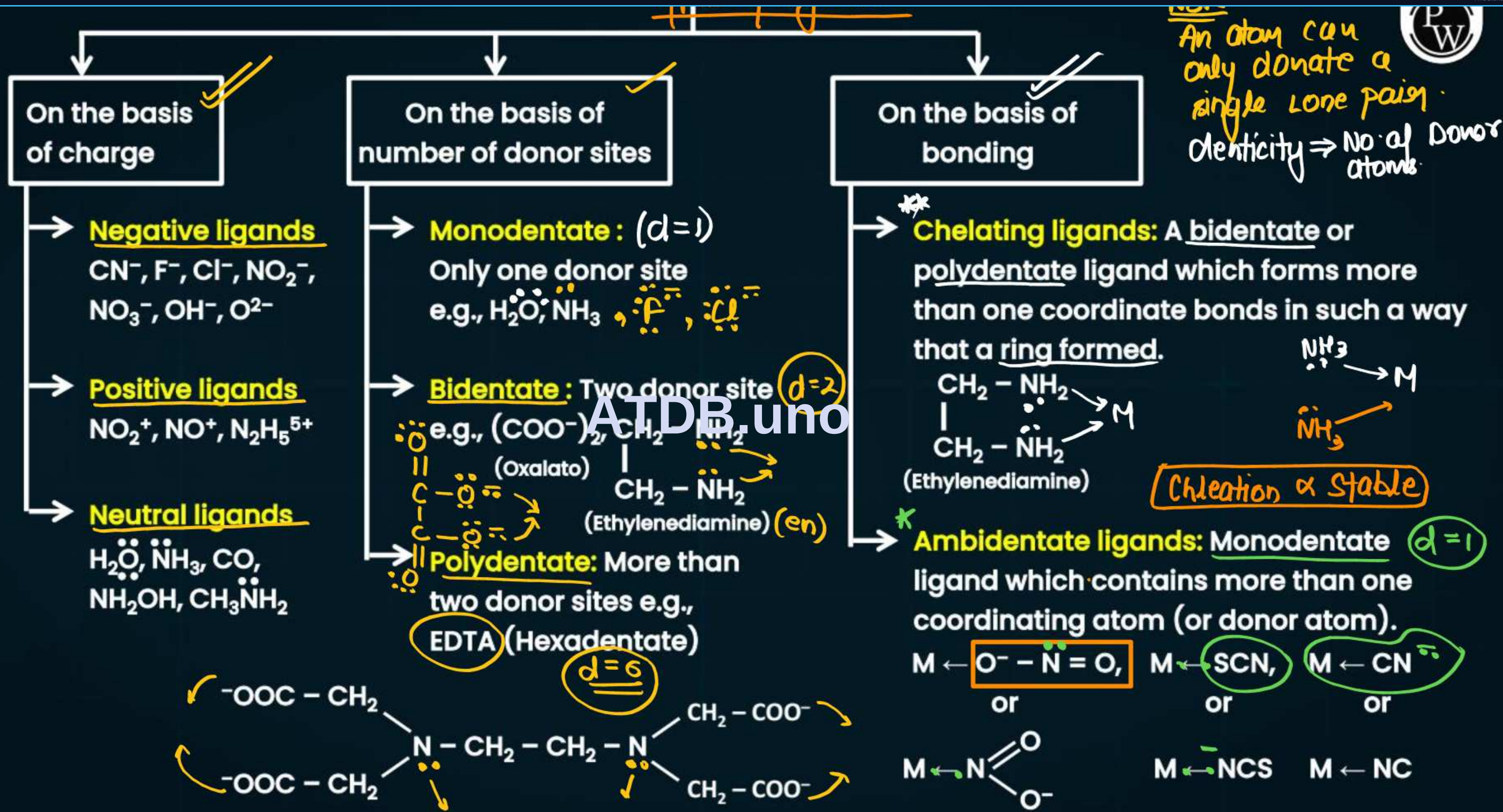
✓ **Ligands :-** The neutral molecules, anions or cations which are directly linked with the central metal atom or ion in a complex are called ligands. They behave as an electron donor due to the presence of Lone pair.

✓ **Central Metal atom/ion :-** These are the metal atom/ions which behave as an electron acceptor due to the absence of empty d orbital or positive charge.

APM ❤️

ATDB.uno





QUESTIONS



Which of the following ligands form a 'chelate' complex with metal ion?

(2021C)

1



3



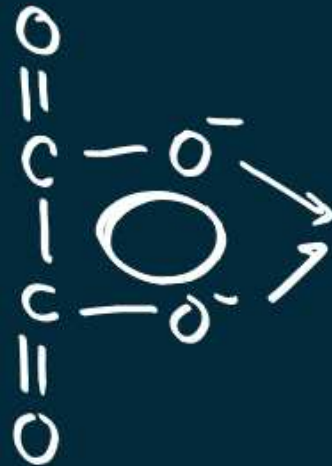
2

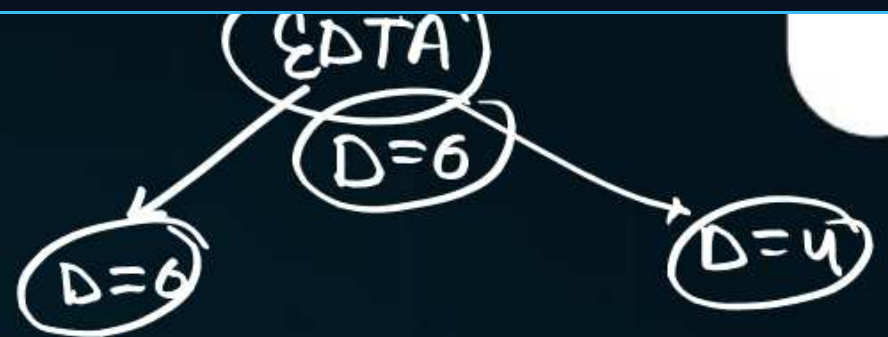


4



ATDB.uno



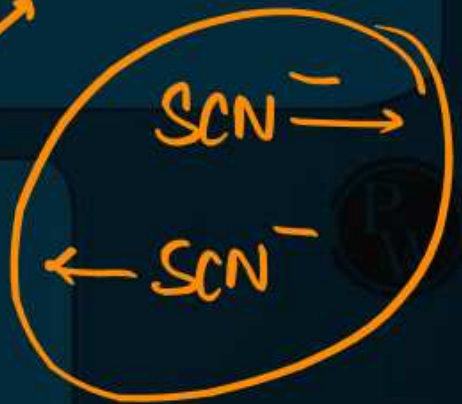
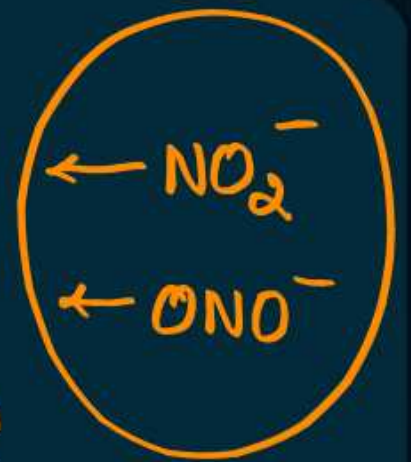
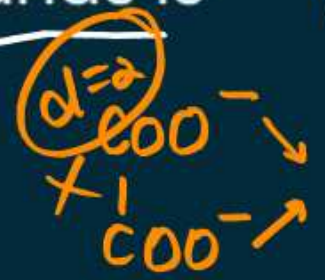


Types of Ligands

Flexidentate Ligand -

A ligand which show variable denticity in different coordination compounds is called as Flexidentate Ligand.

Ex- SO_4^{2-} , EDTA.



ATDB.uno

QUESTIONS

The set which does not have ambidentate ligand(s) is:

- 1

NO_2^- , $\text{C}_2\text{O}_4^{2-}$, EDTA^{4-}
- 2

EDTA^{4-} , NCS^- , $\text{C}_2\text{O}_4^{2-}$
- 3

$\text{C}_2\text{O}_4^{2-}$, NO_2^- , NCS^-
- 4

$\text{C}_2\text{O}_4^{2-}$, ethylene diamine, H_2O

JEE
(2023, 11 April Shift - I)

Samaj Aaya ?



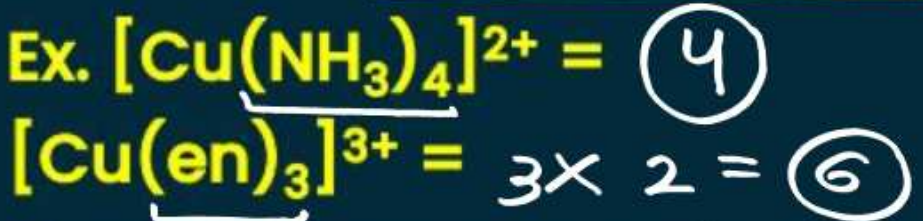
APM 

APM  ATDB.uno



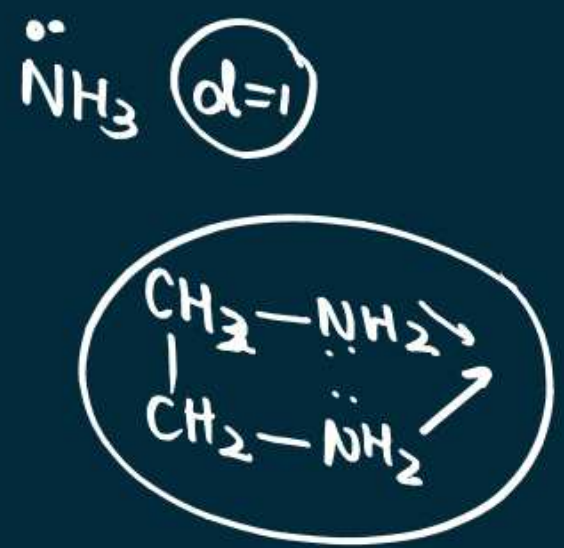
Coordination Number

The no. of atoms of the ligands that are directly bound to the central metal atom or ion by coordinate bond is known as the coordination no. of the metal ion.



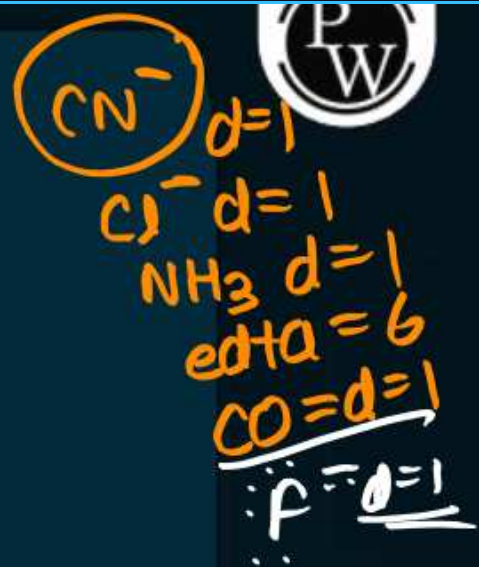
Most common coordination no. are 2, 4, & 6.

C.N. = No. of ligands $\times$ Dentate charc. of ligands.

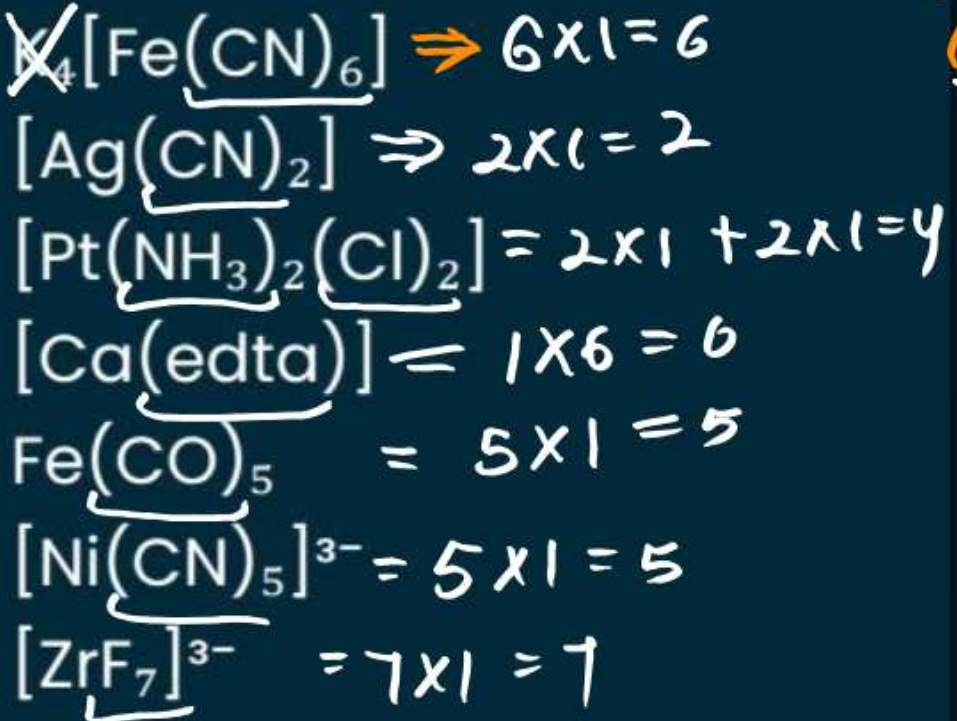


AKA Ligand

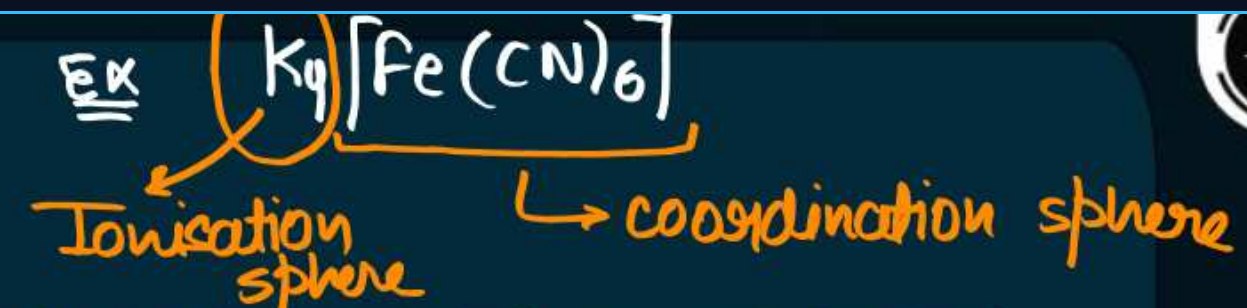
metal ke Baar baar
me how chaye



Example :-



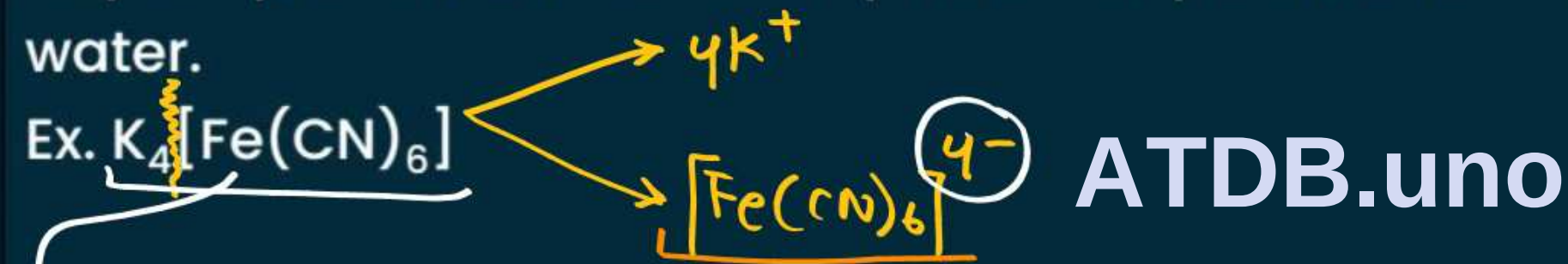
Coordination Sphere



The central atom or ion and the ligands that are directly attached to it are enclosed in a square bracket.

This has been called coordination entity or coordination sphere.

* Any ion present outside this sphere is separated from the complex when dissolved in water.



Charge on the complex ion :- O. No of metal + charge on the ligand



$$\begin{aligned} 4K + Fe + 6CN &= 0 \\ 4(+1) + Fe + 6(-1) &= 0 \\ 4 + Fe - 6 &= 0 \\ Fe - 2 &= 0 \end{aligned}$$

$Fe = +2$

$Fe + 6CN = -4$

$$\begin{aligned} Fe + 6(-1) &= -4 \\ Fe - 6 &= -4 \\ Fe &= -4 + 6 \\ Fe &= +2 \end{aligned}$$

QUESTIONS



The oxidation number of Co in $[\text{Co}(\text{en})_3]_2(\text{SO}_4)_3$ is

Ans PYQ
(2021C)

1

+2

2

+3

3

+4

4

+6

$$2[\text{Co}(\text{en})_3]^{+3} \quad 3\text{SO}_4^{2-}$$

$$2 \times 3$$

6

$$\text{Co} + 3\text{en} = +3$$
$$\text{Co} + 3(0) = +3$$

$$\text{Co} = +3$$

$$2\text{Co} + 6\text{en} + 3\text{SO}_4 = 0$$
$$2\text{Co} + 6 \times 0 + 3(-2) = 0$$
$$2\text{Co} + 0 - 6 = 0$$
$$2\text{Co} = +6$$

$$\text{Co} = \frac{+6}{2} = +3$$

QUESTIONS



The oxidation state Cr in $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$ is

2025

(PYQ)

- 1

0

3

+2
- 2

+1

4

+3

$$\text{Cr} + 4\text{NH}_3 + 2\text{Cl} = +1$$
$$\text{Cr} + 4(0) + 2(-1) = +1$$
$$\text{Cr} + 0 - 2 = +1$$
$$\text{Cr} = +1 + 2 = +3$$

Coordination No
Lxd

QUESTIONS

ATDB.uno

(2019, 12 April Shift-II)

The coordination numbers of Co and Al in $[\text{CoCl}(\text{en})_2]\text{Cl}$ and $\text{K}_3[\text{Al}(\text{C}_2\text{O}_4)_3]$, respectively, are

- 1

5 and 3

3

6 and 6
- 2

3 and 3

4

5 and 6

$$1 \times 1 + 2 \times 2$$
$$1 + 4$$
$$5$$

$$3 \times 2$$
$$6$$

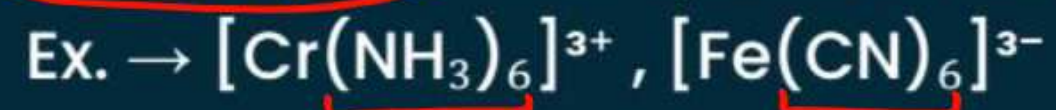




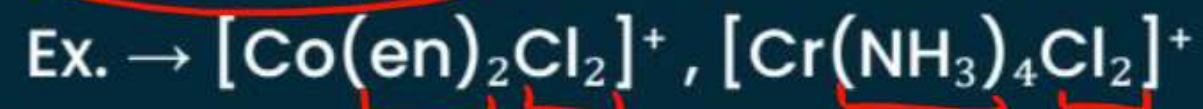
Homoleptic and Heteroleptic Complexes

2024

Homoleptic → Complexes in which a metal is bound to only one kind of donor group.



Heteroleptic → Complexes in which a metal is bound to diff. kind of donor group.



QUESTIONS

2024

ATDB.uno

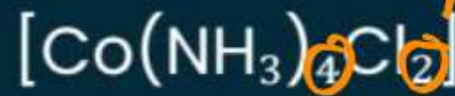
Which of the following is an example of homoleptic complex?

(PYQ)

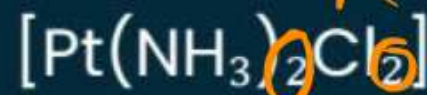
1



3



2



4





Nomenclature of Coordination Compounds

IUPAC

Name of the Ligands-

- a) Anionic ligands ending with **-ide** are named by replacing **-ide** with suffix **-o** or replacing **-e** by **-o**.
- b) Ligands whose names ends in **-ite** or **-ate** become **-ito** or **-ato** i.e by replacing the ending **-e** with **-o**.

ATDB.uno

Anion			Ligand Name			Anion			Ligand Name		
Chloride	Cl^-		Chlorido			Carbonate	CO_3^{2-}		Carbonato		
Bromide	Br^-		Bromido			Oxalate	$\text{C}_2\text{O}_4^{2-}$		Oxalato		
Cyanide	CN^-		Cyano			Sulphate	SO_4^{2-}		Sulphato		
Oxide	O^{2-}		Oxo			Nitrate	NO_3^-		Nitrato		
Sulphide	S^{2-}		Sulphido			Nitrite	NO_2^-		Nitrito		



Nomenclature of Coordination Compounds

c) Neutral ligands are called with the same names as their neutral molecules or with their special names.

H_2O → Aqua

NH_3 → Ammine

CO → carbonyl

NO → Nitrosyl

CS → Thio carbonyl

NS → Thio Nitrosyl



diammine



bis ethylenediamine



dichlorido

d) If the number of a particular ligand is more than one in the complex ion, then the Number used as di, tri, tetra, penta, hexa, etc. But when the name of the ligands Includes a number Ex- Diamine, then bis, tris, tetrakis will be used.

e) Complex positive ions and neutral coordination compounds have no special ending but complex negative ions always ends with suffix- ate.

f) Oxidation state of the central metal is shown by Roman numeral in bracket following its name.

IUPAC Nomenclature

1. $[\text{Co}(\text{NH}_3)_4\text{H}_2\text{O}(\text{Cl})]\text{Cl}_2$ $\xrightarrow{\text{complex}}$ Tetra ammine, aqua, chlorido cobalt () chloride

Handwritten notes: Ligand (Alphabetical) Metal; Oxidation No.

2. $[\text{Cu}(\text{en})_2]\text{SO}_4$ $\xrightarrow{\text{complex}}$ Bis ethylenediamine copper () sulphate

Handwritten notes: 2Cl^- , SO_4^{2-}

3. $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$

4. $[\text{Fe}(\text{H}_2\text{O})_4(\text{C}_2\text{O}_4)]^+\text{SO}_4$ $\xrightarrow{\text{complex}}$ Tetra aqua Oxalato Iron () sulphate

5. $[\text{Ag}(\text{NH}_3)_2]\text{Cl}$ $\xrightarrow{\text{complex}}$ Diammine Silver () chloride

Handwritten notes: Cl^-

6. $\text{K}_3[\text{Fe}(\text{CN})_6]$ $\xrightarrow{\text{complex}}$ Potassium Hexacyano ferrate(III)

Handwritten notes: 3K^+

7. $\text{Na}[\text{Ag}(\text{CN})_2]$

Handwritten notes: Na^+

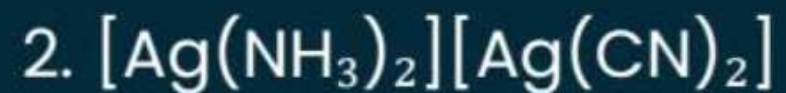
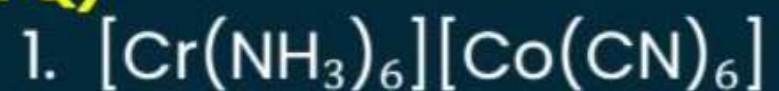
$\oplus$ / Neutral	$\ominus$
cobalt	cobaltate
Iron	ferrate
Silver	argentate
chromium	chromate
Platinum	platinate
Copper	cuprate

$3\text{K} + \text{Fe} + 6\text{CN} = 0$
 $3(+1) + \text{Fe} + 6(-1) = 0$
 $3 + \text{Fe} - 6 = 0$
 $\text{Fe} - 3 = 0$
 $\text{Fe} = +3$



IUPAC Nomenclature

(PYQ)



ATDB.uno

Metal	C.N.
Ag^+	2

Metal	C.N.
Fe^{3+}	6
Co^{3+}	6
Zn^{2+}	4

Metal	C.N.
Sc^{3+}	6
Cr^{3+}	6
Pt^{2+}	4
Pt^{4+}	6

QUESTIONS



The correct IUPAC name of $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]^{2+}$ is

diammine dichlorido platinum(IV) ion
 $\text{Pt} + 2\text{NH}_3 + 2\text{Cl} = +2$
 $\text{Pt} + 2 \times 0 + 2(-1) = +2$
 $\text{Pt} + 0 - 2 = +2$
 $\text{Pt} = +2 + 2 = +4$
PYQ (2025)

- 1

Diamminedichloridoplatinum (II)
- 2

Diamminedichloridoplatinum (IV)
- 3

Diamminedichloridoplatinum (0)
- 4

Diamminedichloridoplatinate (IV)

ATDB.uno

QUESTIONS

The IUPAC name for the complex $[\text{Co}(\text{NO}_2)(\text{NH}_3)_5]\text{Cl}_2$ is

$\text{Co} + \text{NO}_2 + 5\text{NH}_3 + 2\text{Cl} = 0$
 $\text{Co} + (-1) + 5 \times 0 + 2(-1) = 0$
 $\text{Co} - 1 + 0 - 2 = 0$
 $\text{Co} = +3$
 $2+$
 2Cl^-
(PYQ) 2024

- 1

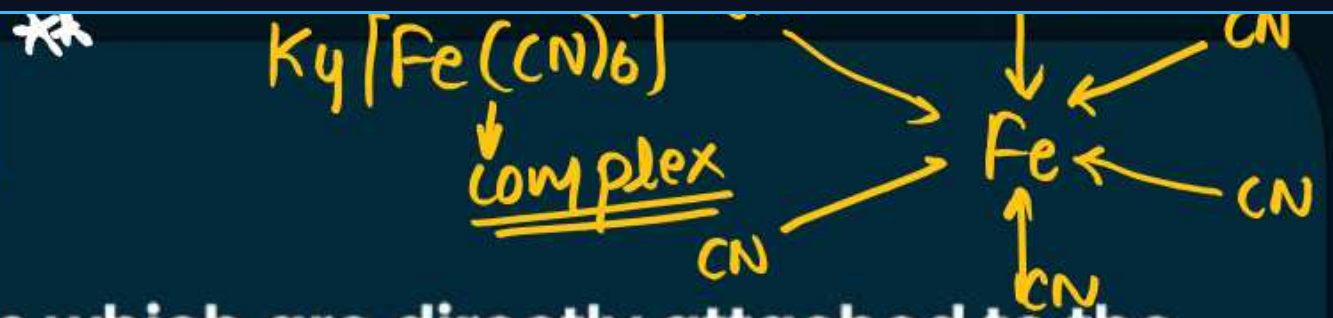
~~nitrito-N-pentamminecobalt (III) chloride~~
- 2

~~nitrito-N-pentamminecobalt (II) chloride~~
- 3

pentammine nitrito-N-cobalt(II) chloride
- 4

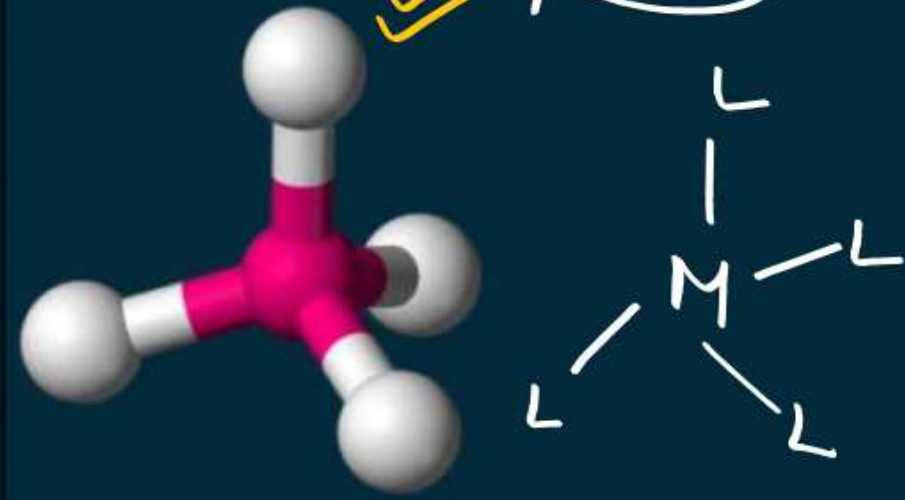
pentammine nitrito-N-cobalt(III) chloride

Coordination polyhedron

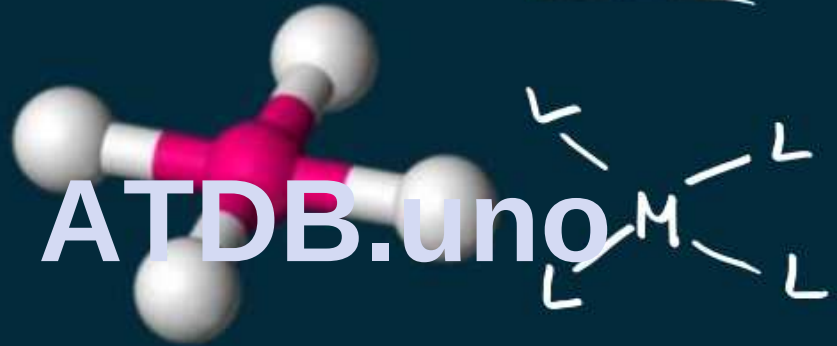


The spatial arrangement of the ligand atoms which are directly attached to the central ion or atom is called coordination polyhedron.

Tetrahedral ✓ CN=4



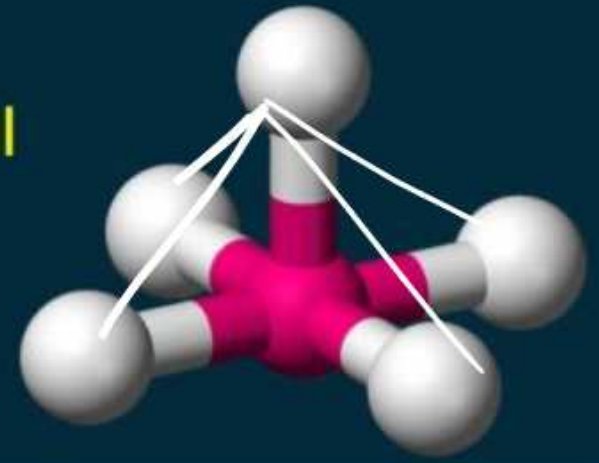
✓ Square Planar C.N.O=4



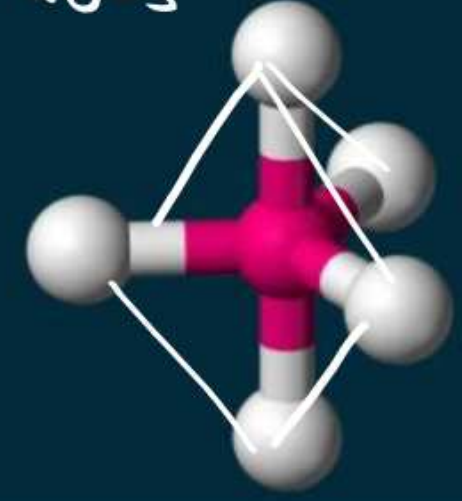
✓ Octahedral CN=6



Square Pyramidal CN=5 ✗



C.N.O=5



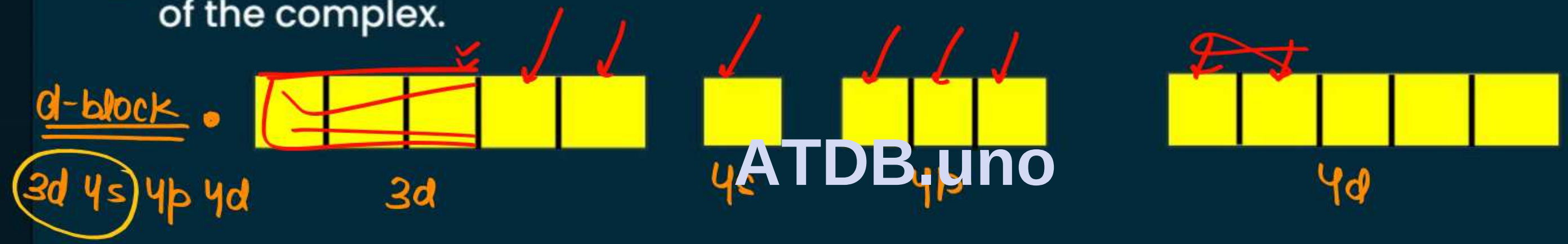
✗ Trigonal Bipyramidal

(A) Valence Bond Theory

Bonding



- This theory describes the bonding in terms of hybridized orbitals of the central metal atom or ion.
- The theory mainly deals with the geometry (shape) and magnetic properties of the complex.



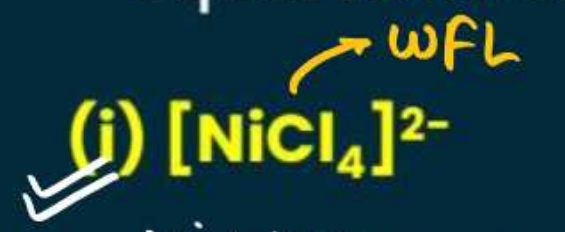
Coordination number	Type of hybridisation	Distribution of hybrid orbitals in space
4	sp^3	<u>Tetrahedral</u>
4	dsp^2	<u>Square planar</u>
5	sp^3d	<u>Trigonal bipyramidal</u> X
6	sp^3d^2	<u>Outer Octahedral</u>
6	d^2sp^3	<u>Inner Octahedral</u>



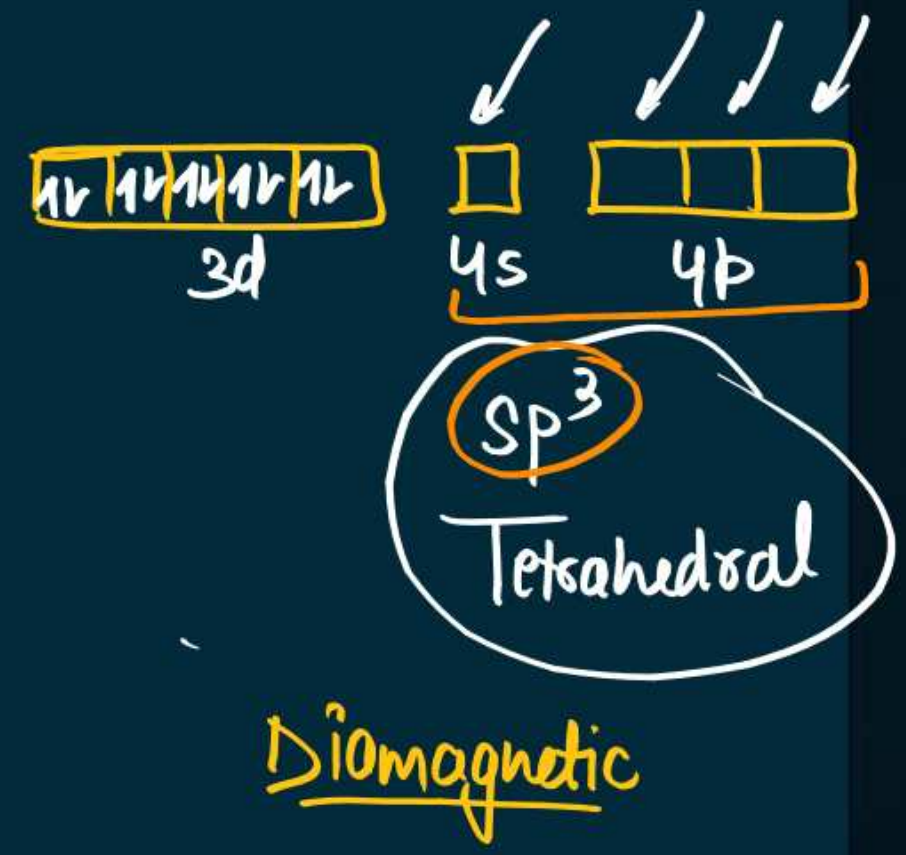
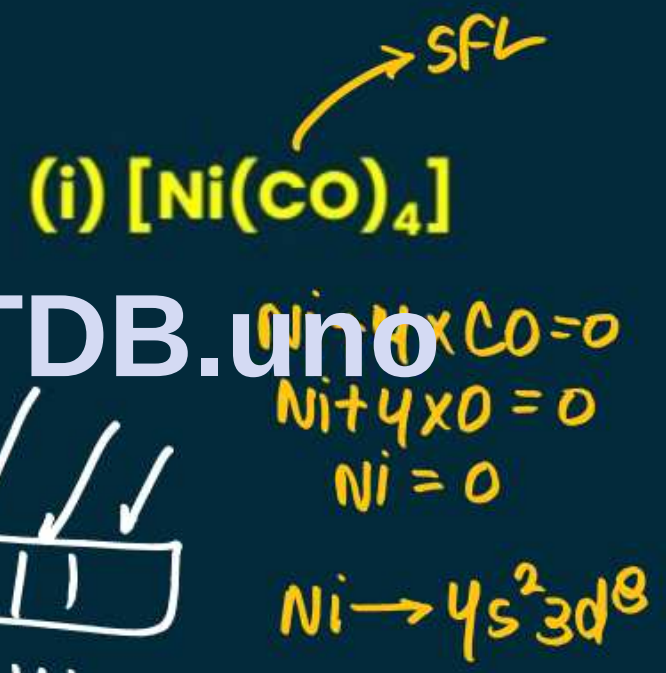
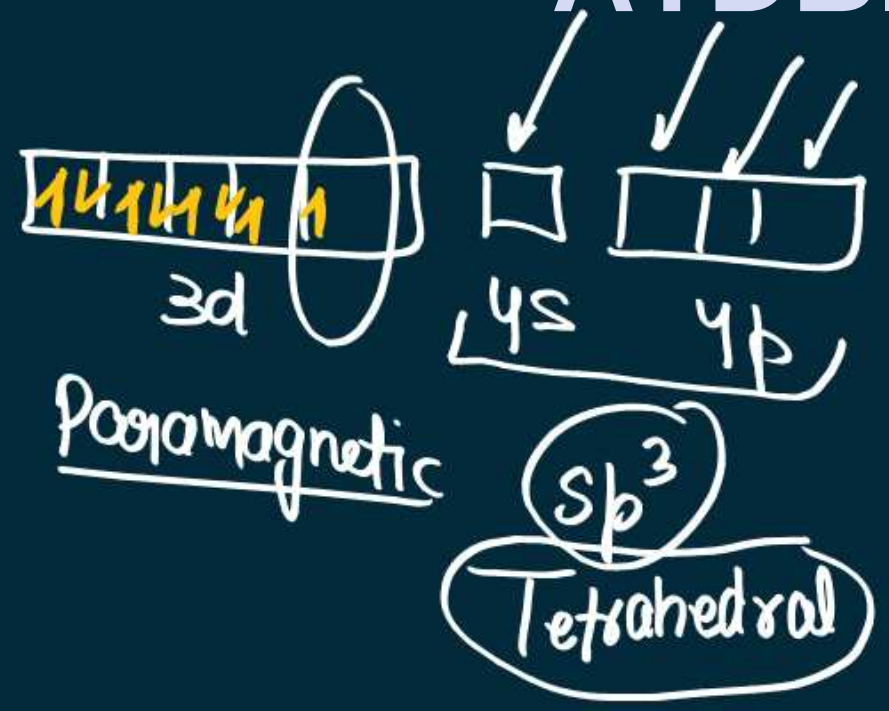
Diamagnetic $\eta=0$ WFL $\rightarrow$ Hund's Rule
SFL $\rightarrow$ Hund's Rule

Postulates

1. The central atoms loses a requisite no. of electrons to form the ion. The no of electrons lost is the valency of the resulting cation.
2. The central metal ion or atom makes available a no. of empty s, p & d orbitals equal to its coordination no.



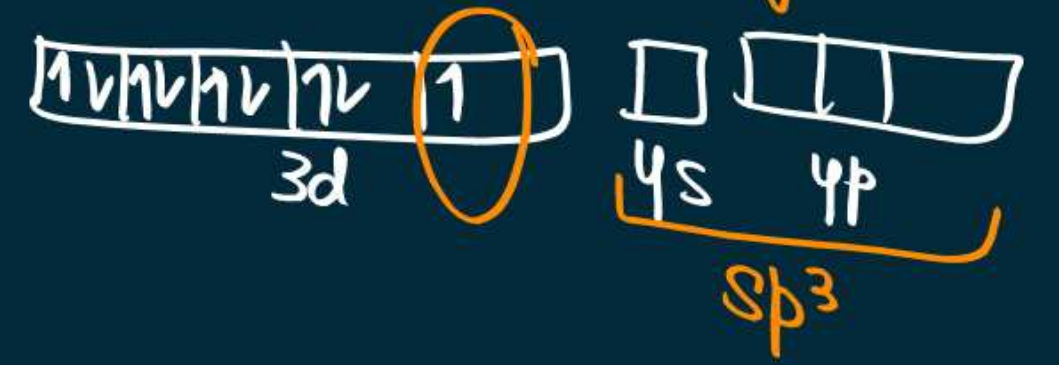
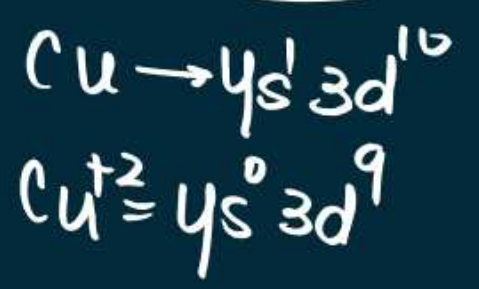
$$\begin{aligned} \text{Ni} + 4\text{Cl} &= -2 \\ \text{Ni} + 4(-1) &= -2 \\ \text{Ni} - 4 &= -2 \\ \text{Ni} &= -2 + 4 \\ \boxed{\text{Ni} = +2} \\ \text{Ni} &\rightarrow 4s^2 3d^8 \\ \text{Ni}^{+2} &\rightarrow 4s^0 3d^8 \end{aligned}$$



Complex with C.No $\Rightarrow$ 4

$\xrightarrow{\text{WFL}}$
(i) $[\text{CuCl}_4]^{2-}$

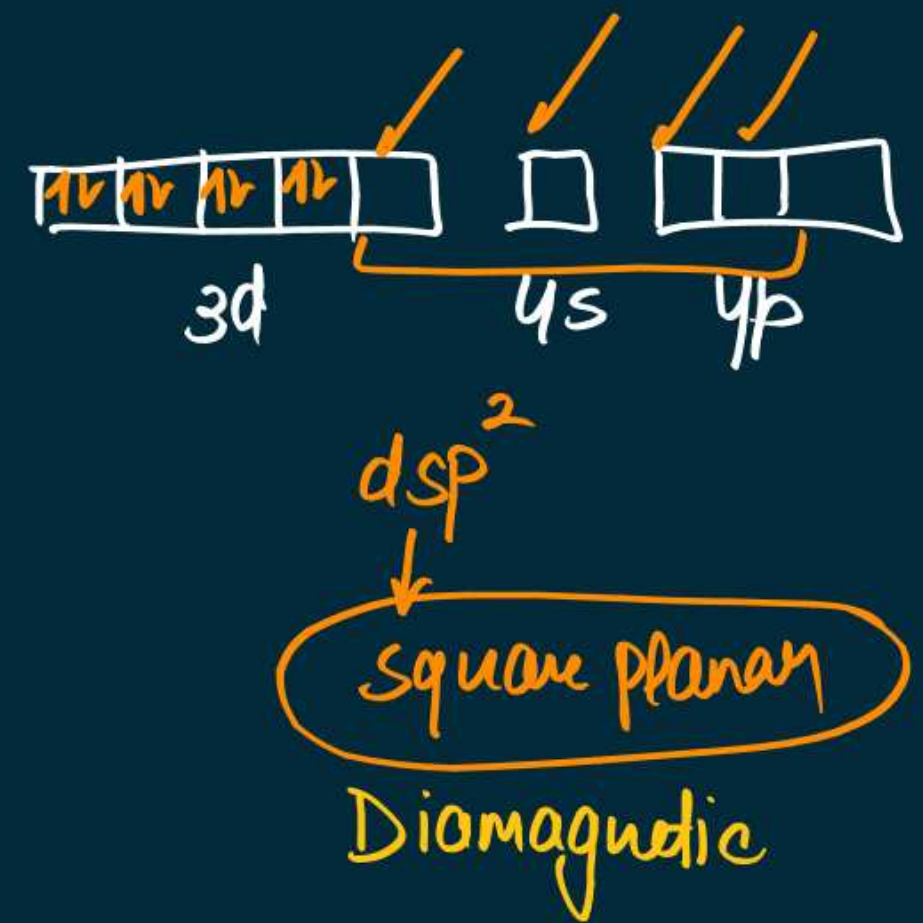
$$\begin{aligned}\text{Cu} + 4\text{Cl} &= -2 \\ \text{Cu} + 4(-1) &= -2 \\ \text{Cu} - 4 &= -2 \\ \text{Cu} &= -2 + 4 \\ \text{Cu} &= +2\end{aligned}$$



$\mu = \sqrt{n(n+2)}$
 $n=1$
 $\mu = \sqrt{1 \times (1+2)} = \sqrt{3}$
Tetrahedral
Paramagnetic

$\xrightarrow{\text{SFL}}$
(ii) $[\text{Ni}(\text{CN})_4]^{2-}$

$$\begin{aligned}\text{Ni} + 4\text{CN} &= -2 \\ \text{Ni} + 4(-1) &= -2 \\ \text{Ni} - 4 &= -2 \\ \text{Ni} &= -2 + 4 \\ \text{Ni} &= +2 \\ \text{Ni} &\rightarrow 4s^1 3d^8 \\ \text{Ni}^{+2} &\rightarrow 4s^0 3d^8\end{aligned}$$





QUESTIONS

The magnetic moment of $[\text{NiCl}_4]^{2-}$ is

Atomic number. $\text{Ni} = 28$

(2023)

- 1

1.82 B.M.
- 2

2.82 B.M.
- 3

4.42 B.M.
- 4

5.46 B.M.

$\text{Ni} + 4\text{Cl} = -2$

$\text{Ni} + 4(-1) = -2$

$\text{Ni} - 4 = -2$

$\text{Ni} = -2 + 4 = +2$

$\text{Ni}^{+2} = 4s^0 3d^8$

$$n = \sqrt{2(2+2)}$$
$$= \sqrt{8}$$



$n = 2$

QUESTIONS

Why is $[\text{NiCl}_4]^{2-}$ paramagnetic but $[\text{Ni}(\text{CO})_4]$ is diamagnetic? (At. no.: $\text{Cr} = 24$, $\text{Co} = 27$, $\text{Ni} = 28$)
(NCERT Intext, 1/3, AI 2014)

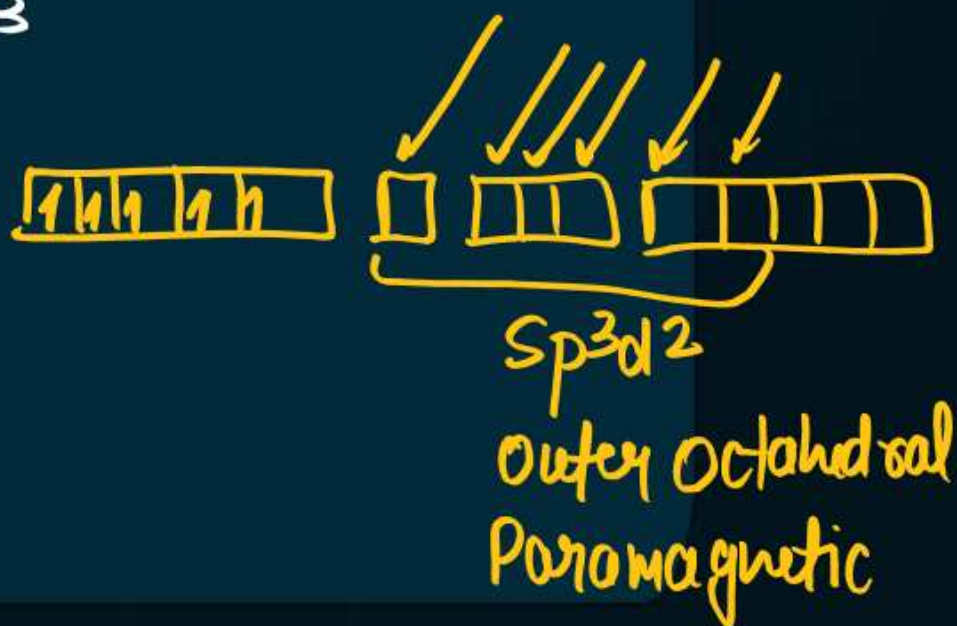
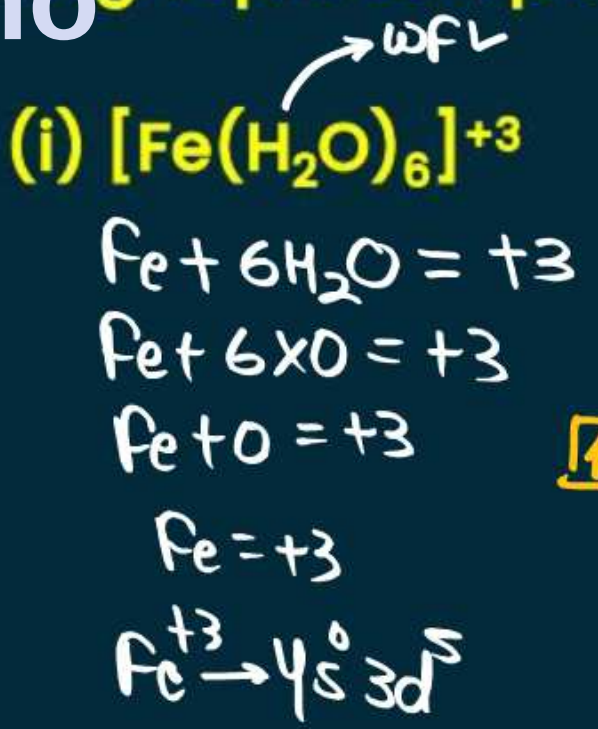
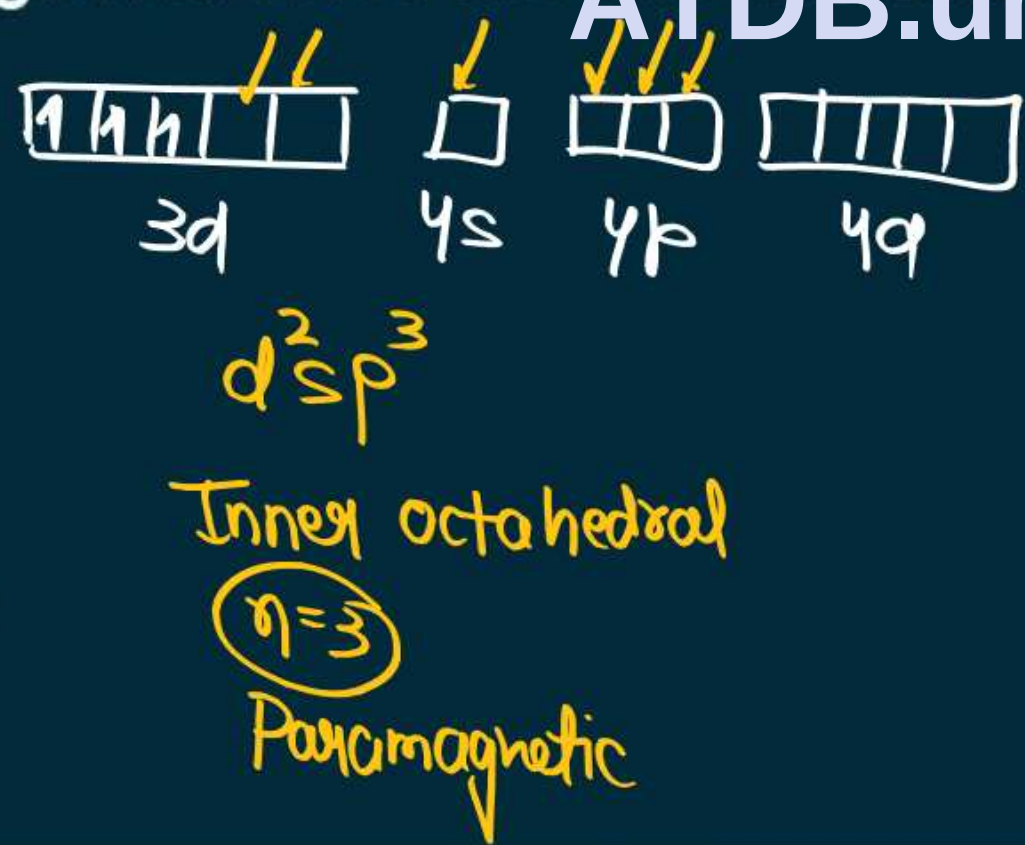
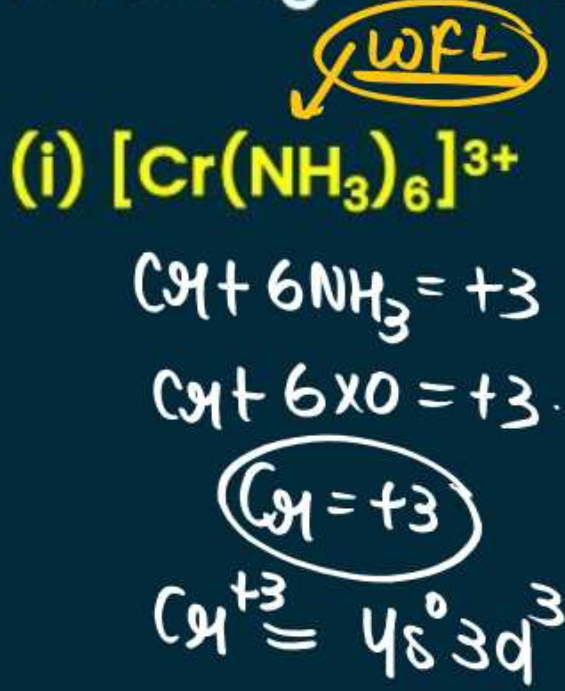
Complex with C.No $\Rightarrow$ 6



They posses two type of complexes:

(i) Inner orbital octahedral complexes $\rightarrow$ These are formed by d_2sp_3 hybridized involving strong ligands. These are also known as **Low spin complexes** (less unpaired e^-)

(ii) Outer orbital octahedral complexes $\rightarrow$ These are formed by sp_3d_2 hybridization involving weak ligands. These are also known as **high spin complexes**. (more unpaired e^-)



Limitations of VBT



1. This theory doesn't after any explanation about spectra of complex (Colour of the complex)
2. This theory was failed to explain why at one time the electron are rearranged against the Hund's rule and other time electronic configuration is not disturbed.
3. This theory doesn't after any explanation for the existence of inner and outer orbital complexes.
4. NH₃ → SFL → For higher C.NO i.e Co⁺³
NH₃ → WFL → For lower C.NO. i.e Ni⁺²

APM ❤️



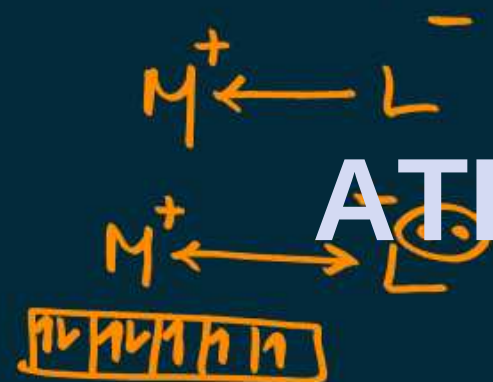
Crystal Field Theory ^{A-1A}

According Crystal Field theory the bonding in complex is not covalent or by overlapping of orbitals but it is purely electrostatic.

There are two types of Force exist between Metal ion and Ligand-

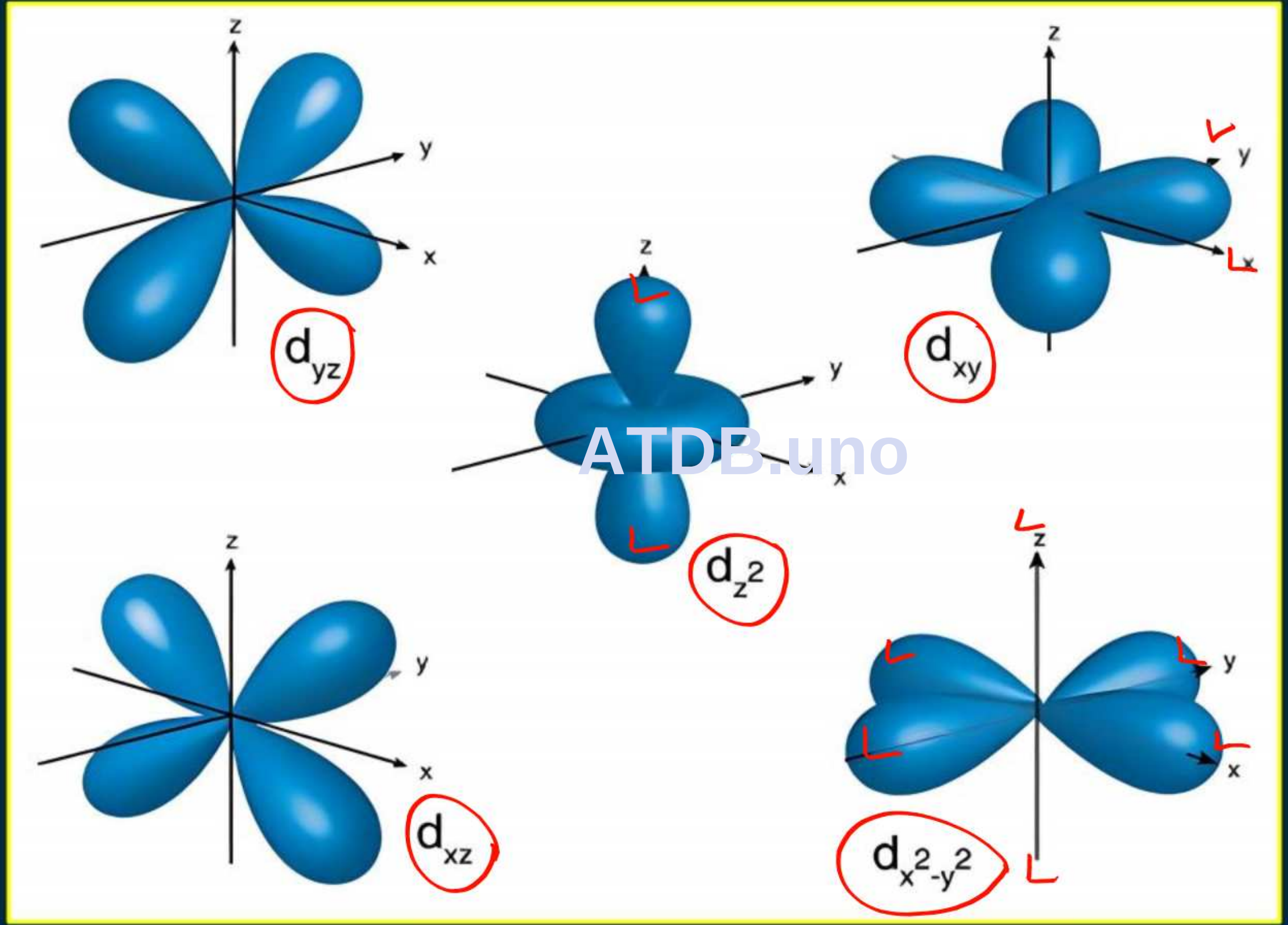
✓ 1) Force of attraction

⊗ 2) Force of Repulsion



ATDB.uno

✓ Crystal field theory mainly focus on the Force of Repulsion between Lone pair of ligands and Electrons in d orbital of Metal ion.



Handwritten notes:

- d_{xy} , d_{yz} , d_{xz} , $d_{x^2-y^2}$ are grouped together with the label "B/w the axis".
- d_{z^2} is labeled "on the axis".
- $d_{x^2-y^2}$ is labeled "double dumbbell".

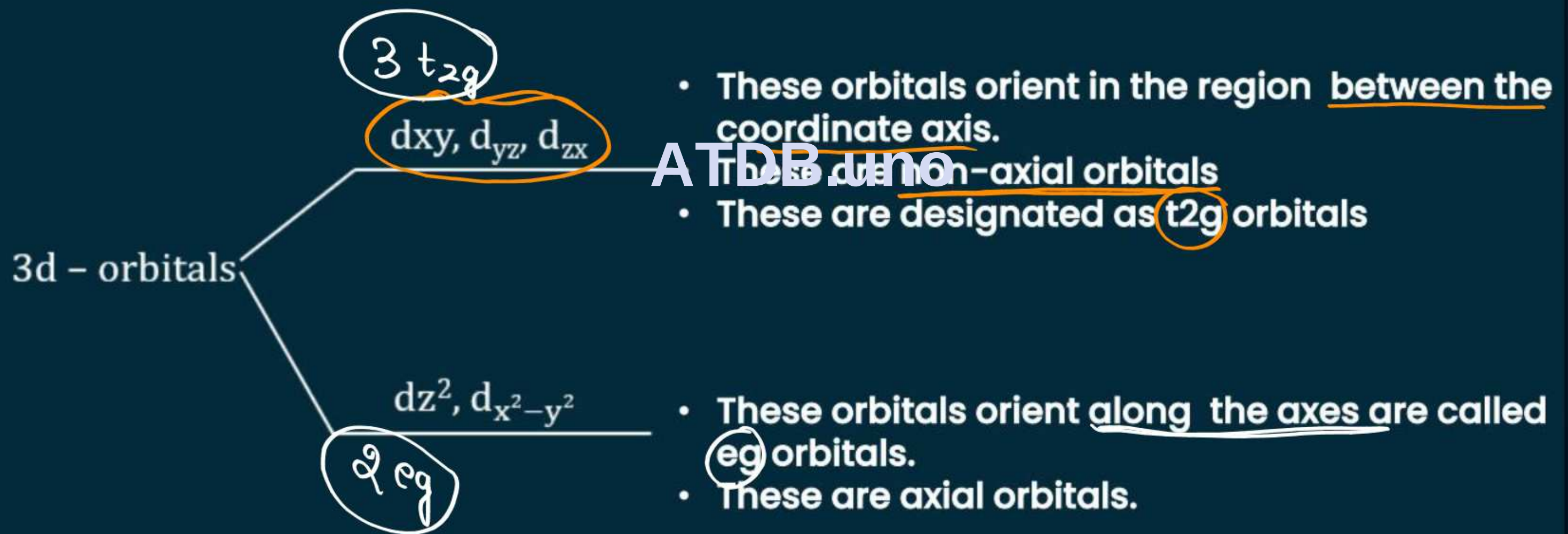


Crystal Field Theory

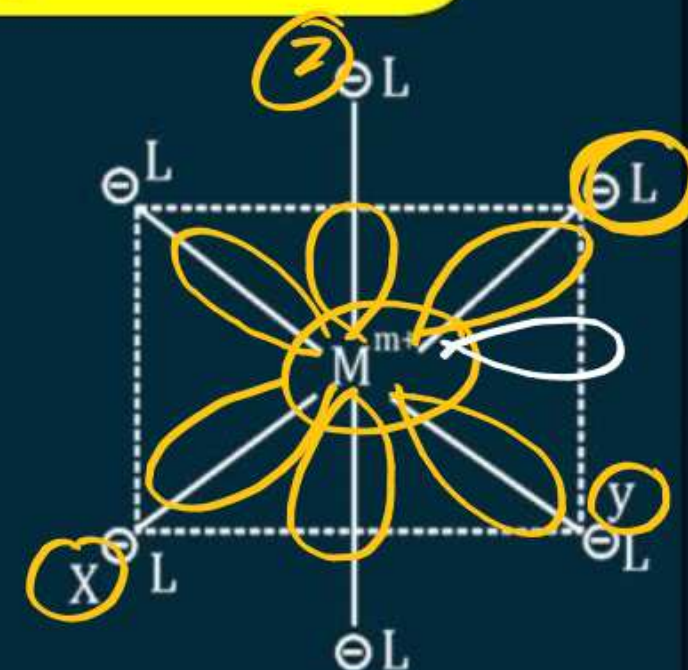
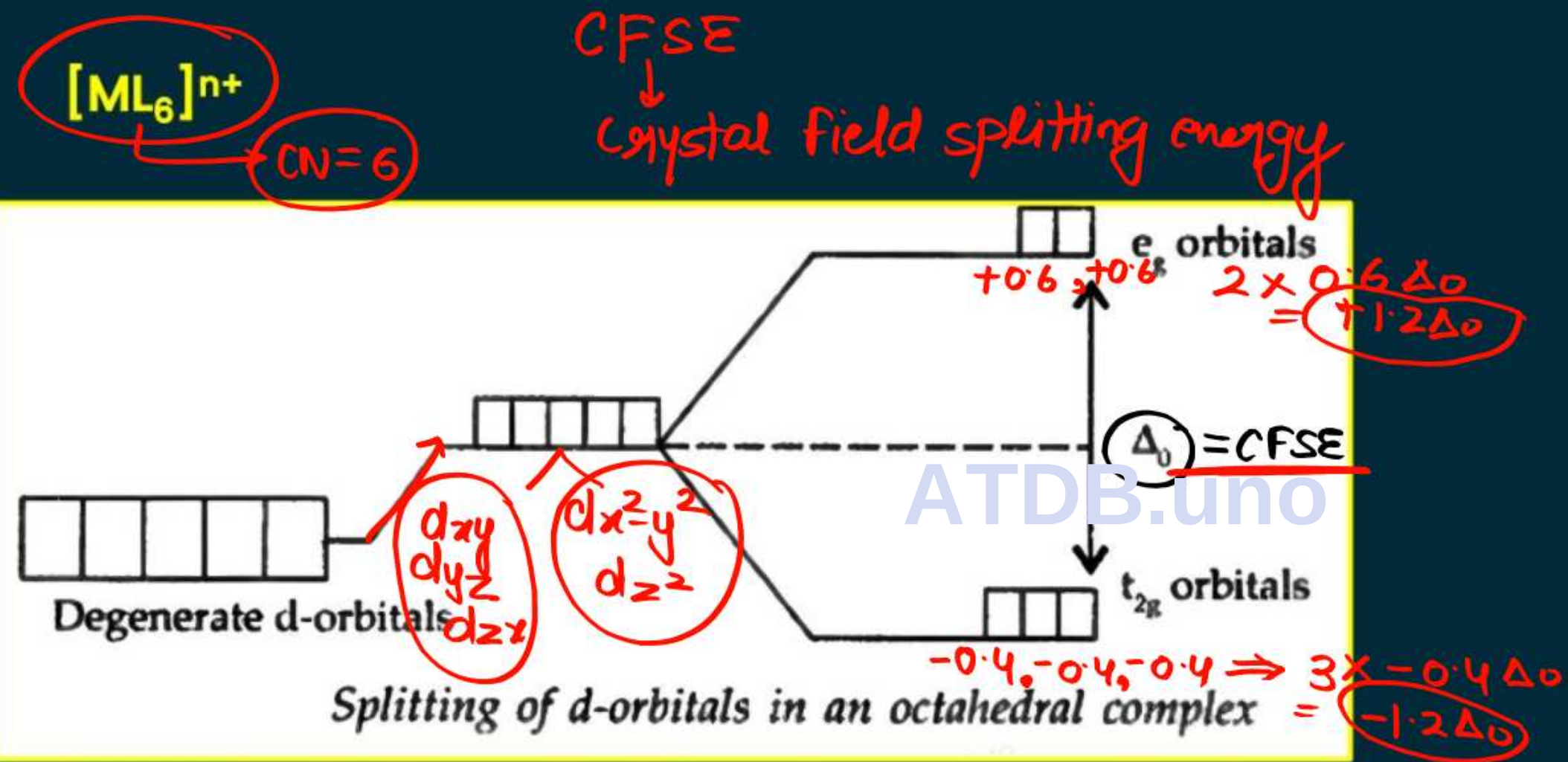
$C.N.O = 6$ / Octahedral

In a free transition metal or ion, there are 5d-orbitals which are designated as dxy, dyz, dzx dx^2-y^2 , dz^2 .

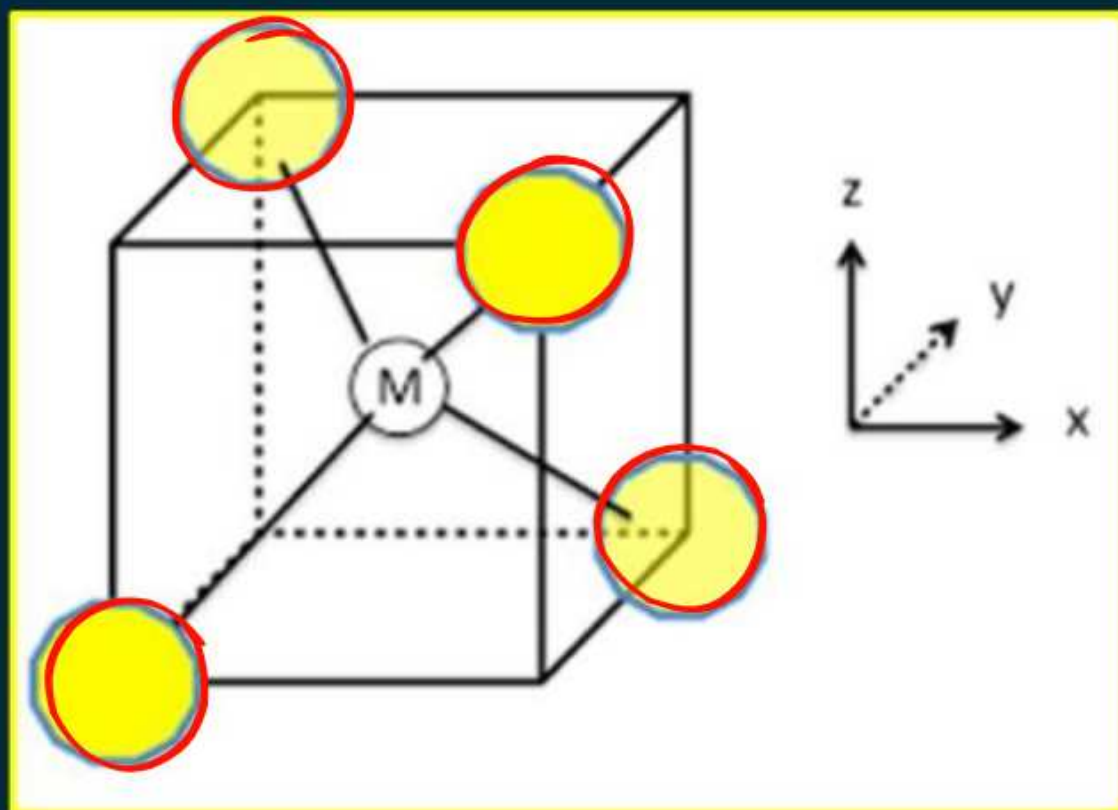
These are divided into two sets:



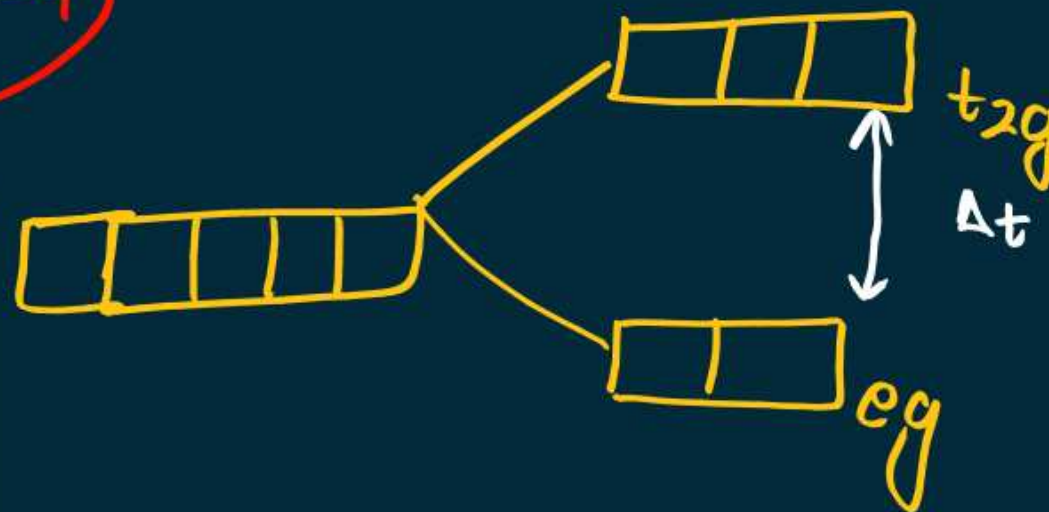
Splitting of d-orbitals in octahedral complex



Splitting of d-orbitals in Tetrahedral complex



$(n=4)$



$$\Delta_t < \Delta_o$$

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

More ligands $\Rightarrow$ More splitting
 less ligands $\Rightarrow$ Less splitting

In this case, three d-orbitals i.e t_{2g} orbitals are close to the approaching ligands. As a result of this, t_{2g} electrons suffer more repulsion than e_g electron.



Spectrochemical series

For any given metal cation, the magnitude of crystal field splitting energy depends on the nature of the ligands.

The greater the ease with which the ligand can approach the metal ion, the greater will be the splitting caused by it.

$$CFSE_{L.S.F} > CFSE_{L.W.F}$$

★

Strong Field Ligand

Ligands which can approach the central metal ion with ease and cause High repulsion thus high splitting.

ATDB.uno

★

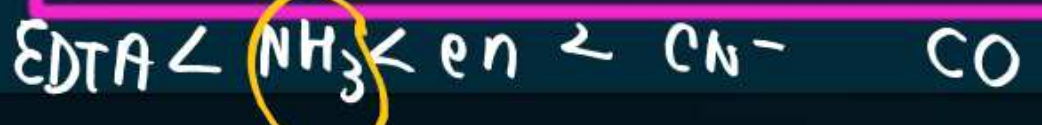
Weak Field Ligand

Ligands which can't approach the central metal ion with ease and cause Low repulsion thus less splitting.

I Brought some Colourful sweets from office containing water | Nancy



ate Nine in Canteen corridor.



Strong field (low spin) $\Delta_0 > P$				Weak field (High spin) $\Delta_0 < P$			
Configure	No. of unpaired e ⁻		C.F.S.E	Config.	No. of unpaired		CFSE
$d^1 \rightarrow t_{2g}^1$	1			$d^1 \rightarrow t_{2g}^1$	1		
$d^2 \rightarrow t_{2g}^2$	2			$d^2 \rightarrow t_{2g}^2$	2		
$d^3 \rightarrow t_{2g}^3$	3			$d^3 \rightarrow t_{2g}^3$	3		
$d^4 \rightarrow t_{2g}^4$	2			$d^4 \rightarrow t_{2g}^3 e_g^1$	4		
$d^5 \rightarrow t_{2g}^5$	1			$d^5 \rightarrow t_{2g}^3 e_g^2$	5		
$d^6 \rightarrow t_{2g}^6$	0			$d^6 \rightarrow t_{2g}^4 e_g^2$	4		
$d^7 \rightarrow t_{2g}^6 e_g^1$	1			$d^7 \rightarrow t_{2g}^5 e_g^2$	3		
$d^8 \rightarrow t_{2g}^6 e_g^2$	2			$d^8 \rightarrow t_{2g}^6 e_g^2$	2		
$d^9 \rightarrow t_{2g}^6 e_g^3$	1			$d^9 \rightarrow t_{2g}^6 e_g^3$	1		
$d^{10} \rightarrow t_{2g}^6 e_g^4$	0			$d^{10} \rightarrow t_{2g}^6 e_g^4$	0		

$CFSE = 1 \times (-0.4\Delta_0) + 0$
 $= -0.4\Delta_0$

$CFSE = 6 \times (-0.4\Delta_0) + 1 \times (0.6\Delta_0)$
 $= -2.4\Delta_0 + 0.6\Delta_0$
 $= -1.8\Delta_0$



Calculation of CFSE

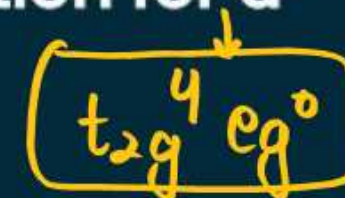
Octahedral

$$\text{C.F.S.E} = \text{No. of } e^- \text{ in } t_{2g} \times (-0.4\Delta_0) + \text{No. of } e^- \text{ in } e_g (+0.6\Delta_0)$$

QUESTIONS

ATDB.uno

(a) On the basis of crystal field theory, write the electronic configuration for d^4 with a strong field ligand for which $\Delta_0 > P$. (SFL)



(b) A solution of $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ is green but a solution of $[\text{Ni}(\text{CO})_4]$ is colourless. Explain.



(2023)



QUESTIONS

The crystal field splitting energy for octahedral (Δ_0) and tetrahedral (Δ_t) complexes is related as

P10
(2020)

ATDB.uno

1

$$\Delta_t = 2/9 \Delta_0$$

2

$$\Delta_t = 5/9 \Delta_0$$

3

$$\Delta_t = 4/9 \Delta_0$$

4

$$\Delta_t = 2\Delta_0$$

Samaj Aaya ?



APM

ATDB.uno



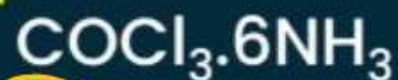
Werner's coordination Theory

Werner proposed coordination theory to explain properties and structure of various coordination compounds.

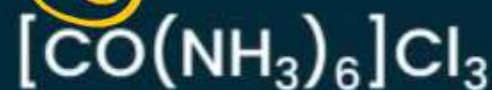
Primary valency corresponds to oxidation state of the central metal. It is satisfied by the negative ions. This is also called principle, ionisable or ionic valency. Its attachment to the metal is shown by dotted lines.

- **Secondary valency** is satisfied by neutral molecules or negative ions.
- It represents the coordination no. of the metal
- This valency is non-ionic or non-ionizable. The atoms of the ligands which satisfy the coordination number are directly attached to the metal atom and shown by thick lines.

Example



+3



$$\boxed{\text{P.V} = 3} \quad \boxed{\text{S.V} = 6}$$



$$\begin{aligned} \text{P.V} &= 3 \\ \text{S.V} &= 6 \end{aligned}$$

QUESTIONS

(2023, 24 Jan Shift-I)



The primary and secondary valencies of cobalt respectively in $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ are

P.V = 3
S.V = 6

$$\begin{aligned} \text{Co} + 5\text{NH}_3 + \text{Cl} + 2\text{Cl} &= 0 \\ \text{Co} + 5(0) + (-1) + 2(-1) &= 0 \\ \text{Co} + 0 - 1 - 2 &= 0 \end{aligned}$$

$$\text{Co} - 3 = 0$$

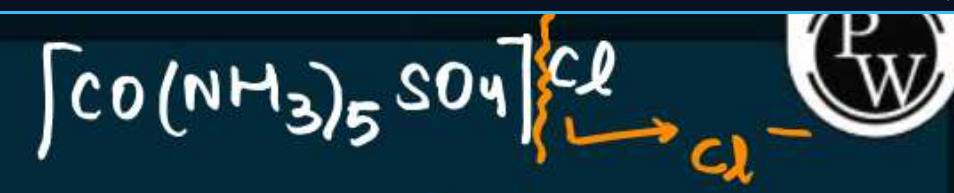
Co = +3

ATDB.uno

- 1 3 and 6
- 2 2 and 6
- 3 3 and 5
- 4 2 and 8

QUESTIONS

+ AgNO₃ → white ppt.



Assertion: $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Cl}$ gives a white precipitate with silver nitrate solution.

Reason: The complex dissociates to give Cl^- and SO_4^{2-} ions. ✗

(PYQ) ²⁰²⁴

- 1 Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
- 2 Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
- 3 Assertion (A) is correct, but Reason (R) is incorrect statement
- 4 Assertion (A) is incorrect, but Reason (R) is correct statement.

ATDB.uno



QUESTIONS

One mole of $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ compound reacts with excess AgNO_3 solution to yield two moles of AgCl(s) .

The structural formula of the compound is:

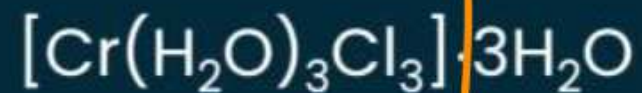
2023
(PYQ)

ATDB.uno

1



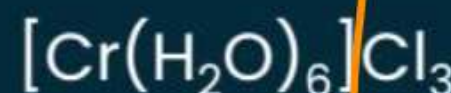
2



3



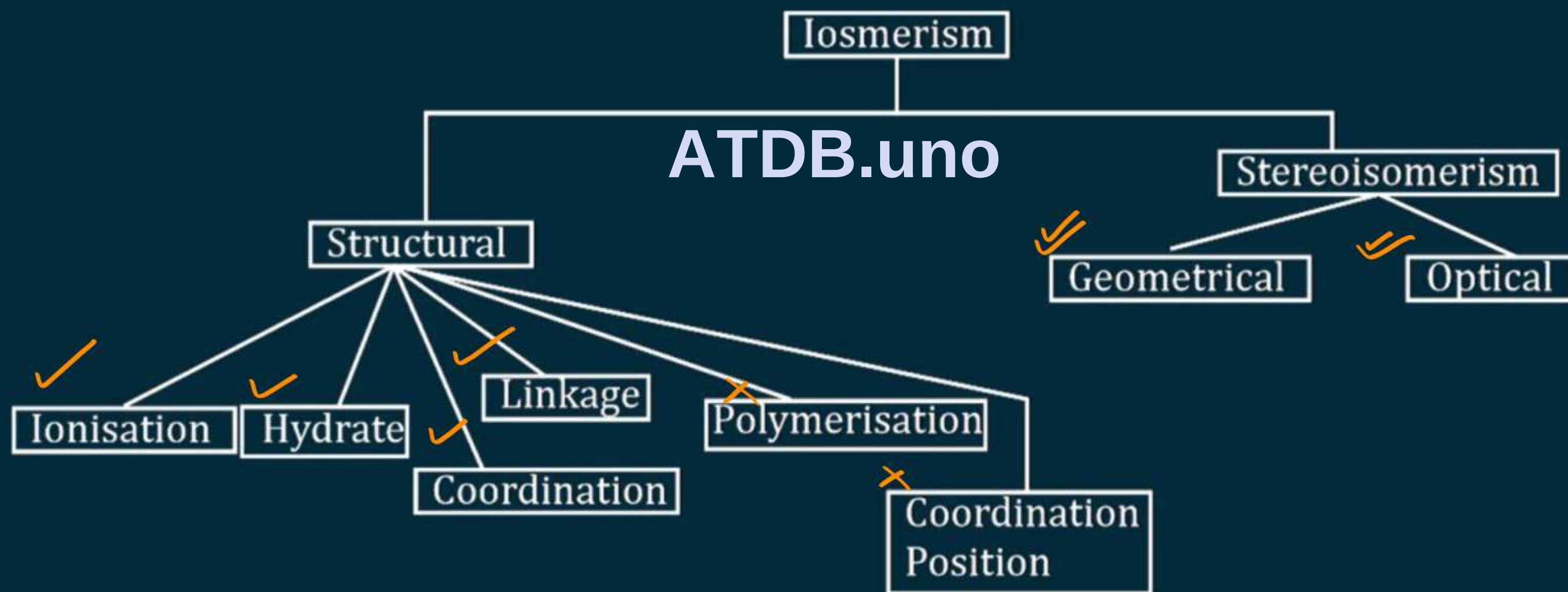
4



Isomerism in coordination compounds



The compounds have same molecular formula but different physical and chemical properties on account of different structures or spatial arrangement are called isomers.



Structural

(i) Ionisation

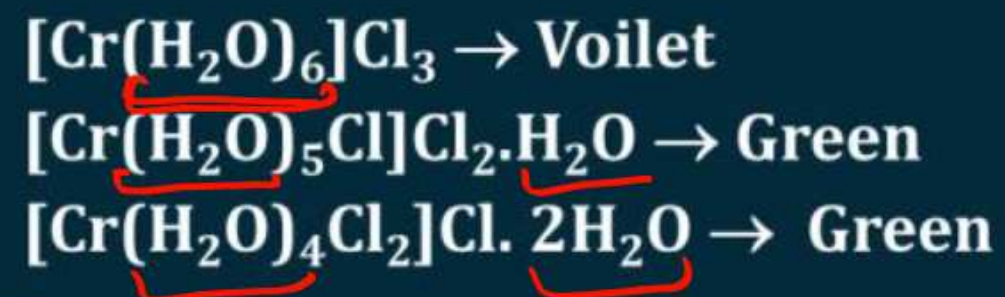
When the coordination compound having same empirical formula give different ions in solution.



(ii) Hydrate Isomerism

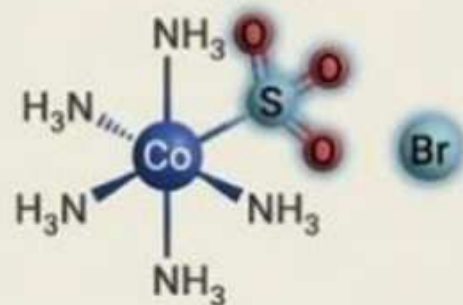
When the empirical formula of coordination comp. is same but have different no. water molecules inside and outside the coordination sphere

Example:



ATDB.uno

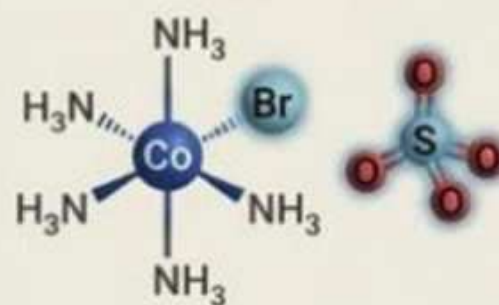
Red-violet
 $[\text{Co}(\text{NH}_3)_5(\text{SO}_4)]\text{Br}$



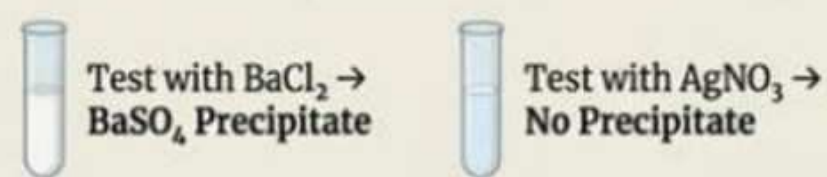
In solution, this yields the bromide ion (Br^-).



Red
 $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$



In solution, this yields the sulphate ion (SO_4^{2-}).



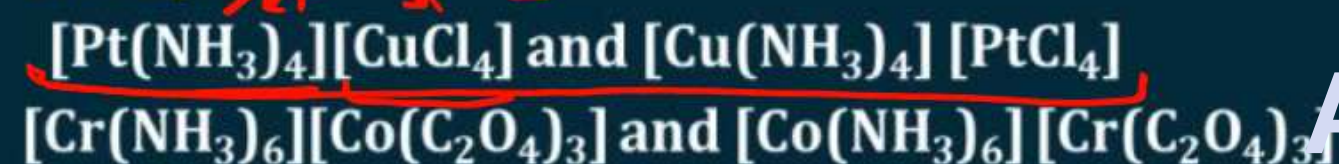


Coordination Isomerism

When the empirical formula of coordination compound is same but both having both cationic and anionic complex ion.

Then Ligands are interchanged in both cationic and anionic ions to form isomers.

Example



Linkage Isomerism

This type of isomerism occurs in complex compound. Which contain ambidentate ligands like NO_2^- , SCN^- , $S_2O_3^{2-}$ and CO . These ligands have two donor atoms but at a time only 1 atoms is directly linked to the central metal of the complex.

Example: $[Co(NH_3)_5NO_2]Cl_2$ and $[Co(NH_3)_5ONO]Cl_2$

QUESTIONS

The compounds $[Co(SO_4)(NH_3)_5]Br$ and $[Co(Br)(NH_3)_5]SO_4$ represent:

(PYQ)

1

Optical isomerism

3

Ionisation isomerism

2

Linkage isomerism

4

Coordination isomerism



QUESTIONS

Assertion (A): Linkage isomerism arises in coordination compounds because of ambidentate ligand.

Reason (R): Ambidentate ligand like NO_2 has two different donor atoms i.e., N and O. 2024 (PYQ)

1

Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

2

Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

3

Assertion (A) is correct, but Reason (R) is incorrect statement

4

Assertion (A) is incorrect, but Reason (R) is correct statement.

ATDB.uno

Stereoisomerism



1. Geometrical isomerism

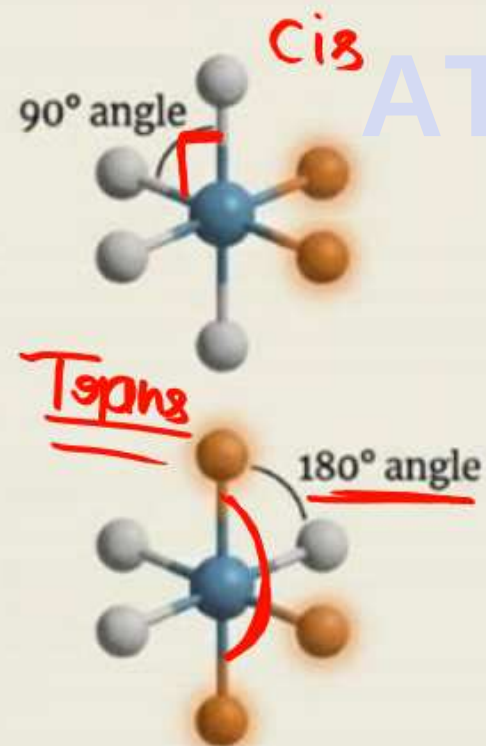
The isomerism is due to ligands occupying different position around the central metal atom or ion. The ligands occupy positions either adjacent or opposite to one another.

This type of isomerism is called as Cis-trans isomerism

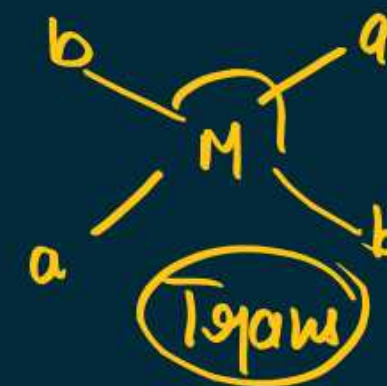
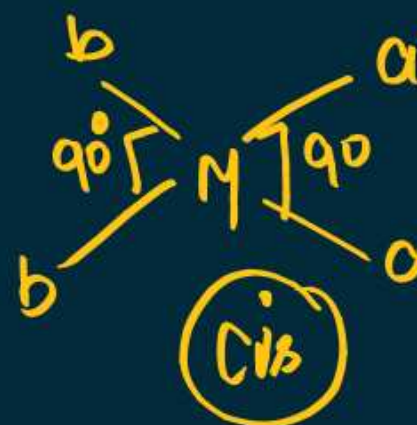
Cis-Trans

cis: Ligands are adjacent (e.g., at 90° in an octahedron).

trans: Ligands are opposite (e.g., at 180° in an octahedron).

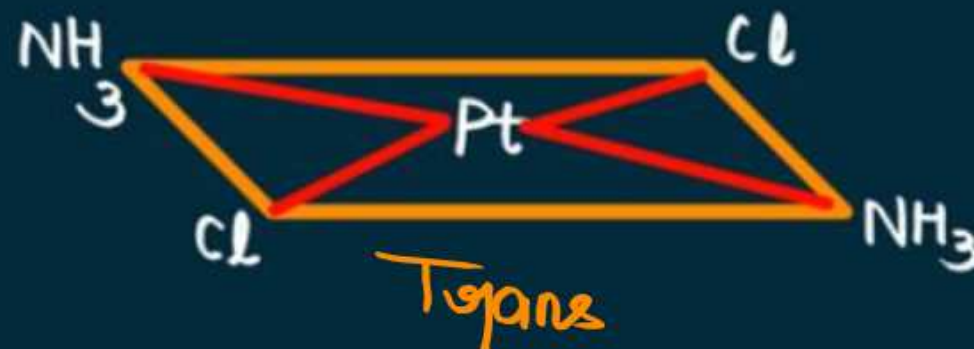
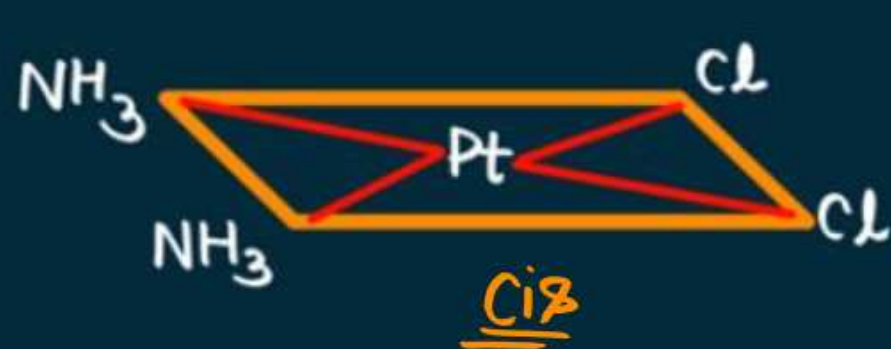
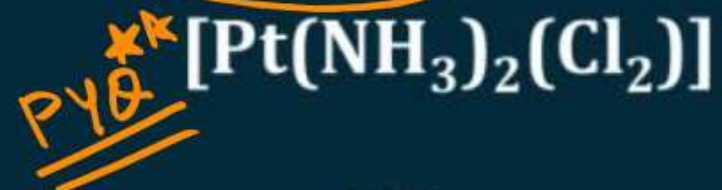


$M O_2 b_2$

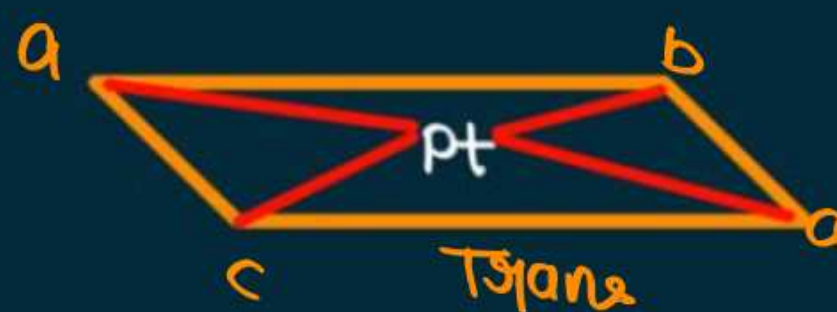
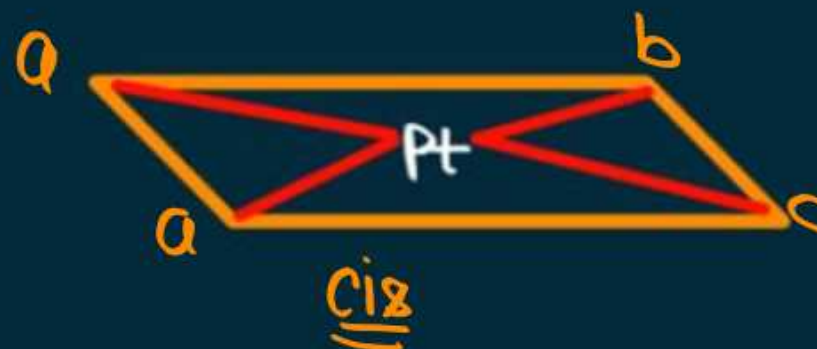


Square planar complexes

(a) Ma_2b_2 , Where a and b both are monodentate.



(b) Ma_2bc , where a, b, c are monodentate

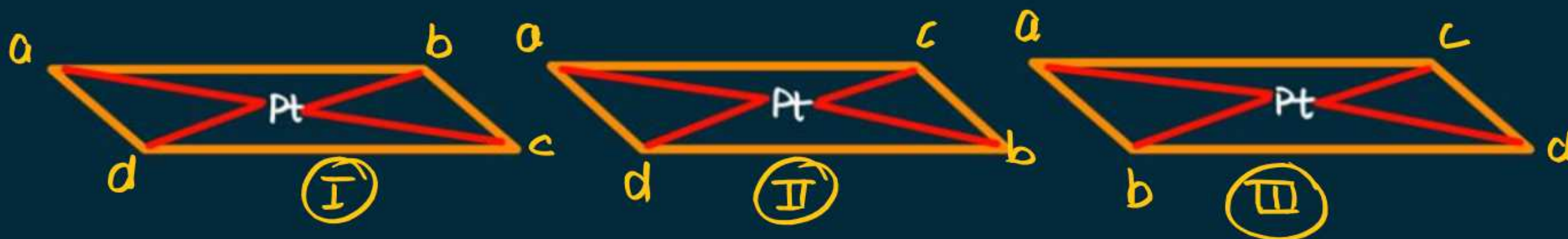


Handwritten notes:

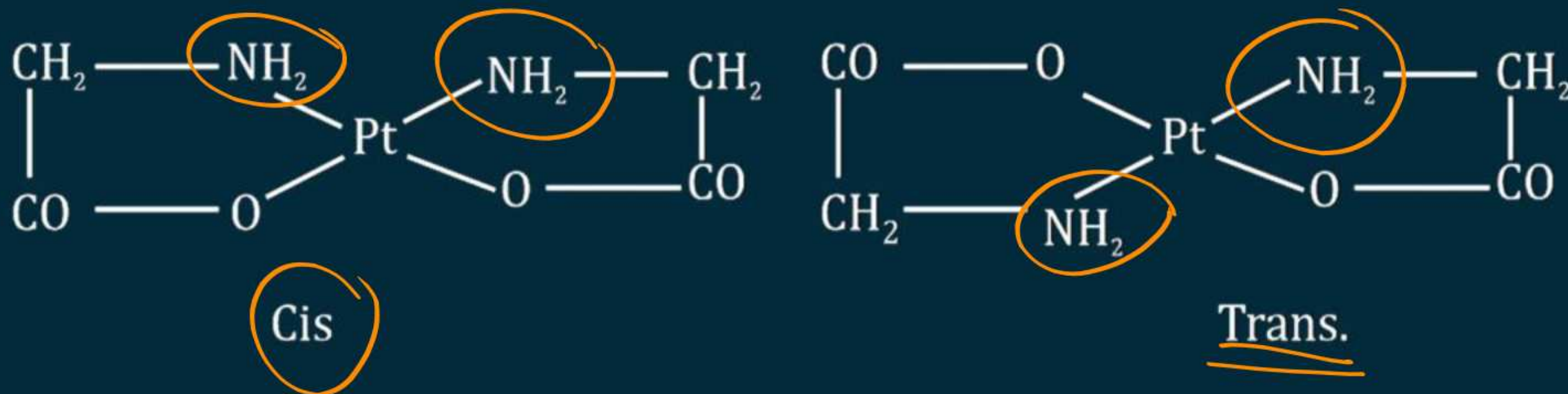
- ✓ Square Planar
- Tetrah X
- $\text{C.N} = 6$ (circled)
- ↓
- Octahedral



(c) Mabcd. Where a, b, c, d are monodentate
 $[\text{Pt}(\text{NH}_3)(\text{NH}_2\text{OH})(\text{NO}_2)(\text{Py})]\text{NO}_2$



(d) Square planar complexes having unsymmetrical bidentate ligands can also show geometrical isomerism.

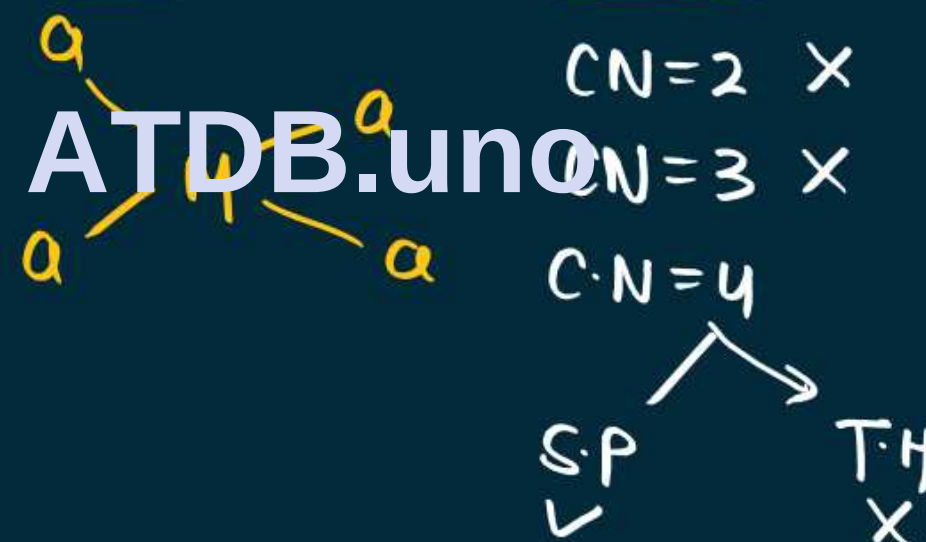


Important notes

square planar



1. Geometrical isomerism is not observed in complexes of C.No. 2 and 3
2. Square planner of type Ma_4 , Ma_3b and Mab_3 do not show geometrical isomerism✓
3. Geometrical isomerism is not observed in complex of C.NO. 4 of tetrahedral geometry. All positions are adjacent to one another.

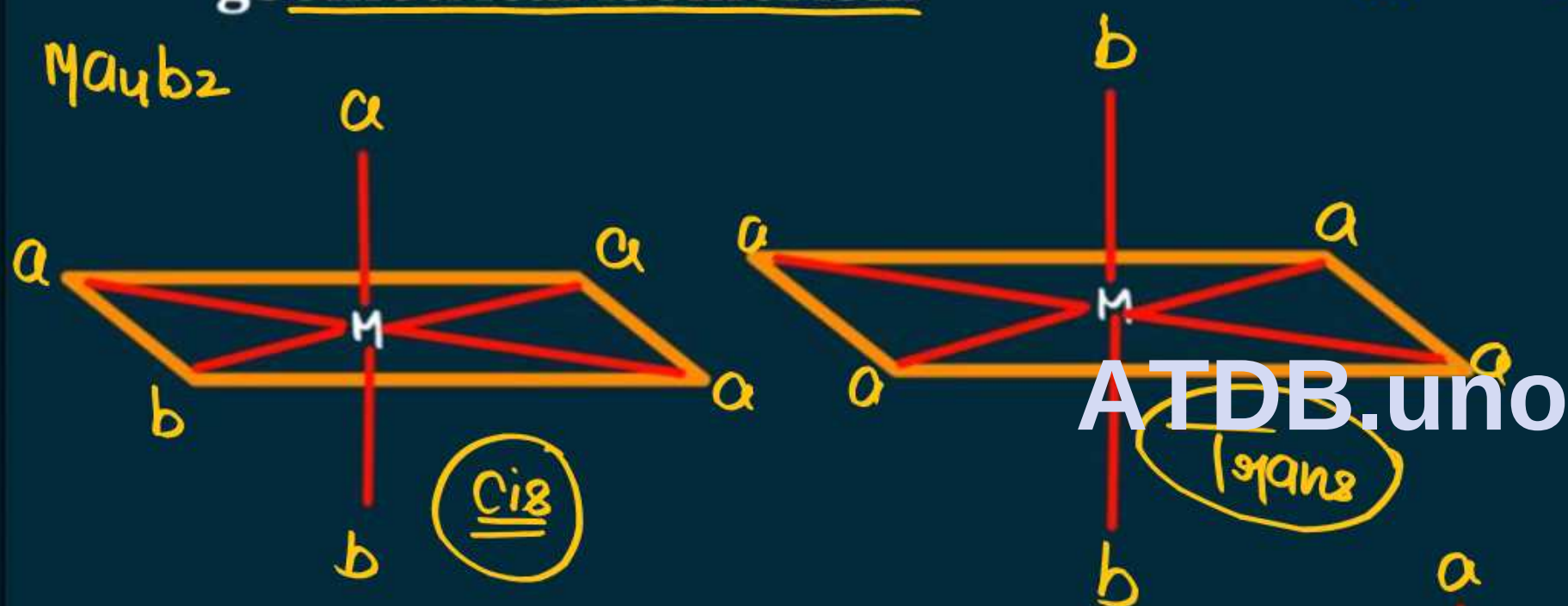


$Ma_2bc \rightarrow 2$
 $Ma_2b_2 \rightarrow 2$
 $Maabcd \rightarrow 3$
 $Ma_4 \rightarrow 0$
 $Ma_3b \rightarrow 0$
 $Mab_3 \rightarrow 0$

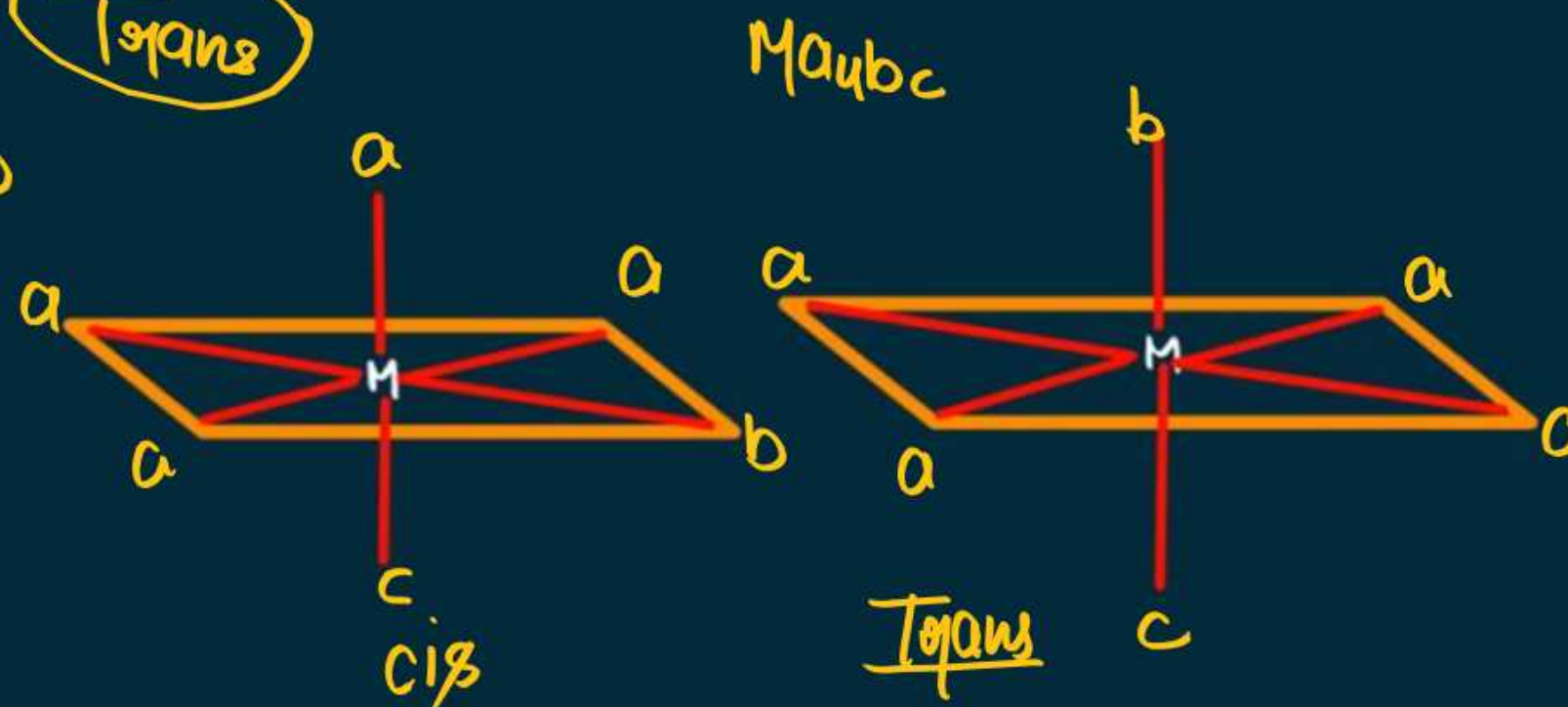


Octahedral Complexes (C.No = 6)

(a) Octahedral complexes of the type Ma_4B_2 , Ma_2B_4 , Ma_4bc and Ma_3b_3 exhibit geometrical isomerism



Ex. $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$, $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$

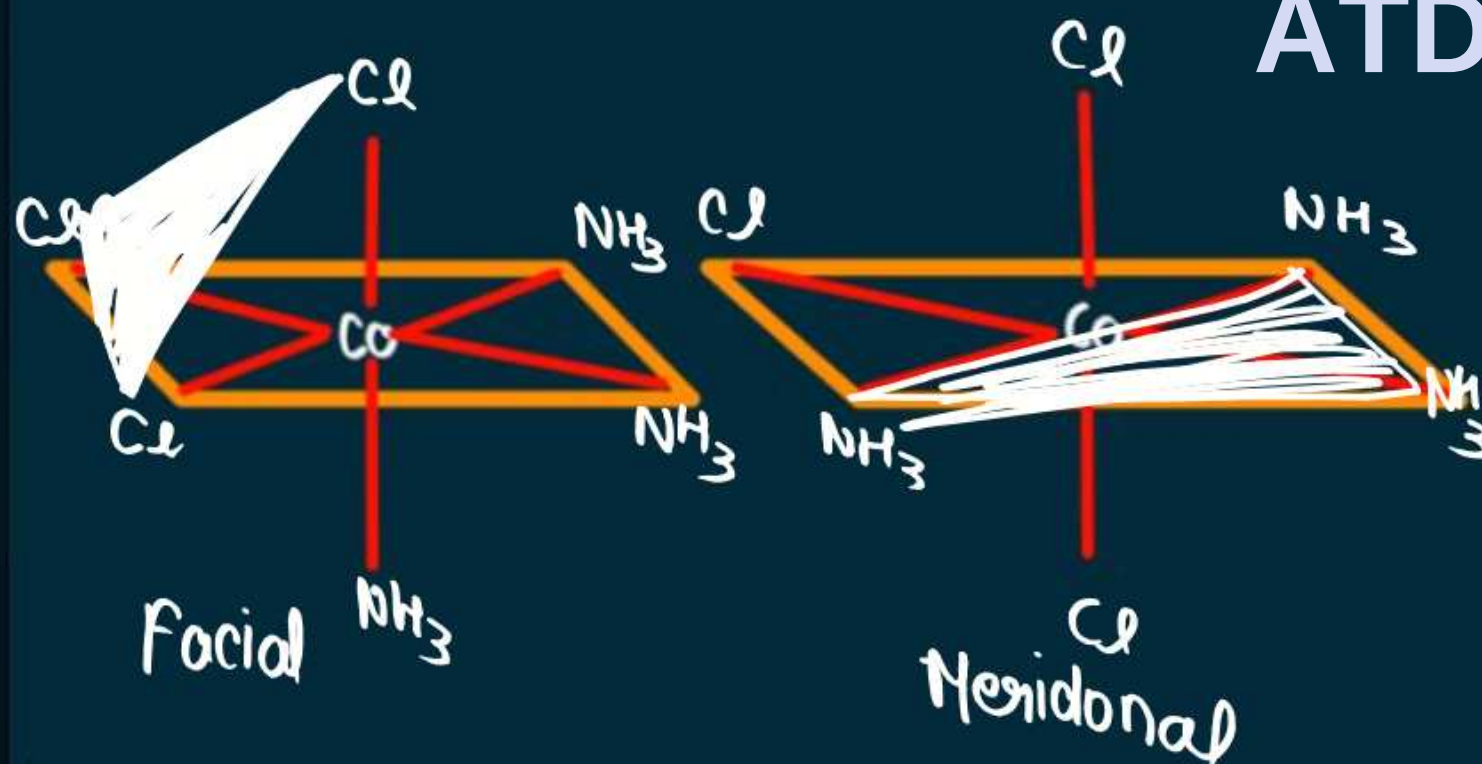




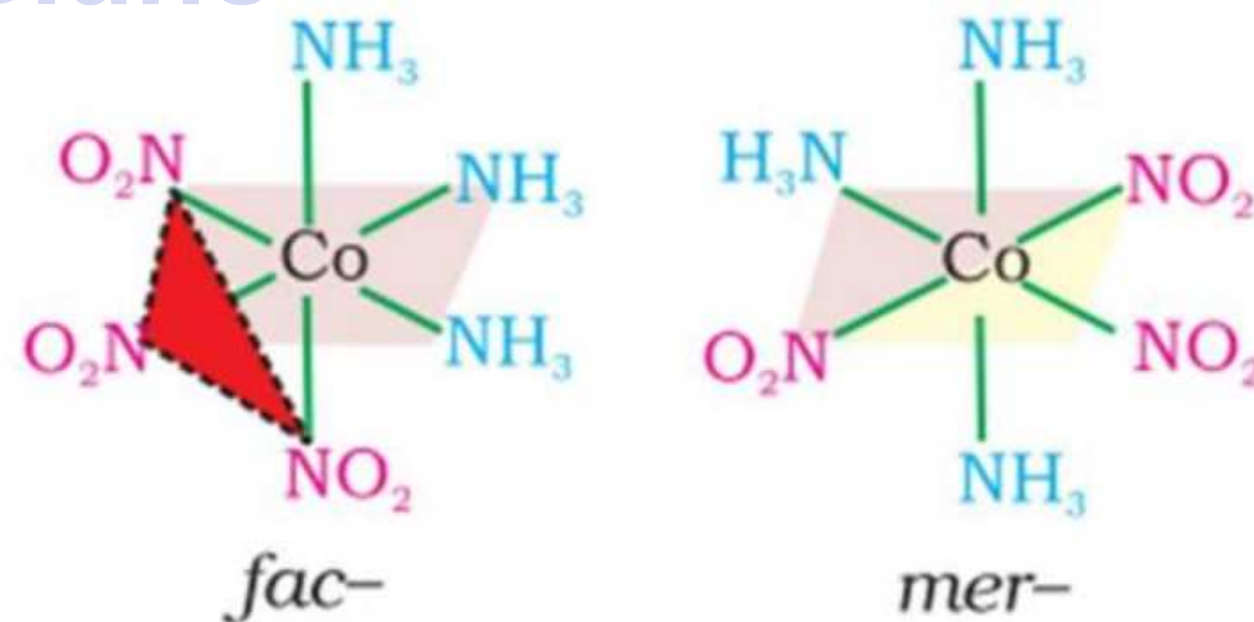
Note :

*** Ma₃b₃ type octahedral complex do not exhibit cis and trans isomerism, they exhibit facial and meridional isomerism.**

Example



ATDB.uno

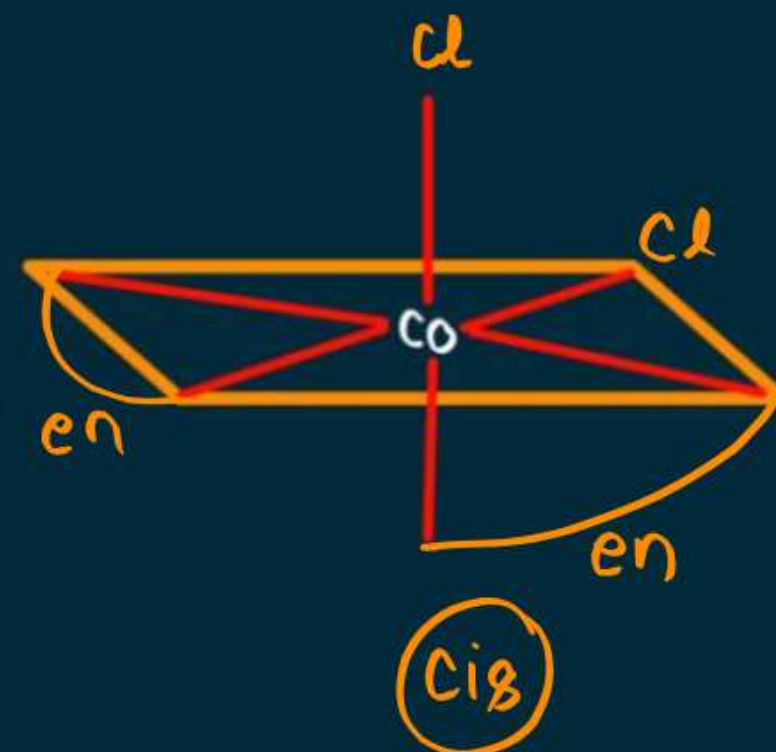
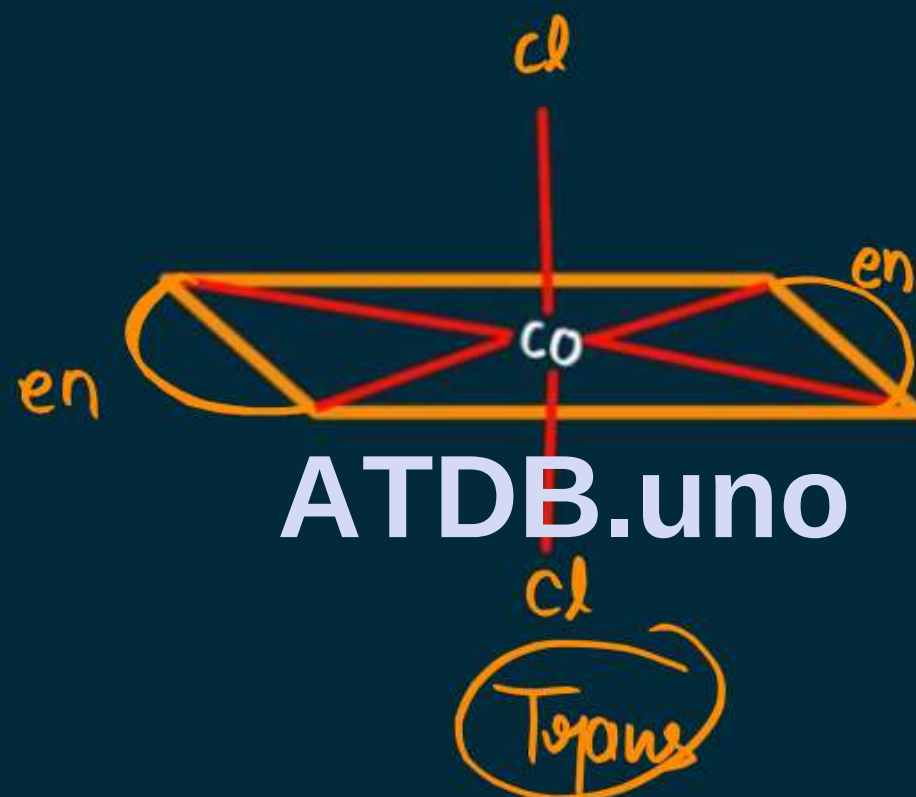




APM ❤️

(b) Octahedral complexes having bidentate ligands of the type $M(aa)_2b_2$ or $M(aa)_2bc$ can also exist in cis-trans isomers where aa is symmetrical bidentate ligands

Example



QUESTIONS

Write IUPAC name of the complex $[Pt(en)_2Cl_2]$.

Draw structures of geometrical isomers for this complex.

(2019)

Optical Isomerism



- A coordination compound which can rotate the plane of polarized light is said to be optically active.
- When the coordination compounds have same formula but differ in their abilities to rotate directions of the plane of polarized light are said to be exhibit optical isomers and molecules are optical isomers.
- The optical isomers are pair of molecules which are non-superimposable mirror images of each other.
- The essential requirement for a substance to be optically active is that the substance should not have a plane of symmetry in its structure.

Axis of Symmetry

Coordination

✓
NO PQS
NO AOS

Mirror Image

① Non-Superimpo

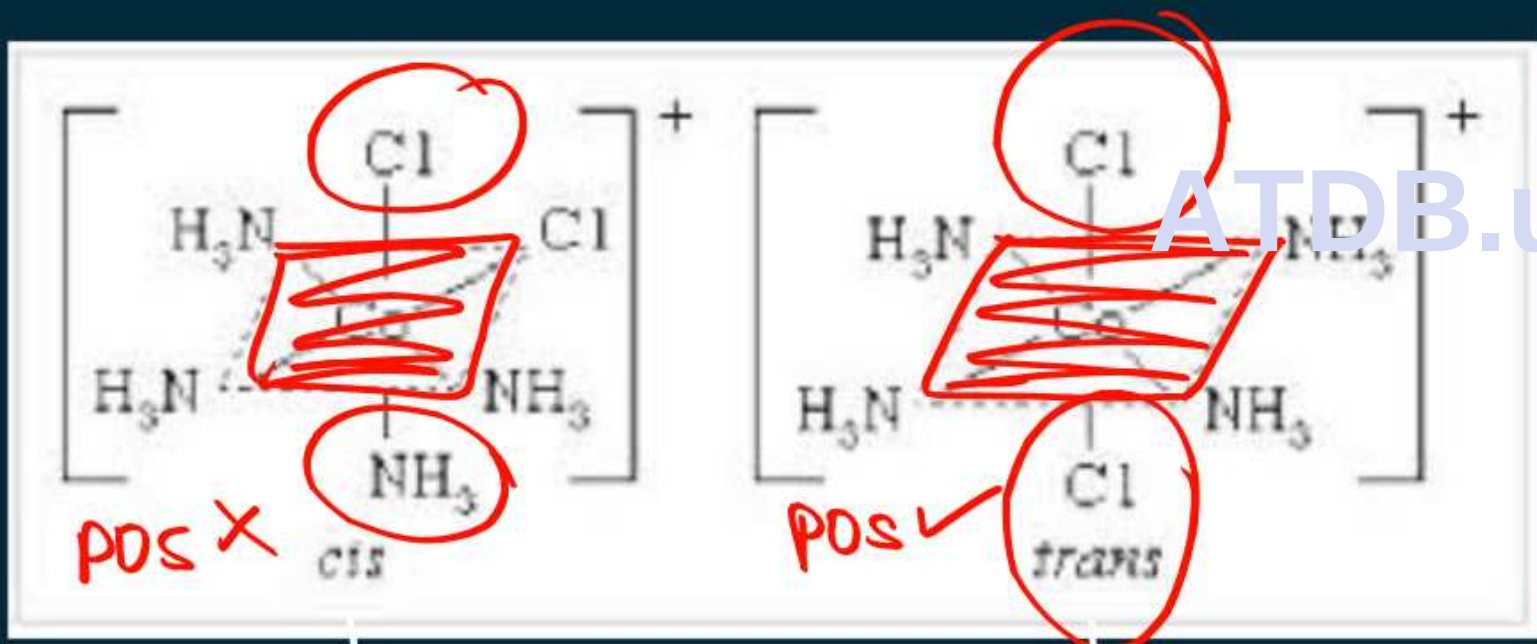
Laeveo Enantiomers Dextro



Note : -

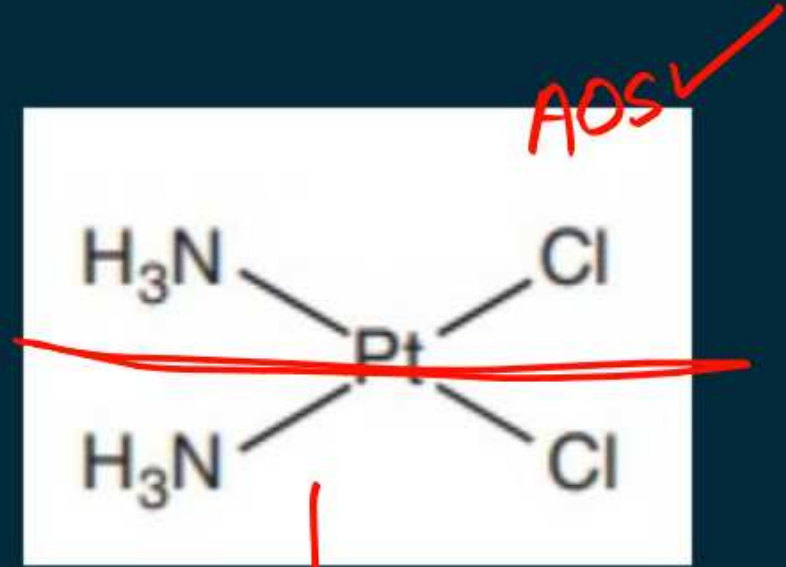
Plane of symmetry → Plane that divides the structure into 2 equal/superimposable halves or 2 parts are mirror images of each other.

Axis of symmetry → Axis (line) that divides the structure into 2 equal/superimposable structure/halves.



Optical
iso.

PDS ✓
No optical iso.



square planar
AOS ✓

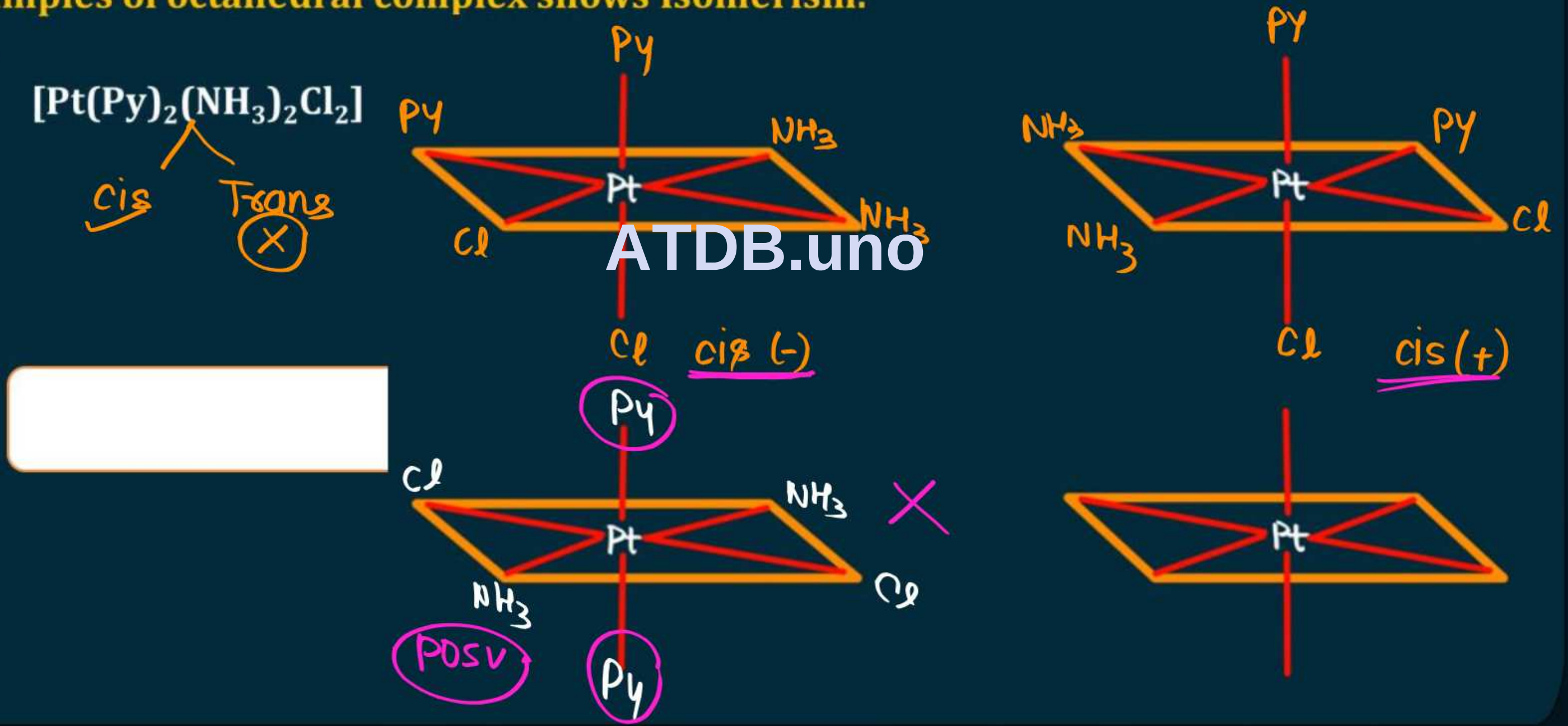
No optical isomerism.

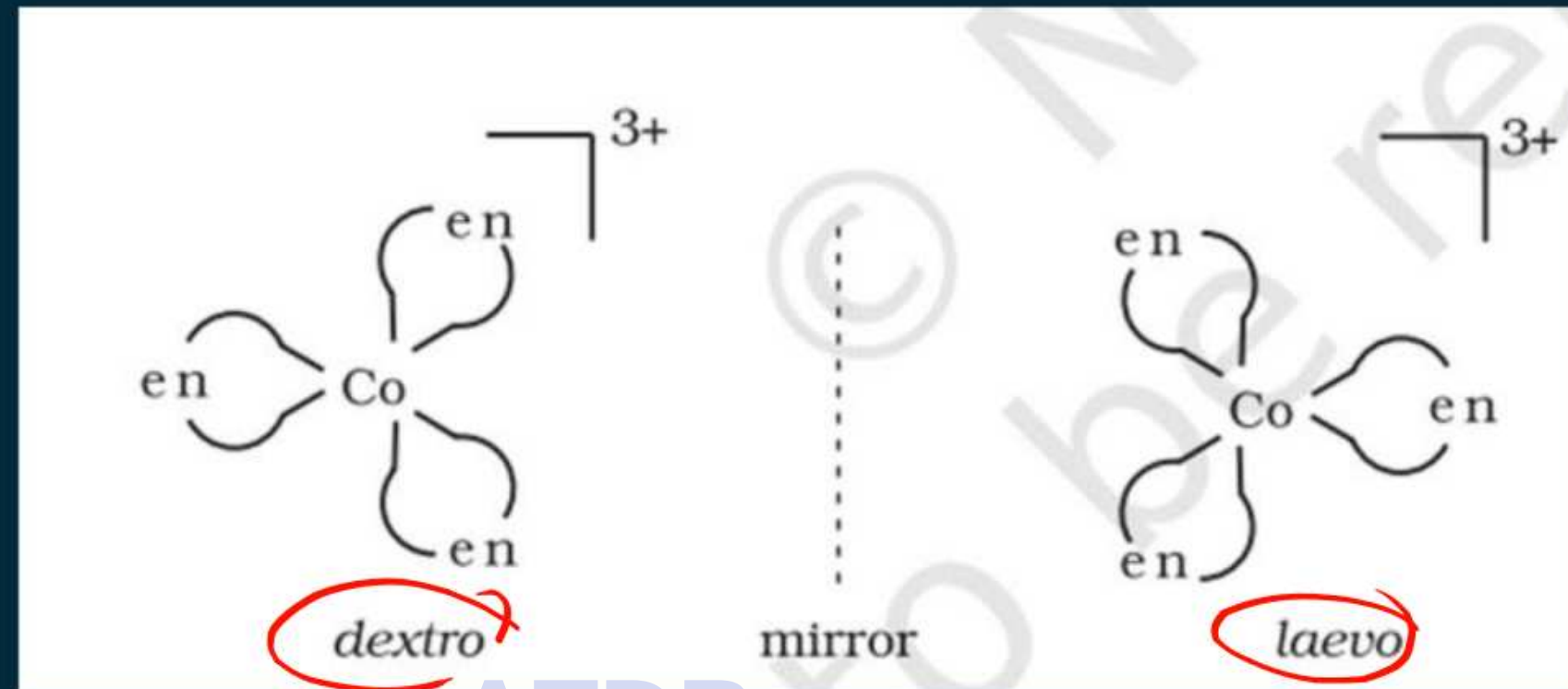


- Optical isomers rarely occurs in square planar complexes on account of the presence of axis of symmetry

Examples of octahedral complex shows Isomerism.

Ex.

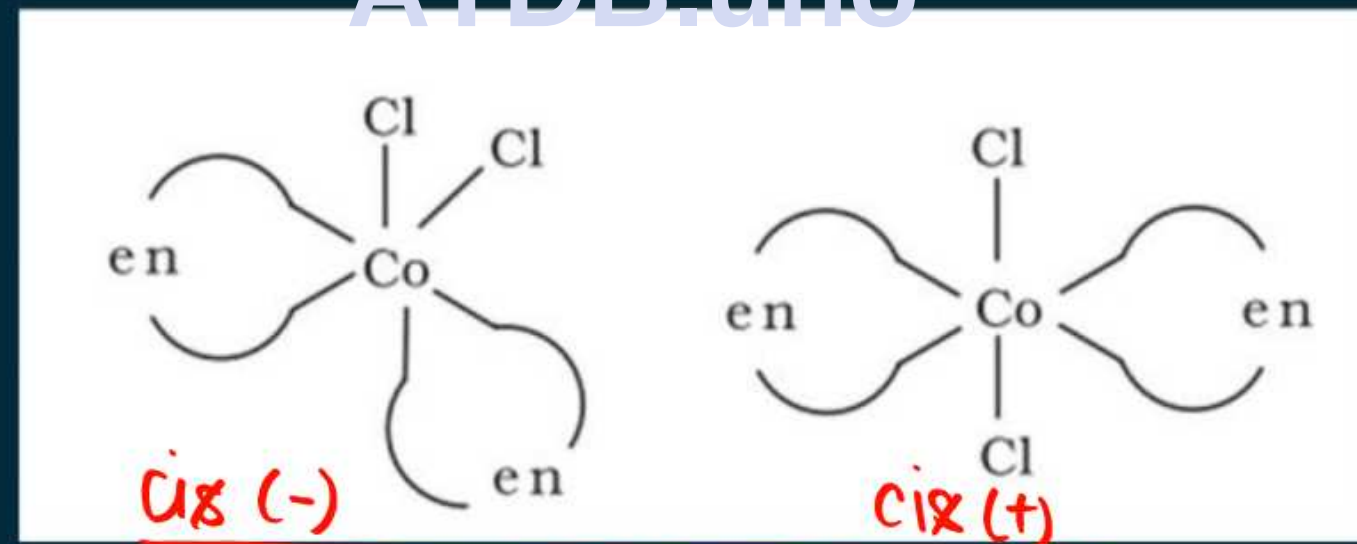




APM



cis Trans X



Colour of coordination compound



Some of the visible spectrum is being removed from white light as it passes through the sample, so the light that emerges is no longer white.

The colour of the complex is complementary to that which is absorbed. The complementary colour is the colour generated from the wavelength left over.

ATDB.uno

VIBGYOR

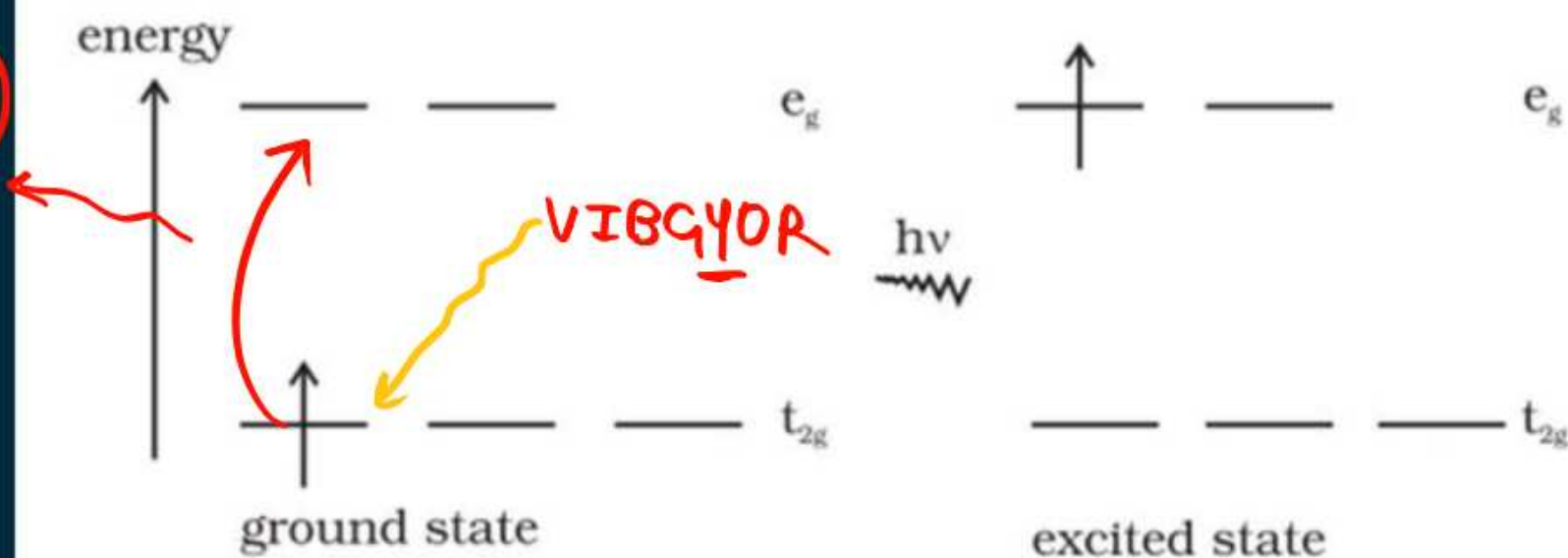


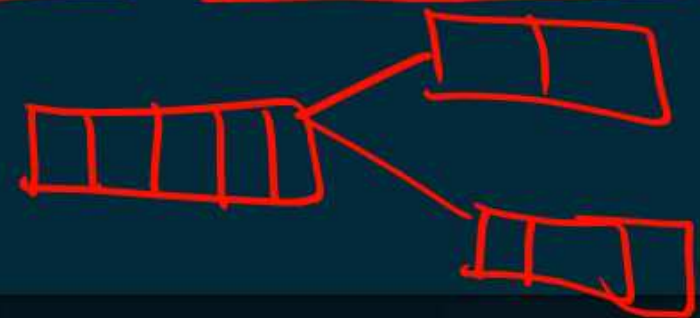
Fig.5.10: Transition of an electron in

Coloured Compounds



Coordinaton entity	Wavelength of light absorbed (nm)	Colour of light absorbed	Colour of coordination entity
$[\text{CoCl}(\text{NH}_3)_5]^{2+}$	535	Yellow	Violet
$[\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+}$	500	Blue Green	Red
$[\text{Co}(\text{NH}_3)_6]^{3+}$	475	Blue	Yellow Orange
$[\text{Co}(\text{CN})_6]^{3-}$	310	Ultraviolet	Pale Yellow
$[\text{Cu}(\text{H}_2\text{O})_4]^{2+}$	600	Red	Blue
$[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$	498	Blue Green	Violet

It is important to note that in the absence of ligand, crystal field splitting does not occur and hence the substance is colourless. For example, removal of water from $[\text{Ti}(\text{H}_2\text{O})_6]\text{Cl}_3$ on heating renders it colourless. Similarly, anhydrous CuSO_4 is white, but $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is blue in colour.

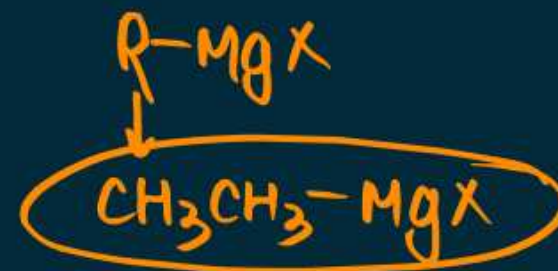


Organometallic compounds

Compounds that contain at least one carbon-metal bond are called organometallic compound.

Ex.

Grignard reagent (RMgx), $[\text{Fe}(\text{CO})_4]$



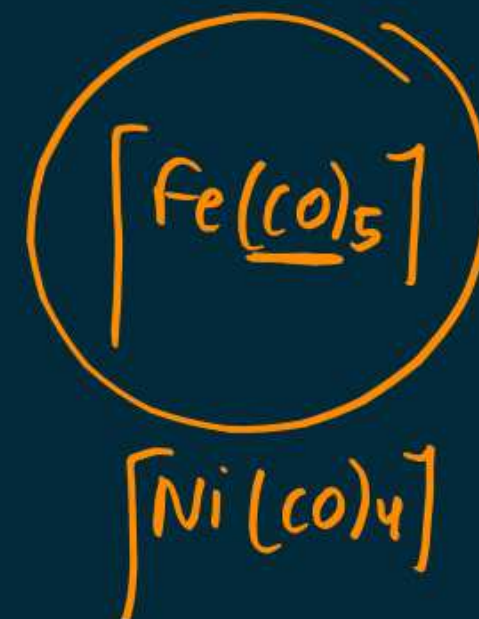
Organometallic compounds may be classified into 3 classes

(A) Sigma (σ) bonded complexes

(B) Pi (π) bonded complexes

(C) Complex containing both σ and π $\rightarrow$ Metal carbonyl

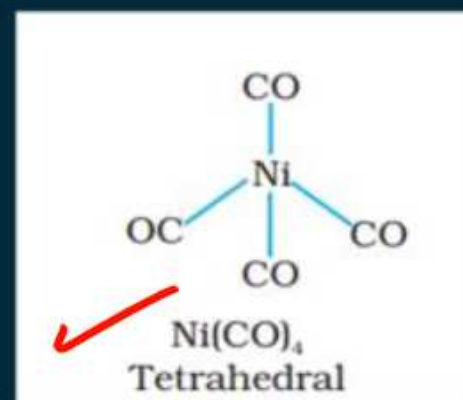
ATDB.uno



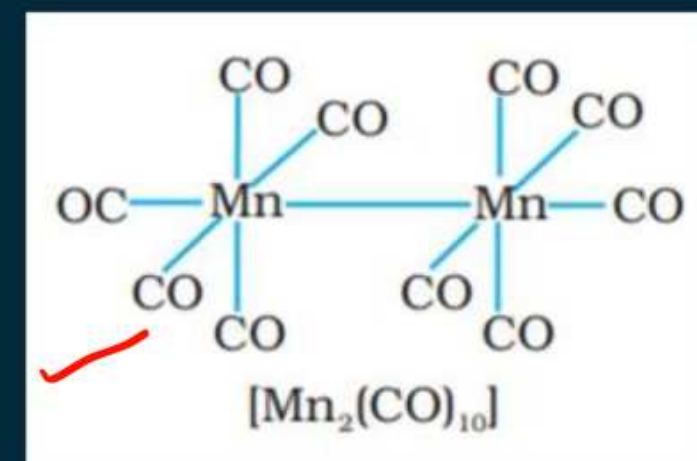
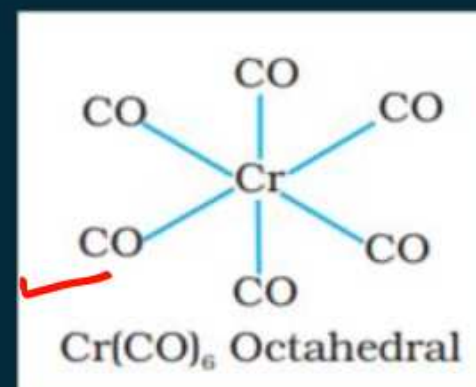
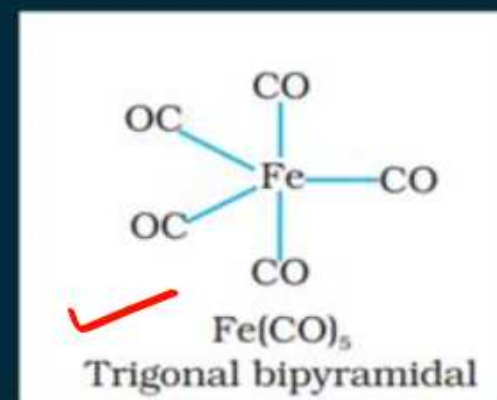
Metal carbonyl

The Homoleptic carbonyls are formed by most of the transition metal

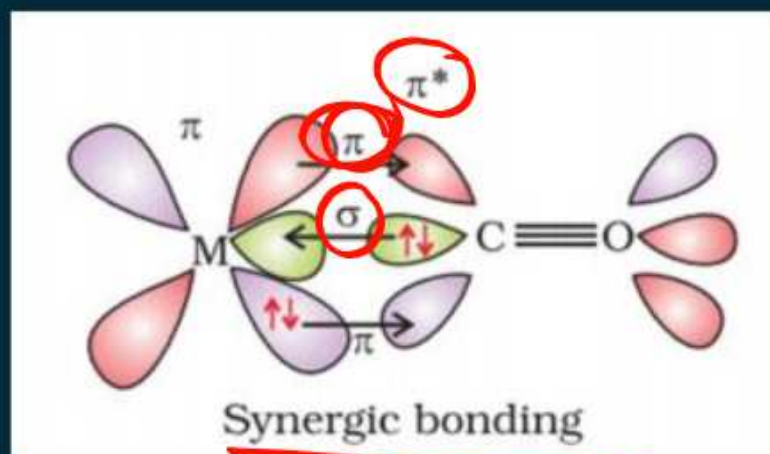
Tetra carbonyl Nickel



Pentacarbonyl Iron



ATDB.uno



- The metal –carbon bond in metal carbonyl possesses both σ and π character.
- The M-C σ bond is formed by the donation of lone pair of e^- of the carbonyl carbon into 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 CO.

Samaj Aaya ?

compent : (OC)
sample paper
High weightage

APM

ATDB.uno



