

Transition metals

Introduction

- ▶ It is defined as the elements which have partially filled d- sub shell or f sub-shell in a metallic state and having at least one stable oxidation state.
- ▶ They are called transition as they lie between S and P block elements.
- ▶ **These elements are sub divided into two types:**

1.The main transition element : it include d- block elements having partially filled d-subshell.

Q) Zn , Cd and Hg are called Non-typical(pseudo transition) transition elements.Why?

- ▶ These element do not contain the partially filled d-subshell and they do not exhibit the typical properties of transition elements like
 - ▶ Zn exhibit only one oxidation state
 - ▶ Zn compound are color less.
 - ▶ Zn do not show catalytic activity.

2.Inner transition elements : f-block elements which include that have partially filled d-sub shell in metallic or at least one stable oxidation state. They are subdivided into two type

- ▶ Lanthanides or rare earths
- ▶ Actinides

D-block elements

d-block elements →

hydrogen 1 H 1.0079																	helium 2 He 4.0026						
lithium 3 Li 6.941	beryllium 4 Be 9.0122																	boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305																	aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selecnium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80						
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29						
cesium 55 Cs 132.91	barium 56 Ba 137.33	lanthanum 57 La 138.91	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]						
francium 87 Fr [223]	radium 88 Ra [226]	actinium 89 Ac [227]	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [263]	bohrium 107 Bh [264]	hassium 108 Hs [265]	meitnerium 109 Mt [266]	unnilium 110 Uun [271]	ununium 111 Uuu [272]	unbibium 112 Uub [273]	ununquadium 114 Uuq [289]										

* Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
** Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

Characteristics of transition metals

Metallic property: All transition elements are metals. They are malleable ductile and hard due to strong metallic bond.

High Melting and Boiling Points: Transition metals typically have high melting and boiling points due to the strong metallic bonding involving delocalized d-electrons.

Incompletely Filled d-Orbitals: Transition metals have incompletely filled d-orbitals, which contribute to their ability to form various types of bonds and complex structures.

Formation of Colored Compounds: Many transition metals form colored compounds. This is due to the d-d electron transitions and the interaction of these electrons with ligands.

Catalytic Properties: Many transition metals and their compounds act as catalysts in chemical reactions. This is often due to their ability to change oxidation states and form complexes with reactants, facilitating the reaction process.

Formation of Complexes: Transition metals have a strong tendency to form coordination complexes with various ligands, which can significantly alter their chemical behavior and reactivity.

Hardness and Strength: They tend to be very hard and strong, which makes them useful in construction and manufacturing industries.

Incompletely Filled d-Orbitals: Transition metals have incompletely filled d-orbitals, which contribute to their ability to form various types of bonds and complex structures.

Variable Oxidation States: Transition metals often exhibit multiple oxidation states, meaning they can lose different numbers of electrons, leading to compounds with various colors and properties.

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Oxidation states

Transition element	Known oxidation states	Electron configuration	Orbital diagram (4s and 3d sub-levels only)	
Sc	<u>+3</u>	[Ar] 4s ² 3d ¹	4s $\boxed{\uparrow\downarrow}$	3d $\boxed{1} \quad \boxed{} \quad \boxed{} \quad \boxed{} \quad \boxed{}$
Ti	<u>+2</u> <u>+3</u> <u>+4</u>	[Ar] 4s ² 3d ²	4s $\boxed{\uparrow\downarrow}$	3d $\boxed{1} \quad \boxed{1} \quad \boxed{} \quad \boxed{} \quad \boxed{}$
V	<u>+1</u> <u>+2</u> <u>+3</u> <u>+4</u> <u>+5</u>	[Ar] 4s ² 3d ³	4s $\boxed{\uparrow\downarrow}$	3d $\boxed{1} \quad \boxed{1} \quad \boxed{1} \quad \boxed{} \quad \boxed{}$
Cr	<u>+1</u> <u>+2</u> <u>+3</u> <u>+4</u> <u>+5</u> <u>+6</u>	[Ar] 4s ¹ 3d ⁵	4s $\boxed{1}$	3d $\boxed{1} \quad \boxed{1} \quad \boxed{1} \quad \boxed{1} \quad \boxed{1}$
Mn	<u>+1</u> <u>+2</u> <u>+3</u> <u>+4</u> <u>+5</u> <u>+6</u> <u>+7</u>	[Ar] 4s ² 3d ⁵	4s $\boxed{\uparrow\downarrow}$	3d $\boxed{1} \quad \boxed{1} \quad \boxed{1} \quad \boxed{1} \quad \boxed{1}$
Fe	<u>+1</u> <u>+2</u> <u>+3</u> <u>+4</u> <u>+5</u> <u>+6</u>	[Ar] 4s ² 3d ⁶	4s $\boxed{\uparrow\downarrow}$	3d $\boxed{\uparrow\downarrow} \quad \boxed{1} \quad \boxed{1} \quad \boxed{1} \quad \boxed{1}$
Co	<u>+1</u> <u>+2</u> <u>+3</u> <u>+4</u> <u>+5</u>	[Ar] 4s ² 3d ⁷	4s $\boxed{\uparrow\downarrow}$	3d $\boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow} \quad \boxed{1} \quad \boxed{1} \quad \boxed{1}$
Ni	<u>+1</u> <u>+2</u> <u>+3</u> <u>+4</u>	[Ar] 4s ² 3d ⁸	4s $\boxed{\uparrow\downarrow}$	3d $\boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow} \quad \boxed{1} \quad \boxed{1}$
Cu	<u>+1</u> <u>+2</u> <u>+3</u>	[Ar] 4s ¹ 3d ¹⁰	4s $\boxed{1}$	3d $\boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow}$

Complex ions

- ▶ An electrically charged ions which consist of central metal atom or ion surrounded by a group of ions or neutral molecules is called complex ion. For example $[\text{Ni}(\text{NH}_3)_6]^{+2}$ is a complex ions in which Ni is surrounded by 6 NH_3 molecules.
- ▶ Coordination compound generally contains one or more complex ions
In $[\text{Cu}(\text{NH}_3)_4] \text{SO}_4$ contains $[\text{Cu}(\text{NH}_3)_4]^{+2}$ complex ions.
In $[\text{Ag}(\text{NH}_3)_2] \text{Cl}$ contains $[\text{Ag}(\text{NH}_3)_2]^+$ complex ions.

Ligands

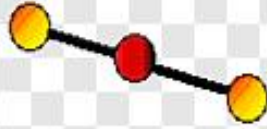
- ▶ Ionic species or neutral molecules that gets directly attached to the central metal atom to form complex compound.
- ▶ In $[\text{Fe}(\text{CN})_6]^{4-}$ ion, CN^- is ligand.
- ▶ Different types of ligands:
 1. Monodentate ligand: shares only one pair of electron to central metal atom. Eg; F^- Br^- Cl^- CN^- H_2O NH_3 CO etc.
 2. Bidentate ligand: Shares two pairs of electron to M-atom. Eg; $\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}_2$ (ethylene diamine), CO_3^{2-}
 3. Polydentate ligand: shares many electron pairs to M-atom. Eg: EDTA (Ethylenediamine tetraacetate) acts as hexadentate ligand.

Shapes of complex compound:

- ▶ 1. Linear :linear complex is forms when the ligands and the metals forms the straight line.eg; structure of CO_2
- ▶ 2. Square Planner: the square planar shape isn't very common. The square planar shape forms when the ligands around a metal are all on the same plane; in other words, it's completely flat. This occurs when there are four ligands attached to a transition metal with a d^8 electron configuration. When there are four bonds this means that there are four other unpaired electron pairs. There are two ligands pointing up and two ligands pointing down.
- ▶ Tetrahedral:Tetrahedral complexes have four coordindate bonds. The four ligands are arranged around the central metal ion at the corners of a tetrahedron.The bond angles between the ligands are approximately 109.5 degrees. The metal ion in a tetrahedral complex has a coordination number of 4.
- ▶ Ligands can be either anions (e.g., Cl^- , Br^-) or neutral molecules (e.g., NH_3 , H_2O).
- ▶ **Examples:**
- ▶ ZnCl_4^{2-} : A tetrahedral complex of zinc with chloride ligands.
- ▶ CoCl_4^{2-} : A tetrahedral complex of cobalt with chloride ligands, often blue in color.

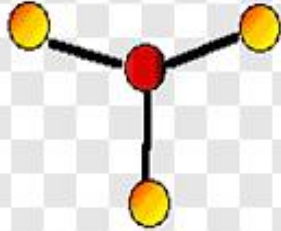
- ▶ Octahedral: Octahedral complexes are a type of coordination compound where a central metal ion is surrounded by six ligands positioned at the corners of an octahedron.
- ▶ The metal ion in an octahedral complex has a coordination number of 6.
- ▶ Ligands can be either anions (e.g., Cl^- , NO_3^-) or neutral molecules (e.g., H_2O , NH_3).
- ▶ **Examples:**
- ▶ $\text{Fe}(\text{CN})_6^{3-}$: An octahedral complex of iron with cyanide ligands.
- ▶ $\text{Co}(\text{NH}_3)_6^{3+}$: An octahedral complex of cobalt with ammonia ligands.

1- Linear



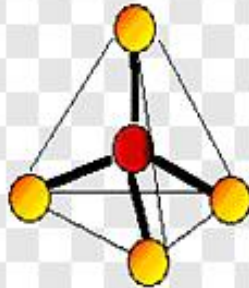
LINEAR

2- Triangular (Trigonal) plana



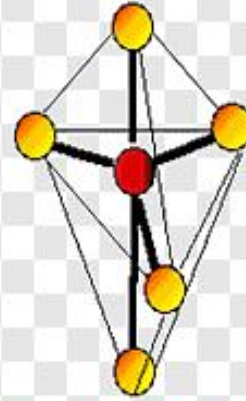
TRIGONAL PLANAR

3- Tetraédrica



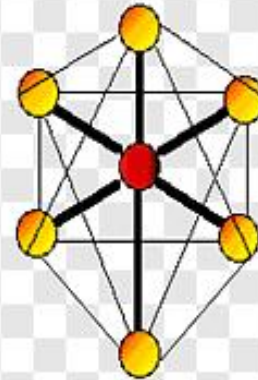
TETRAHEDRAL

4- Bipirâmidal trigonal



TRIGONAL BIPYRAMIDAL

5- Octaédrica



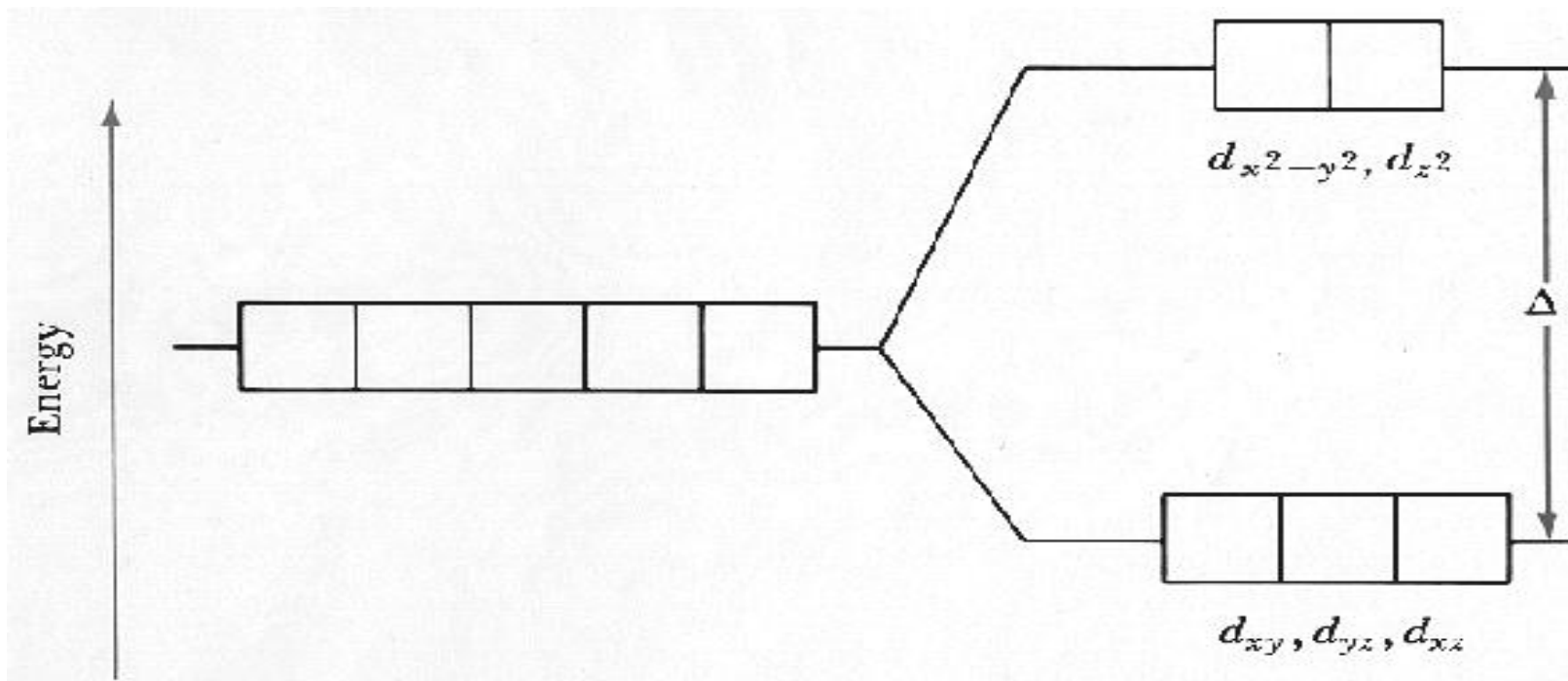
OCTAHEDRAL

Crystal field theory

- ▶ This theory was proposed by Hans Brethe and Ven Vleck.
- ▶ This theory was originally applied mainly to ionic crystals.
- ▶ Therefore it is known as Crystal field Theory.

Some postulates of CFT:

- ❑ According to crystal field theory the bonding between central metal atom and ligands is ionic bond.
- ❑ The d-orbitals of metal ions are degenerate(having same energy) in absence of ligands.In presence of ligands,interaction between central metal atom and ligands take place.the intereaction will be repulsive one so the repulsion causes the splitting of degenerate d-orbitals of metal.
- ❑ In octahedral complexes,d-orbitals splits into two sets;



T_{2g}: higher energy set (d_{xy}, d_{xz}, d_{yz})
 e_g: lower energy set ($d_{x^2-y^2}, d_{z^2}$)

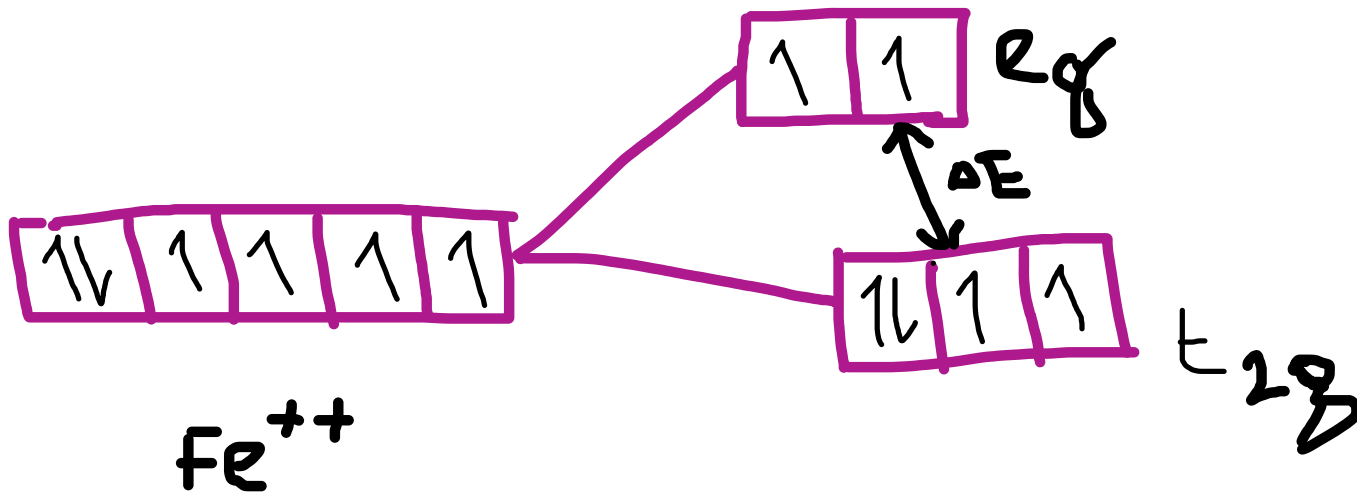
Fig; Splitting of d-orbitals in octahedral complex

Color of transition metal compounds:[d-d transition]

Transition metals are usually colored because absorption of radiation from visible region of light to promote an electron from lower energy d-orbital to a higher energy d-orbital, which is called d-d transition.

The energy of excitation corresponds to the frequency of light absorbed, so, most of the compounds of transition metals are colored due to d-d transition.

Eg: Splitting of d-orbitals in $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ is given as,



Color absorbed	Color observed
Violet	YellowGreen
Blue Violet	Yellow
Blue	Orange
BlueGreen	Red
Green	Purple
YellowGreen	Violet
Yellow	Blue Violet
Orange	Blue
Red	Bluegreen