The Chemistry of d-block element (Transition Element)

The d-orbitals are partially filled, they are called transition element

Why are they called d- block? because they've Outer Orbital in the d- orbital

Introduction:

~~The followin~~ Course Outline

(i) Position of d- block in periodic table, electronic
~~(ii)~~ Configuration
(ii) Trends in properties of these elements wrt to size of atoms and ions reactivity, catalytic activity, Oxidation state, Colour, complex formation ability, magnetic properties, ~~non stoichiometry~~
(iii) Non stoichiometry, melting and boiling point

Introduction

In the periodic table, the d- block consists of the element of group 3-12.

The d- orbital ~~of~~ of the d- block element in 4th periods are filled. The three (Triad) Series of the transition metals are; the 3d series from Scadium to Znc, 4d Series from ~~[illegible]~~ ~~Yittrium~~ (Yttrium) to Cadium, the 5d Series from La - Hg

La ↓ Lanthanum

The 4th 6d series, begins ~~from figures from~~ Actinium and incomplete till now.

Position of d-block in periodic Table

The element ~~pos~~ with incompletely d-orbitals or sub shells in their ground state or most stable oxidation state are called ~~the~~ d- block element.

They are additionally named as transition element. The Partially filled sub shells incoporate the (n-1)d orbitals

All the d-block element have a similar number of electron in the farthest shell. Consequently, because they have similar number no. of electron in the farthest shell, the display comparable chemical properties

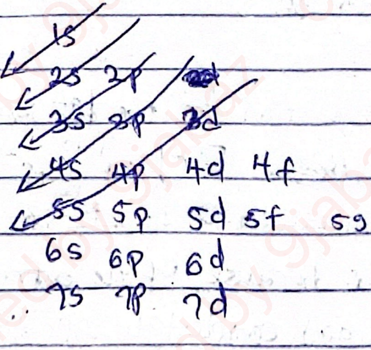
The transition element are set amongst s and p block shells.

Electronic Configuration

The external electronic configuration remains consistent, so electron is added to the penultimate shell till the d subshell achieves its

There are three series of elements, relying upon the (n-1)d orbitals that is being filled. the orbitals are dispatched altogether of their expanding energy in which case, an orbital of lower energy is filled first (Afbau principle).

Therefore, 4s orbitals with lesser energy is filled first to its full degree, then the 3d orbitals with higher energy is filled.



$4s < 3d$

Triad $1s < 2s < 2p < 3s < 3p < 4s < 3d$

The precisely half filled and totally filled orbital are extraordinary stable (Cr; $4s^1 3d^5$ and Cu; $4s^1 3d^{10}$)

$[1s^2 2s^2 2p^6 2s^2 3p^6] = Ar$

$_{21}Sc = [Ar] 4s^2 3d^1$

$_{22}Ti = [Ar] 4s^2 3d^2$

$_{23}V = [Ar] 4s^2 3d^3$

$_{24}Cr = [Ar] 4s^1 3d^5$

$_{25}Mn = [Ar] 4s^2 3d^5$ or $[Ar] 3d^5 4s^2$

$_{26}Fe = [Ar] 4s^2 3d^6$

$_{27}Co = [Ar] 4s^2 3d^7$

$_{28}Ni = [Ar] 4s^2 3d^8$

$_{29}Cu = [Ar] 4s^1 3d^{10}$

$_{30}Zn = [Ar] 4s^2 3d^{10}$

The electronic configuration of the 1st series can be represented as [illegible] $[Ar] 3d^{1-10} 4s^2$ except ~~The electronic configuration of the 1st ser~~ Chromium and copper because of the extra stability due to half filled and completely filled orbital.

$_{25}Mn = [Ar]\,3d^5\,4s^2$

$Mn^{2+} = [Ar]\,3d^5$, $Mn^{3+} = [Ar]\,3d^4$; $Mn^{4+} = [Ar]\,3d^3$

$Mn^{5+} = [Ar]\,3d^2$; $Mn^{6+} = [Ar]\,3d^1$; $Mn^{7+} = [Ar]\,3d^0$

The electronic configuration of the 2nd series, can be represented; $[Kr]\,4d^{1-10}\,5s^2$

$3d = [Ar]\,3d^{1-10}\,4s^2$

$4d = [Kr]\,4d^{1-10}\,4s^2$

$5d = [Xe]\,5d^{1-10}\,6s^2$

The electronic configuration of the 3rd series can be represented as; $[Xe]\,5d^{1-10}\,6s^2$

Oxidation states

All the elements aside from the first and the last individual from the d-series, display variable oxidation states. They indicate variable valency in their compound. Some fundamental oxidation conditions the primary, second, and third transition element are listed below

Atomic Number	Elements	Outer Electronic Configuration	Oxidation state
21	Sc	[Ar] $3d^1 4s^2$	+2, +3
22	Ti	[Ar] $3d^2 4s^2$	+2, +3, +4
23	V	[Ar] $3d^3 4s^2$	+2, +3, +4, +5
24	Cr	[Ar] $3d^5 4s^1$	+2, +3, +4, +5, +
25	Mn	[Ar] $3d^5 4s^2$	+2, +3, +4, +5, +6,
26	Fe	[Ar] $3d^6 4s^2$	+2, +3, +4, +5, +6
27	Co	[Ar] $3d^7 4s^2$	+2, +3, +4, +5
28	Ni	[Ar] $3d^8 4s^2$	+2, +3, +4
29	Cu	[Ar] $3d^{10} 4s^1$	+2, +3
30	Zn	[Ar] $3d^{10} 4s^2$	+2

Size of Atoms and Ions

Generally, the sizes of atoms/ions of the element go on decreasing from left to right across the rows in the transition series. Thus, the extra nuclear charge increases as atomic number increases. The extra electrons are added into the same d-shell ~~or~~ orbitals, and the d-orbital electrons are having poor shielding effect.

Therefore, the size of atoms and ions goes on increasing from the first transition series element in the group of transition elements.

The atomic and ionic size goes on increasing from top to bottom due to addition of new shell everytime.

The electrons fill into the antipenultimate shell of Lanthanide which causes steady decrease in size called Lanthanide contraction: It is only applicable to Scandium group

* What exactly leads to variable oxidation state?

Causes of Variable Oxidation State

The valence electron of the transition elements are (n-1)d and ns orbitals which have a little distinction in energies. Both energy levels are utilized as part of bond development

They demonstrate the +2 oxidation state because of the two electrons in ns orbitals, while the electrons in the (n-1)d orbitals remains unaffected

The higher oxidation state from +3 to +7 is because of the utilization of all the ns orbitals and d-electrons in the transition series of the element. In the excited state, the (n-1)d electrons get to be bonding and give the variable state. Subsequently the variable oxidation state is because of the support of both ns and (n-1)d orbitals in bonding

Important Features of Oxidation State of Transition Metals

The most basic oxidation state of transition metals is +2, with the exception of Scadium ~~and Zinc~~ because of the loss of two ns electron

This demostrates d-orbitals are more stable than s orbital after Scadium. The ionic bonds are bi and large framed as +2 and +3 state while the covalent bond are shaped in higher oxidation state.

Covalent bonds are framed by the sharing of d-electrons for instance, the Permaganate particle (MnO_4^-)

All bonds are shaped among Mn and O

~~The variable oxidation state is because of the support of both ns an (n-1)d orbitals in bond~~

The most not worthy oxidation state increment with expanding nuclear number of elements achieves greatest in the center and after that begins diminishing.

What are complex

for instance, Fe demostrates the normal oxidation state condition of +2 and +3, however, Ruthenium and Osmium in a similar group shape compounds in the +4, +6 and +8 oxidation state

The element at the beginning of the series displaces less oxidation number because of having less number of electron to lose or contribute

The elements in the midst of the series, demostrate the best number of oxidation

For instance, Mn demostrate all the oxidation state from +2 to +7. The most elevated oxidation state appeared by any transition metal is 8, and this demastrated by Ruthenium and Osmium

4d series under Fe

5d series under Ru

Complex Formation Ability

~~Formation of~~ Formation of Complex Compounds

the cations of transition metals have great tendancy to form complexes with several molecules or ions called ligands

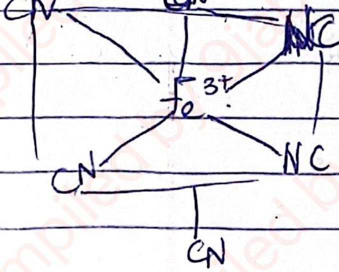
The bonds involved in the formation of complexes are coordinate/dative and therefore, the complexes are called coordinate complexes, sometimes coordination compounds

$[\cancel{Fe(H_2O)_6}]^{3-}$

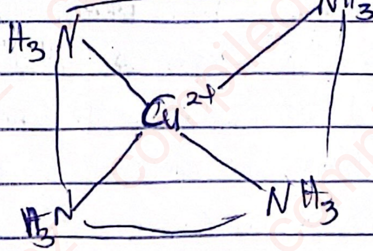
The structure of this complex ion may be linear, square planer, tetrahedral and octahedral depending upon the nature of hybridization of metal ions. The highly electronegative and basic ligand like fluoride ion, chloride ion can form complexes with transition metals even though there are in higher oxidation state due to the presence of small, highly charged or neutral ligands with lone pairs of electron that can form strong sigma bonds by donating a lone pair of electrons.

In a transition series, the stability of complexes increases with increase in atomic number, hence, the transition metal atom reveals multiple oxidation state. So, the higher valent ion, forms more stable complexes

$[Fe(CN)_6]^{3-}$



octahedral

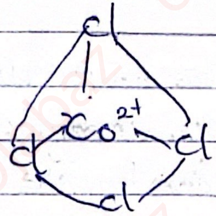


~~tetrahedral~~

d^5 and d^{10} are more willing

* discuss complex formation in transition metals

$[Ag(NH_3)_2]^+$
↓
linear



They are found to form complexes due to the following factors;

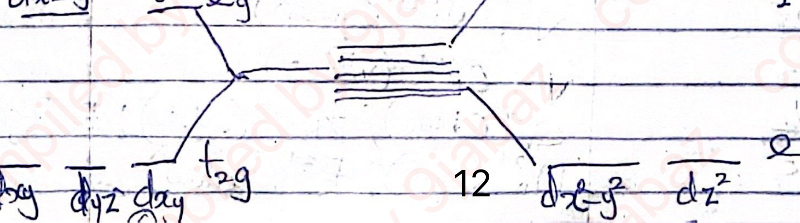
(i) Small size and high charge of metal ions

(ii) Availability of vacant low d-orbitals to accept lone pairs of electrons donated by other group of ligand

(iii) Availability of variable oxidation state and ability to form pi bonds, i.e multiple bond

Colour Formation

Most d-metal compounds are coloured in their solid or liquid states. In the case of transition metal ions under the influence of ligands, the degeneracy of the 5d orbital is lost and they seperate into two distinct energy levels



In the transition metal compounds, the electrons can be advanced from one energy level to another energy level in a similar d- subshe This is referred to as d-d transition. By this property, transition elements display colour

Now, when white light is incident on a transition metal ion the electron in the lower energy d-orbital set absorbs certain radiations and gets promoted to a d-orbital set of higher energy.

The transmitted radiations devoid of the absorbed radiation is the complementary colour of the absorbed light. This complementa colour is the colour of the substance

The Oxidation States of Metals and Their Colour

Number of unpaired electron	Oxidation states/ colour of the compound
0	Sc^{3+}, ~~Cu~~ Ti^{4+}, V^{5+} Cu^{+}, Zn^{2+} (Colourless)
1	Ti^{3+}, Purple; V^{4+}, Cu^{2+} (blue)
2	V^{3+}, Ni^{2+} (green)
3	V^{2+}, Cr^{3+} (violet)
4	Cr^{2+} (blue); Mn^{3+} (violet); Fe^{2+} (green)
5	Mn^{2+} (pink); Fe^{3+} (yellow)

Magnetic Properties

The magnetic properties of transition elements; or d-block elements are dictated by the number of unpaired electrons.

There are however some compounds that are diamagnetic, in that they are repelled by the magnetic line of force; when there are no unpaired electron.

When we have unpaired eletrons, it is paramagnetic.

There are two fundamental sources of substances

① Paramagnetic substances: The paramagnetic character imagines in view of the nearness of unpaired electrons. Substances that are paramagnetic are pulled in by the magnetic field

② Diamagnetic substances: Emerges as a result of the non-appearance of unpaired electron. In other words, electrons are paired. These substance are repelled by the magnetic field either completely filled d-orbitals or d^0 are all diamagnetic

A large portions of the transition elements and their compounds are paramagnetic and are pulled in by the magnetic field. The More prominent, the number of electron in the substances, the more noteworthy is the paramagnetic character and the magnetic character of the substance is expressed as magnetic moment

Notwithstanding paramagnetic and diamagnetic substances, there are a couple of substance. For example, fe, Co and Ni is exceedingly magnetic in contrast with other metals. These substances are known as ferro magnetic substances

~~Dens~~ Density

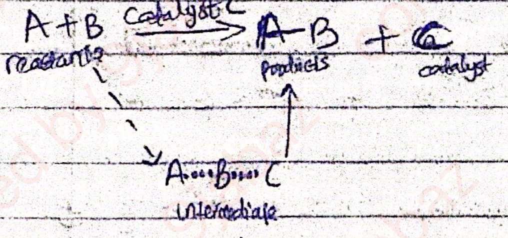
The nuclear volume of transition element is much lower than those of s and p block element. This is a result of the filling of the (n-1)d orbitals that cause an expansion in the atomic charge and pulls the electron internally. This clearly leads to decrease in nuclear volume with the decline in nuclear volume, the nuclear thickness of these elements increases.

Osmium consist of the highest density. In a given transition series, the thickness increment in moving over the period achieve the greatest value at group 18. The thickness increases as we move down the group. The nuclear size of elements of the second and third transition series are approximately the same. Yet, their nuclear weights increment to almost double and the density of elements of third transition series are by and large twice corresponding second transition series.

Other factors that affect variable colour
(1) Intraligand charge transfer e.g $n - \pi^*$, $\pi - \pi^*$
(2) Ligand to metal charge transfer (LMCT)
(3) Metal to ligand charge transfer (MLCT).

Catalytic Analysis

The rate of the chemical reaction increases by decrease in energy of activation of the reactant. This decrease is caused by the catalyst by altering the pathway of reaction. For instance;



Intermediate is of lower energy transition state

Bonds are formed between reactant molecules and atoms on the surface of the catalyst (The first row transition metals uses 3d and 4s electron for bonding), 4d and 5s (second row), 5d and 6s (3d row)

The results in the formation of reaction intermediate which provides the activation energy and therefore, increases the rate of the reaction.
The reaction intermediate decompose to form the product and regenerate catalyst. Many transition metals are used as catalyst for a number of reaction. For example, Iron in Haber process, Vanadium in contact process of sulphuric acid and Nickel in hydrogen atom.
The catalytic activity of these transition elements are due to their variable oxidation states. The transition metals can absorb and re-emit quite range of energies. Thus, providing necessary energy of activation

Consider a reaction between Iodide and Thiosulphate

$$I^- + S_2O_8^{2-} \xrightarrow{Fe^{3+}} I_2 + SO_4^{2-}$$

The above reaction occurs in two stages;

$2I^- + Fe^{3+} \longrightarrow Fe^{2+} + I_2$ .... (i)

$2Fe^{2+} + S_2O_8^{2-} \longrightarrow 2Fe^{3+} + 2SO_4^{2-}$ ..... (ii)

Many transition elements display catalytic activity eg metalloenzymes are biological catalysts that require metal ions of their activity
Nitrogenase enzyme contains Iron and Molybdenum (Mo)
Haemoglobin contains Fe^{2+}

Ribo nucleotide reductase consits of cobalt

Stabilization of Oxidation State

Stability is relative term The Stability of an individual oxidation state for d-block metals depends on the following factors;

① Enthalpy of hydration or solvation: The higher the hydration energy/enthalpy, the higher the Stability

② Electronic Configuration; Half/fully filled electronic configurations leads to higher stability

③ Ligand filled environment and crystal filled splitting energy: The higher the crystal field spliting energy, the higher the stability

④ Size of d-orbitals; Larger size d-orbitals leads to higher metal ligand interaction, thereby leading to higher crystal field spliting energy and consequently higher stability

⑤ Metal ligand bond energy and effect of π-back bonding; The higher the bond energy, the higher the stability-

⑥ π-Acid Ligands e.g CO, bipyridine, nitrogen monoxide and Cyanide stabilize lower oxidation states by withdrawing electron density from the metal.

⑦ Highly electromagnetic element (oxygen and fluorine) can stabilize the higher oxidation states between oxygen and fluorine, oxygen can form multiple bonds with metal cations and stabilize the higher oxidation state better than fluorine

Generally, the d-block elements have greater tendency to form coloured complexes. The colour of these complexes may arise due to two reasons;

(i) The d-d transition

(ii) The Charge transfer transition

In the presence of ligand field. The d- orbitals of the metals get splitted according to crystal field theory. The extent of the splitting Δ or 10dq depends upon the nature of ligand and the metals, and as well as the coordination number of the metals

Transition between these two orbitals is called "d-d transit

The following are the transition ....

Coordination number 6 : $t_{2g} \longrightarrow e_g$ Octahedral

" " 4 : $e \longrightarrow t_2$ tetrahedral

" " 4 Square planar : $d_{xz} = d_{yz} \longrightarrow d_{z^2}$

$d_{xz} = d_{yz} \rightarrow d_{xy}$

$d_{xz} = d_{yz} \rightarrow d_{x^2-y^2}$

d-d transition

Charge Transfer Transition

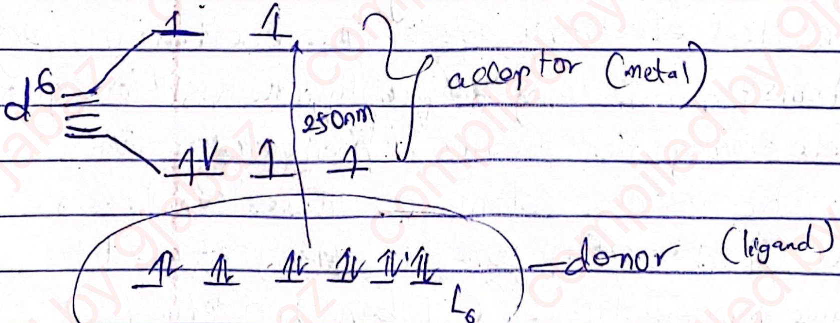
A charge transfer complex (CT complex) or electron donor acceptor complex is an association of two or more molecules, or of different parts of one large molecule in which a fraction of electronic charge is transferred between the molecular entities. The resulting electrostatic attraction provides a stabilizing force for the molecular complex. the source from which the charge is transferred is called the electron donor and the recieving specie is called the electron acceptor.

Many such complexes can undergo an electronic transition into an excited electronic state. The excitation energy of this transition occurs very frequently in the visible region of the electromagnetic spectrum which produces the characteristic intense colour for these complexes. This optical absorption band are often reffered to as charge transfer band (CT band). Optical spectroscopy is a powerful tool for characterising charge transfer band.

Charge transfer occurs often in inorganic ligand Chemistry involving metals. Depending on the direction of charge transfer, they are classified as either ligand-metal (LMCT) or metal-ligand (MLCT) Charge transfer.

Ligand-Metal Charge Transfer (LMCT)

Ligand-Metal charge complexes (LMCT) arise from transfer of electrons from molecular orbitals with ligand like character to those with metal-like character. This type of transfer is predominant if complexes have ligands with relatively high energy lone pairs (example, sulphur or selenium) or if the metal has low-lying empty orbital, many such complexes have metals in high oxidation state, even D_0. These conditions implies that the acceptor level is available and low in energy



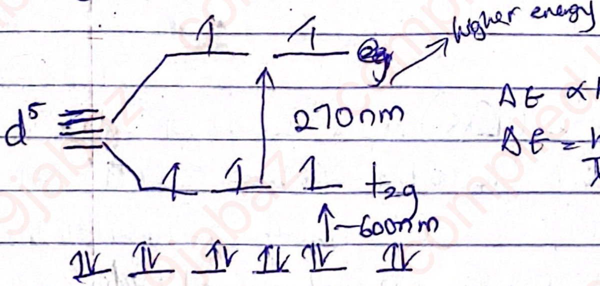
Consider a d-series octahedral complex such as $[CoBr_6]^{3-}$ (hexabromocobaltate(III) ion) whose t_{2g} orbital as fixed.

$_{27}Co = [Ar]\,3d^7\,4s^2$

$Co^{3+} = [Ar]\,3d^6 \rightarrow d^6$

As a consequence, and intense absorption is observed around 250nm corresponding to a transition from ligand sigma molecular orbital to the empty e_g molecular orbital

However, in hexabromocobaltate(III) ion $[CoBr_6]^{2-}$ that is a d^5 complex, two absorption, one near 600nm and another near 270nm are observed. ~~and another near 27~~ This is because two transitions are possible, one to t_{2g} that can now accomodate 1, 1 electron, and another to e_g. The 600nm band corresponds to transition to the t_{2g} transition band and the 270nm to the e_g molecular orbital of the cobalt.



$\Delta E \propto h\nu$

$\Delta E = \frac{hc}{\lambda}$

Charge transfer band may also arrive from transfer of electrons from non bonding orbital from the ligand to the e_g molecular orbitals. The energy of transitions correlates with the order of the electrochemical series. The metal ions that are most easily reduced corresponds to the lowest energy transition. For instance,

+7 $MnO_4^- < TcO_4^- < ReO_4^-$

+6 $CrO_4^{2-} < MoO_4^{2-} < WO_4^{2-}$

+5 $VO_4^{3-} < NbO_4^{3-} < TaO_4^{3-}$

The energy

Example includes ① permanganate ion having tetrahadral geomotry is intensely purple due to strong absorption involving charge transfer from molecular orbital derived primarily from fill oxyge p orbital to empty molecular orbital derived from Mn (VII)

(ii) Cadium Sulphide (CdS): The colour of active pigment, cadium yellow is due to transition of Cd (II) ion 5s orbital to sulphide ion, π - orbital (p - orbital)

(iii) Mecury Sulphide is red 6s orbital to sulphide ion π-transition.

(iv) Iron (III) oxide red or yellow, due to transition from 3d to oxide π-orbital

Metal-Ligand Charge Transfer Complexes

This arise from transfer of electrons from molecular orbitals with metal-like character with those with ligand like character.

This is most commonly observed in complexes with Ligands having low line π^* orbital especially aromatic ligands. The transitions occur at Low energy if the metal ion has a low oxidation number. For its d-orbitals will be relatively high in energy. Examples of such ligands taking part in metal-ligand charge transfer include; CO, CN^-, bipyridines, phenanthroline.

Question

Comment on the Magnetic Property & Colour

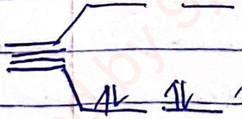
$[Co(CN)_6]^{3-}$ hexa cyanate cobalt (III)

$[Co(Cl)_6]^{3-}$

(find the oxidation number of the metal

$Co = [Ar]\,3d^7 4s^2$

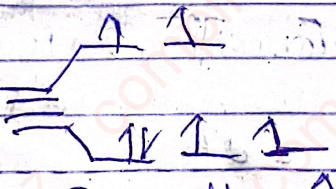
$Co^{3+} = d^6$



$[Co(CN)_6]^{3-}$

Diamagnetic

no magnetic moment



Paramagnetic

$[Co(Cl)_6]^{3-}$

⇅ ⇅ ⇅ ⇅ ⇅ ⇅

For $[Co(Cl)_6]^{3-}$, magnetic moment is

$\mu = \sqrt{n(n+2)}$ n = number of unpaired electrons

$\mu = \sqrt{4(4+2)}$

$\mu = \sqrt{24} = 4.96BM$

Steps:

① Work out the oxidation number of the metal

② Deduce the number of electron in the d orbital

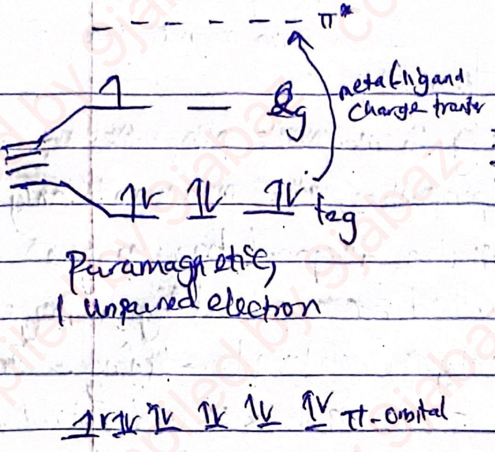
③ Determine whether the ligand is strong or weak. If it is a strong ligand, it forces the the electron to pair, if it is a weak ligand, it simply obey Hund's rule, by singly filling before pairing.

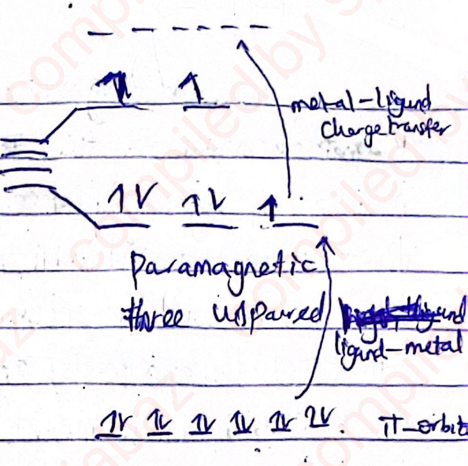
④ Draw the Crystal field splitting diagram, thereafter fill the diagram with electrons according to the strength

$[Co(CN)_6]^{4-}$ — $[Co(Cl)_6]^{4-}$

oxidation number is +7

$Co^{2+} = d7$





Assignment

$[Fe(CN)_6]^{3-}$ and $[Fe(H_2O)_6]^{3+}$

comment on the magnetic property colour.

State the similarities and differences of 3d and higher d-block elements

13/11/25

* If it attracted, para
* if it repels, di
* can form magnetic bar, ferro

Magnetochemistry

Magnetochemistry is the study of magnetic properties of materials, by magnetic properties, we mean not only that a material will make a good bar magnet but whether it will be attracted or repelled by a magnet. This includes synthesis, analysis, and understading. This short description is meant to give a basic understanding before going into more complex treatment.

Magnetism arises from moving charges such as an electric current in a coil of wire. In a material which does not have any current present, there are still magnetic intera
Atoms are made of charged particles (proton and electro which are moving constantly. The processes which creates magnetic ~~properties are~~ fields in an atom are;

① Nuclear spin: Some nuclear such as a hydrogen atom have a net spin which creates a magnetic field

② Electron spin: An electron has two intrinsic spin states (similar to a top spining) which we call up and down

③ Electron orbital motion: This is a magnetic field due to the electron moving around the nucleus. Each of this magnetic fields interacts with one another and with external magnetic fields. However, some of these interactions are strong and others are negligible

Measurement of interactions with nuclear spin are used to analyze compounds in nuclear magnetic resonance (NMR) and ~~e~~electron spin resonance (ESR) spectrosc

In most other situations, interactions with nuclear spin is a very minor effect. Interactions between the intrinsic spin of one electron and the intrinsic spin of another ~~spin~~ electron are strongest for very heavy elements such as the Arctinite this is called spin-spin coupling

For these elements, the coupling can shift the electron orbital energy level.

The interaction between an electron intrinsic spin and its orbital motion is called spin orbit coupling

Spin orbit coupling has a significant effect on the energy levels of the orbital in many inorganic compounds.

Macroscopic effects such as the attraction of a piece of iron to a bar magnet are primarily due to the numbe of unpaired electron in the compounds and their arrangemen The various possible cases are called magnetic states of matter

~~Magnetic Sta~~

Magnetic States of Matter

① Diamagnetic: A diamagnetic compound has all of electron spin paired, given a net spin of zero

$\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}$

| ↑ | ↑ | ↑ | ↑ | ↑ | = net = $5/2$

$+\frac{1}{2}\ -\frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}\ \frac{1}{2}$

| ⇅ | ↑ | ↑ | ↑ | ↑ | = net = $4/2 = 2$

Diamagnetic compounds are weakly repelled by a magnet

② Paramagnetic: A paramagnetic compound will have some electrons with unpaired spins. Paramagnetic compound a attracted by a magnet

③ Ferromagnetic: There are unpaired electron spin whi are held in alignment by a process known as ferromagn coupling. Ferromagnetic compounds such as Fe, Co, Ni are strongly attracted to magnets.

④ Ferrimagnet: Have unpaired electron spins which are held in a pattern with some up and some down, this is known as ferrimagnetic coupling

In a ferrimagnetic compounds, there are more spins held in one direction, and so the compound is attracted to a magnet.

⑤ Antiferromagnetic: The unpaired electrons are held in an alignment with an equal number of spins in each direction, the substance in strongly repelled by a magnet. This is referred to as antiferromagnet.

⑥ Superconductor: Superconductors are repelled by a magnetic field because the magnetic field is excluded from passing through them. This property of superconducto Called the meissner effect is used to test the presence of a super conducting state.

The underlying theory of how superconductivity arising is still a matter of serious research.

Interaction With External Magnetic Field

A magnetic field H ~~Which~~ is a vector quantity, Since it has both direction and magnitude, it means it is in one direction, that make H and many other quantities will be defined Scalars. This gives ~~a[illegible] of a~~ us result for a homogenous magnetic field and is a very good approximation for the way that most magnetic measurement are performed. The magnitude of the magnetic field is usually given in unit of Gauss (G) or Tesla (T) where 1T = 10,000G.

When a material is placed in a magnetic field, the magnetic field inside the material will be the sum of the external magnetic field and the magnetic field generated by the material itself. The magnitude of the magnetic field in a material is called Magnetic induction and is given the symbol B

$$B = H + 4\pi M \quad — ①$$

where B = magnetic induction

H = external magnetic field

$\pi = \frac{22}{7}$ or 3.142

M = magnetization

For mathematical and experimental convenience, this equation is often written as;

$$\frac{B}{H} = 1 + \frac{4\pi M}{H} \text{ ———— } ⑤$$

$\frac{M}{H} = \chi_v$ χ_v = volume magnetic susceptibility

$$\therefore \frac{B}{H} = 1 + 4\pi\chi_v$$

χ_v is so named because B, H, and M are defined by unit volume. This result in χ_v being unitless
It is covenient to use volume magnetic susceptibility instead of magnetization because the magnetic susceptibility is independent on the magnitude of the external magnetic field H for diamagnetic and paramagnetic materials
Many studies are done using χ_g (magnetic susceptibility per gram), which is $\frac{\chi_v}{\rho}$ (ρ = density)

$$\rho = \frac{m}{v} \Rightarrow \frac{\chi_v \times g}{\cancel{v}} = \chi_{(g)}$$

This gives unit $cm^3 g^{-1}$
Another useful for is χ_m (molar magnetic susceptibility) whi
is χ_g ~~× M~~ multiplied by molecular mass. this gives unit of $cm^3 mol^{-1}$

Another measure of magnetic interaction that is often used is an effective magnetic moment M.

Where $M = 2.828 (X_m T)^{1/2}$

M = effective magnetic moment

X_m = molar magnetic susceptibility

T = temperature (usually in absolute value).

The numeric factor puts M in unit of Bohr magnetons (BM) Where $1 BM = 9.274 \times 10^{-24} J T^{-1}$.

The effective magnetic moment is a convenient measure of the materials magnetic property because it is independent of temperature as well as external field strength for diamagnetic and paramagnetic material.