**TRANSITION ELEMENTS**

These are elements with partially filled d subshell containing between one to nine d electrons of normal and oxidized state. Their outer electrons are added to three (3) inner d subshell

BLOCK D ELEMENTS:

These are elements in which outer mod election is added to inner 3d subshell.

Not all block d elements are transition elements .E.g.

1. Scandium. Is 22s2 2p63s23p64s23d1 or 1s22s22pb3s23s23p63d14s2

The stable oxidation state of scandium is +3 and lacks electrons in 3d subshell in oxidized state and therefore it is not a member of transition elements:

 Sc3+ - 1s22s22p63s23p63s23p6

2. Zinc.

 Is22s22p63s23p63d104s2

Zn2+ - Is2ds22p63s23p63d10

The stable oxidation state of Zinc is +2 and its 3d subshell is fully filled with electrons therefore it is not a member of transition metal.

|  |  |  |  |
| --- | --- | --- | --- |
| **Elements**  | **Simble**  | **Atomic No** | **Electronic configuration** |
| Scandium  | Sc | 21 | Is2 2s2 2p6 3s2 3p6 3d1 4s2 |
| Titanium  | Ti | 22 | Is2 2s2 2p6 3s2 3p6 3d2 4s2 |
| Vanadium  | V | 23 | Is2 2s2 2p6 3s2 3p6 3d3 4s2 |
| Chromium  | Cr | 24 | Is2 2s2 2p6 3s2 3p6 3d5 4s1 |
| Manganese | Mn | 25 | Is2 2s2 2p6 3s2 3p6 3d5 4s2 |
| Iron  | Fe | 26 | Is2 2s2 2p6 3s2 3p6 3d6 4s2 |
| Cabalt  | Co | 27 | Is2 2s2 2p6 3s2 3p6 3d7 4s2 |
| Nickel  | Ni | 28 | Is2 2s2 2p6 3s2 3p6 3d8 4s2 |
| Copper  | Cu | 29 | Is2 2s2 2p6 3s2 3p6 3d10 4s1 |
| Zinc  | Zn | 30 | Is2 2s2 2p6 3s2 3p6 3d10 4s2 |

**Physical properties**

TRANSITION ELEMENTS

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Element  | K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn |
| Atomic No | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| Melting point  | 640 | 850 | 1540 | 1680 | 1900 | 1890 | 1340 | 1500 | 1540 | 1450 | 1080 | 1020 |

**Sketch – graph showing melting points of transition elements**



Generally transition elements have higher melting points due to inter atomic bonding – the bond formed between same atoms of transition metals.

The strength of inter atomic bonding depends on the number of unpaired d-subshell electrons. From scandium to chromium, the number of unpaired d-subshell electrons increases thus the strength of inter atomic bond increase from Sc to Cr and their m.pt also increases from Sc to Cr.

The number of unpaired electrons decreases from Mn to Zn. The strength of inter atomic bond generally decreases from Mn to Zn and hence the m.pt generally decreases from Mn to Zn.

**Qn.**

*1. Briefly explain why m.pt of Ca is abnormally low compared to that of scandium.*

*2. Explain why the m.pt of Zn is abnormally low compared to other transition metals.*

**Solution**

1. Ca atom has vacant d-subshell hence it cannot undergo inter atomic bond hence its m.pt only depends on the strength of its metallic bond. Sc however has a single unpaired electron in d-subshell hence can undergo inter atomic bonding in addition to metallic bonding.

2. Zn has low m.pt, it has full d-subshell and no un-paired electrons hence no inter atomic bonding and low melting point than all the other transition metals which have unpaired electrons. Other transition metals can undergo interatomic bonding in addition to metallic bonding hence high m.pts.

 **CHARACTERISTICS OF TRANSITION METALS**

1. They have variable oxidation state.

2. They form coloured compounds.

3. They form complex ions

4. They have magnetic properties

5. They have catalytic activities

1. **VARIABLE OXIDATION STATES**

*Oxidation state*,

This refers to a net charge left on the central atom when all other surrounding legands (gp of atom changes) are removed.

MnO2 x+(-2\*2) = 0; x = +4

MnO4- x + (-2 x 4) = -1

 x - +7

MnO42- x – 2 x 4 = -2

Mn(OH)2 x = +2

The possible oxidation states are +2, +4, +6 and +7

**COMMON OXIDATION STATES**

Sc Ti V Cr Mn Fe Co Ni Cu Zn

+3 +4 +5 +5 +7 +6 +4 +4 +2 +2

 +3 +4 +3 +6 +3 +3 +2 +1

 +2 +3 +2 +4 +2 +2

 +2 +3

 +2

NB: where there is circle representing stable oxidation states.

Reasons why transition elements have variable oxidation state

Transition elements are capable of using electrons in 3d subshell and 4s subshell for chemical reaction.

*Qn*.

Calculate the oxidation states of the following central ions

i) Cr in Cr2O72-  (iv) Fe in Fe (CN)6 4-

 2x + (-2x7) = -2 x + (-1 x 6) = -4

 2x = 12 x = +2

 X = 12

 X = +6

ii) Cr in CrO42- (v) Cr in Cr (CN)6 3-

 x + (-2x4) = -2 y + (-1 x 6) = -3

 x = +6 y = +3

iii) Mn in KMnO4

 x + 1 + (-2x4) = 0

 x = +7

1. **MAGNETIC PROPERTIES**

Transition metals ions show Para magnetism because of the presence of unpaired d- subshell electrons. Para magnetism arises due to spring of unpaired number of electrons. The magnitude of Para magnetism effect depends on a number of unpaired d-subshell electrons.

Para magnetism

moment

 0 Sc3+ 1Ti3+ 2 Cr2+3Mn4+ 4fe 5mn2+ 3co2+ 1Nit  0zn

 Diamagnetic

Paragnentic Ferromagnetic

Diamagnetic ion substance – Not attracted by magnets. (Zn2+1sc3+)

Paramagnetic ion substances – weakly attracted by magnets (Ti3+ cr3t Mn2+, Co2+,Ni+mn4+

Diamagnetic substance are weakly expelled by magnetic fields because they don’t have unpaired electrons hence their magnetic moment is zero they include Sc3+ and Zn2+

Ferromagnetic substance are strongly and permanently attracted to a magnet because they have highest number of unpaired 3d – orbital electrons which generate the highest magnetic moment. They include Fe3+, Fe2+, Co2+ .

Para magnetism substances are weakly attracted to the magnetic field because they have low number of unpaired 3d – orbital electoral electrons hence generate relatively low magnetic moments.

**3. FORMATION OF COLOURED COMPOUNDS IONS**

This is associated with presence of partially filled 3d – subshell. When visible light falls on a metal ion, the 3d – subshell is filled with two energy levels i.e the paired electrons in high energy level absorb visible light energy and are promoted to high energy level, in this process the remaining part of the visible light is released in term of electromagnetic radiations whose wave length corresponds to the color of the compound.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Ion | Sc3+ | Ti3+ | V3+ | Cr3+ | Mn2+ | Fe2+ | Fe3+ | Ni2+ | Cu2+ | Co2+ | Zn2+  |
| Colour | Colourless | Purple | Green | Green | pink | Green | Brown | Green | Blue | Pink | colourless |

***Question***

*Briefly explain why scandium and Zinc form colourless ions*

Zn2+ 1S2 2P6310 have fully filled 3d- subshell. After absorbing visible light, the 3d- subshell electrons. There is no emission of electromagnetic waves corresponding of color hence the ions are colorless

For Sc3+ Is 2s2 2p6 3s23p6, it lacks electrons in 3d subshell thus on absorption of visible light, no splitting of 3d subshell occurs.

**4. FORMATION OF COMPLEX COMPOUNDS**

A complex ion is a chemical species with the central atom or metal ion bonded to other atom, ions are molecules called ligands through dative bond and they can exist on their, own.

A ligand is aspecies which is capable of donating at least one pair of electrons to a central metal ion through dative bonding.

Examples to common ligands include.CL-, H2O, NH3, CN-,F-

Transition metal ions form many complexes because of the following factors

 ***1. The ions have higher charge destiny / polarizing power***.

 Due to their high charge density, they are capable of attracting ion pair of electrons on a ligand through dative bonding to from a complex.

***2. Availability of vacant 3d subshell.***

The vacant 3d- subshell accommodates ion pair of electrons on a ligand through dative bonding to form a complex.

**COORDINATING NUMBER**

Refers to the number of ligands datively bonded to the central metal ion. OR.

Is the number of dative bonds formed by the central metal ion?

Examples

 **Complex coordinating number**

 CU (H2O)4 2+ 4

 CU CL4 2- 4

Fe (CN) 6 3-  6

 Fe (CN)6 4- 6Zn(NH3)4CL2  4

 K3Fe (CN)6 6

 CU(NH3)4 (0H)2 4

**STEPS OF NAMING COMPLEXES**

1. State the number of ligands around the central metal ion atom in Greek process e.g 1-mono-2-Di, 3-tri, 4 – tetra, 5 – penta, 6- hexa etc.
2. Identifying the ligands ground the central metal ion / atom.eg

 Cl- - chloro H2O – aquo CN- -cyano

 Br- - Bromo OH – hydroxo NO2 – nitro

 NH3 –amino/amine F- -flouro NO2 – nitro

1. For positively charged complexes name the central ion using their English names e.g Cu – copper, Cr- cronium, Zn – zinc ,Fe- iron, P6- lead , Al- aluminium, Be –Berillium,
2. For a negatively charged complex, name the central metal ion, the name ending with the suffic – (ate) eg Cu – cupprate, Zn – zincate, Fe – ferrate, Pb – plumbate, Al – aluminate, be – berylate, Pt – platinate.
3. State the oxidation state of the central metal iron/ atom.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Complex ion | 1 | 2 | 3/4 | 5 |
| CuCNH3 2+ | Tera  | Amino  | Copper  |  II ion |
| Al(OH)6 3- | hexa | hydroxo | aluminate | III ion |
|  CuCl4 2- | tetra | chloro | cuprate | II ion |
|  Fe(CN)6 4- | hexa | cyano | ferrate | II ion |
|  Cr(H2O)6 3+ | Hexa  | aguo | chromium | III ion |
|  Fe(CN)6 3- | hexa | cyano | ferrate | III ion |

***Qn****: Name the following complexes.*

 K3Fe(CN)6 potassium hexacyanoferrate (III)

 Zn(NH3)4  2+ tetra amino zinc (II) ion

 Zn(NH3)4Cl2 tetra amino zinc (II) chloride

 Cr(H2O)4Cl2 Cl tetra aquo di chloro chromium (III) chloride

 Cu(H2O)3OH + Tri aquo monohydroxo copper (II) ion.

 CrCl2(H2O)4 + Tetra aquo di chloro chromium (III) ion.

***Qn:*** *State the co-ordination number, oxidation state of the central metal ion of the following complexes.*

|  |  |  |  |
| --- | --- | --- | --- |
|  | Co-ordination number | Oxidation state | name |
| Cr(H2O)6Br3 | 6 | +3 | Hexa aquo chromium (II) bronid |
| CoCl4  2- | 4  | +2 | Tetra chloro cabaltate (II) ion |
| Ni(H2O)6 2+ | 6 | +2 | Hexa aquo nickel (II) ion |

*b) Briefly explain why transition elements form complexes.*

Due to the high polarising power of transition elements, they are capable of attracting/one pairs of electrons on a ligand to form a compound.

They also have vacant d-subshell electrons we can accommodate/one pair of electrons from a ligand to form a dative bond hence forming complexes.

*Qn.2 One of the properties of transition metals is complex ion formation.*

a) i) *Define the term complex ion.*

Complex ion refers to chemical species with central metal ion/atom bonded to all atoms, ions, or molecules called ligands thru’ dative bond and they exist on their own.

*ii) Explain why transition metals form complexes.*

Transition metals have high polarising power hence are capable of attracting/one pair of electrons on a ligand thru’ dative bonding to form complexes. They also have vacant 3d-subshell which accommodates /one pair of electrons on a ligand thru’ dative bonding hence form complexes.

b) *Fe(CN)6 3- and CuCl4 2- are complexes formed by iron and copper respectively. State oxidation state of*

 *(i) iron - +3*

 *(ii) copper --------- +2*

 The co-ordination number of

 Fe – 6

 Cu – 4

 *iii) Name of the complexes*

 Fe(CN)6  3-  ----------- hexa cyano ferrate (III) ion

 CuCl4 2- ------------- tetra chloro cuprate (II) ion

**AQUO COMPLEXES**

These are complexes where water molecules are datively bonded to the cental metal ion.Transition metal ions are heavily hydrated with water molecules due to their high charge density and polarising powers.

e.g Fe(H2O)6 3+ Cu(H2O)4 2+

 Cr(H2O)6 3+

 Ni(H2O)4 2+ Co(H2O)6 3+

*Qn. briefly explain why aqua complexes are acidic/have PH less than 7*.

Due to high polarising power/charge density of transition metal ions, they are heavily hydrated with water molecules and undergo cationic hydrolysis releasing hydrozonium ions which are responsible for the acidity of aquo complexes.

Fe(H2O)6 (aq)3+ + H2O(l) Fe(H2O)3OH aq2+ + H3O+(aq)

Qn.

*a) Explain why the aquo complex of Cr3+ is acidic*

*b) Explain the following observation*

 *i) Aqueous solution of Cr3+ turns blue litmus paper red.*

 *ii) When sodium carbonate is added to aqueous solution of iron (III) chloride, bubbles of a colourles gas and reddish brown ppt are observed.*

Solution

a) Due to high charge density of Cr3+ ion, it is heavily hydrated by water molecules and undergoes cationic hydrolysis to release hydrozonium ions which are responsible for the acidity of the aquo complex of Cr3+

b) i) Due to high polarising power of Cr3+ ion, it is heavily hydrated by water molecules and undergoes cationic hydrolysis to release hydrozonium ions which are responsible for changing blue litmus paper to red as in eqn.

 Cr(H2O)6 (aq)3+ + 3H2O(l) Cr(OH)3.3H2O(s) + 3H3O+(aq).

 ii) Due to high polarising power of Fe*3*+ ion, it is heavily hydrated by water molecules and undergoes cationic hydrolysis to release hydrazonium ions and forming.

 Hydroxide which is a reddish brown ppt. The hydrozonium ions then reacts with carbonate ion to release bubbles of a colourless gas called CO2.

**LIGAND EXCHANGE AND STABILITY CONSTANT**

LIGAND EXCHANGE:

Ligands which are datively bonded to the central metal ion/atom can be substituted with another ligand depending on the number of/one pair of electrons on a ligand and concentration of the ligand.

e.g [Cu (H20)4] aq +4NH3 [CU(NH3)4] aq +4H2O(i)

From the above equation ammonia is a stronger ligand than water and is capable of displacing water molecules which are datively bonded to the central metal ion.

**STABILITY CONSTANT (KST)**

It can also be called ligand exchange constant and is defined as the ratio of the product of concentration of products to the pit of concentration of reactants raised to appropriate powers in equation equation for above Equation

 KST = [CU(CNH3)4] [H2O(i)]4

 [(CUCH20)]aq [NH3(aq]4

The higher value of KST implies that the products are more stable than the reaction.

RELATIVE STRENGTH OF DIFFERENT LIGANDS

Edta2->S2- >S2O32->Br-> NH3 >Cl>OH>H2O

The colour of the transition metal ion/cpds depends on the *nature of ligands* datively to it.

A stronger ligands replaces the weaker ligand in a complex solution e.g ammonia displaces chloride ion in its complex.

[ CUCL4]2-ag + 4NH3(ag) [ CU(NH3)4]2+(aq) + 4Cl-(aq)

Yellow – green deep blue

**Equation:** Explain the following observations

1. When dilute ammonia solution is added to tetra chloride culprate (II) Ion solution a yellowish green solution turns deep blue.
2. When dilute ammonia solution is added to the green solution of nickle (ii) solution a blue solution is formed.
3. When conc HCL is added to the copper (ii) solun a yellowish green soln is observed

[CU(H2O)4]2+aq +4Cl-aq [ CUCl4]2-aq +H2O

**Solution**

i) Ammonia is as stronger ligand than chloride ion and therefore it displaces the chloride ions from their complex to form tetra amino copper (ii) ion solution which as a deep blue solution as in equation.

[ CUCl]2-(aq) +4NH3(aq) [CU(NH3)4]2+(aq) +4Cl- (aq)

ii) Ammonia being a stronger ligand than the water displace water molecules from their complex hence terms a complex solution whose colour is blue

 [Ni(H2O)6 ]2+ (aq) + 6NH3(aq) [Ni(NH3)6]2+(aq) 6H2O(aq)

iii) The chloride ions in HCI are strong ligands than water molecules hence are able to displace the water molecules from their complex to form tetra chloro cupprate (ii) ion solution which is green is green in colour.

 [CU(H2O)4] 2+(aq) +4CI (aq) [CUCI4]2- (aq) + 4H2O(i)

**CHROMIUM**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| IonOxidation stateColour | CrO42-+6Yellow  | Cr2O72-+6-orange  | Cr3++3Green  | Cr2++2Blue  |

 **Manganese**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| IonOxidation statecolour | MnO4-+7Dark purple  | MnO2+4Black  | Mn2O+2Brown  | MnO42-+6Green  |

**Iron**

|  |  |  |  |
| --- | --- | --- | --- |
| IonOxidation statecolour | FeO42-+6Real  | Fe3++3Yellowish Brown  | Fe2++2Green  |

* The colour of the complex depends on the oxidation state of the central metal ion or atom.
* The stability of the complex depends on the oxidation state of the central metal ion.

**Qtn** *Briefly explain why complex of Cr+6 are more stable than complex 2 Cr+3*

Cr+6 has a high polarising power due to the high oxidation state and can therefore strongly strongly attract ion. Pair of electrons on a ligand to form a stable complex however, due to the law polarising power of Cr3+ , it cannot strongly attract ion pairs of electrons on a ligand to form a complex.

**STRUCTURE OF COMPLEXES**

A complex with co- ordation number 4 has a tetra hedral structure a

 [ Zn (NH3)4]2+

 NH3

 $Z\_{n}^{2+}$ Tetrahedral structure

 H3N NH3

 HN3

 [NiCl4]2-

 Cl

 $Ni^{2+}$

Cl Cl

 Cl

 [CoCl4]2- Cl

 $Co^{2+}$

 Cl Cl

 Cl

Some few complexes with co-ordination number of 4 adapt square planar structure.

Examples include.

[CuCl4]2- Cu(NH3)4]2+ [Ni(CN)4]2-

Cl Cl NH3 NH3 CN NC

 $Cu\_{2}^{2+}$ $Cu^{2+}$ $Ni^{2+}$

Cl Cl H3N NH3 CN NC

Complexes with oxidation number 6 have octahedral structure e.g

[Cr(NH3)6]3+  [Co(NH3)6]3+

 NH3 NH3

NH3 NH3 NH3 NH3

 $Cr^{3+}$ Co

H3N NH3 H3N NH3

 NH3 NH3

5. **CATALYTIC PROPERTIES**

A catalyst is a substance that alter rates of chemical reaction and remains unchanged after the reaction. Transition irons/ meals are good heterogeneous catalyst e.g in manufacture of ammonia harbor process, finely divided iron is used.

In manufacture of sulphuric acid by contact process, vanadium v oxide is use.

For decomposition of hydrogen peroxide manganese IV oxide is used

**Explanation**

The presence of unpaired 3d- subshell electrons enable transition metal ions to form stable bonds with reactants. This increases the concentration of the reactant molecules on the surface of metal ions and weakens the bonds in the reactants. This increases the rate at which new parts are formed.

Due to their variable oxidation states; they can speed rate of chemical reactions either by donating electrons to the reacting molecules or by accepting electrons from the reacting molecules.