

# Metallurgy

## 1. METALLURGY

The chemistry of extracting metals from their ores is called metallurgy. The following steps are involved in the extraction of metals

- (i) Concentration of ore
- (ii) Conversion of concentrated ore into metal oxide
- (iii) Conversion of metal oxide into metals
- (iv) Purification of metal.

### 1.1 Concentration of ore

The metal ores obtained from mines are generally mixed with non metals, sand, lime, clay and rock materials. These impurities are known as gangue or matrix. The removal of impurities from the ore is called concentration of the ore. The common methods of concentration are as follows

#### [1] Gravity separation-

This separation is based on the fact that specific gravities of metallic ore and the earthy impurities are different. The finely powdered ore is agitated with water or washed with a running stream of water on a willey table. The lighter impurities are washed away leaving behind ore particles on the table.

#### [2] Froth flotation process -

This method is generally applied to sulphide ores because sulphide ores are preferentially wetted by oils. The finely powdered ore is introduced into water to which small quantity of a suitable oil is added. Water is then agitated with a stream of air. The ore which is preferentially wetted by oil rises to the surface along with the foams while the gangue which is preferentially wetted by water remains in the water in the bottom. The foam along with ore is separated. This process is called froth flotation process.

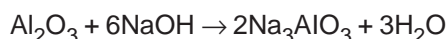
In froth flotation two types of substances are used - Frothing agent and flotation agent. Pine oil and eucalyptus oil are generally used as frothing agents and sodium ethyl xanthate or sodium amyl xanthate as flotation agents.

#### [3] Electromagnetic separation -

This method is used only when impurities present or the metallic ore are magnetic in nature. The finely powdered ore is dropped over electromagnetic rollers. At the other end, the magnetic portion of the ore is attracted by the magnetic roller and falls nearer to the roller while non magnetic impurities fall away from the roller.

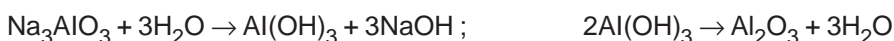
#### [4] Chemical method or leaching -

This method depends upon the chemical nature of the ore. For example bauxite ore of aluminium contains the impurities of iron oxide, titanium oxide and silica etc. Bauxite is heated in a solution of NaOH at 150-200°C. It dissolves in the solution forming a soluble complex while the impurities remain insoluble which are removed by filtration.



Sodium aluminate

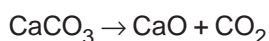
The filtrate is boiled with water, aluminium hydroxide gets precipitated which on heating at high temperature changes to alumina.

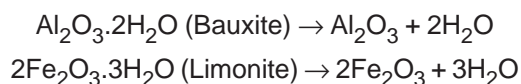


### 1.2 Conversion of concentrated ore into metal oxide

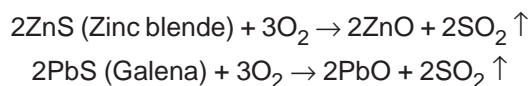
#### [1] Calcination-

It is a process in which the concentrated ore is heated to expel the organic matter and moisture present in the ore. The ores are heated in the absence of air below their melting point. Ores are converted to metal oxide. This process is also used to remove water from hydrated hydroxide ores and carbon dioxide from carbonate ores. The process is generally carried out in reverberatory furnace. It renders the ore porous.

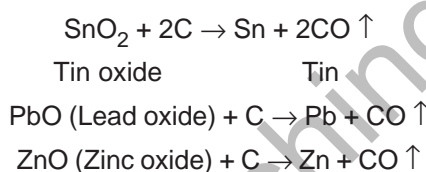


**Lime stone****[2] Roasting -**

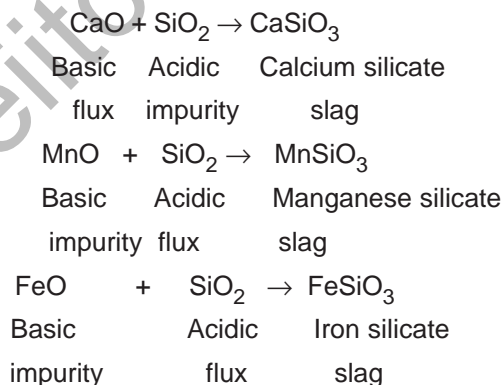
This process is generally done with sulphide ores. Sulphide ores alone or in the presence of other substance are heated in the presence of air below their melting points. The impurities like sulphur, arsenic, phosphorus etc. are removed in the form of their volatile oxides. This process is generally carried out in reverberatory furnace or blast furnace.

**1.3 Conversion of metal oxide into metal****[1] Carbon reduction method**

Smelting - The roasted or calcinated ore is mixed with suitable quantity of coke, the reducing substance and the flux and heated to a high temperature above the melting point of the metal. The metal oxide reduces to metal and the flux combines with impurities (gangue) to form easily fusible product known as slag. Slag is not soluble in molten metal. It is lighter and can be easily skimmed off from the surface of the molten metal. This process is done in reverberatory furnace or blast furnace.

**Flux -**

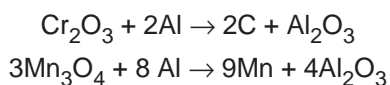
Metal ore contains some acidic or alkaline impurities which can form fusible products by combining with some substances. These substances are added during smelting and are called flux. The fusible product is called slag. For acidic impurity basic flux is used and for basic impurity acidic flux is used.



Slag is generally a silicate or phosphate and melt before the melting point of the metal.

**[2] Aluminio thermic process - (Goldschmidt thermite process) -**

A mixture of metal oxide and aluminium powder (thermite) is ignited in a closed crucible by means of a lighted magnesium ribbon having ignition mixtures ( $\text{Mg} + \text{BaO}_2$ ) at one end. This is an exothermic reaction. The temperature of the crucible reaches to  $3000^\circ\text{C}$ . At this temperature metal oxide is reduced to metal by aluminium.

**[3] Precipitation method-**

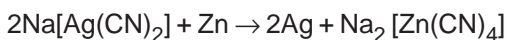
More reactive element (more electropositive) replaces the less reactive (less electropositive) element from its salt solution. For e.g. iron can precipitate Cu from copper sulphate solution while copper can not precipitate iron from iron sulphate solution. This principle is used in the precipitation method. Silver can be extracted from its

ores by using this theory.

If zinc is added to a solution of silver, silver precipitates out.



Silver glance      Sodium argentocyanide



#### [4] Electrolytic method -

If metal oxides, chlorides or hydroxides in fused state are electrolyzed the metals deposit at cathode. The reduction of active elements such as alkali metals, alkaline earth metals and the oxides of Al with carbon is difficult because these form carbides with carbon at high temperature.

#### 1.4 Purification

Metals can be purified by following methods

**[1] Distillation** - The metals with low boiling points can be purified by distillation.

**Examples** - Zn, Cd, Hg etc.

**[2] Liqutation** - This process is used when the impurity is less fusible than the metal itself. The impure metal is placed on the sloping hearth of the furnace and heated. The metal melts and drains away leaving behind the impurities. For e.g. tin.

**[3] Oxidation method** - This method is employed when the impurity have greater affinity with oxygen as compared to metal. The impurities are oxidized to form scum. The scum is skimmed off. Some times metal oxides are used as oxidizing agents. For e.g. copper oxide is added to impure copper.

#### [4] Electrolysis -

Most of the metals are purified electrolytically. The metal salt is taken as electrolyte, impure metal rod as anode and thin pure metal rod or strip as cathode. On electrolysis pure metal is deposited at cathode. Cu, Ag, Al, Zn, Cr etc. metals are purified by this method.

#### 2. Extraction of Copper, Cu

(i) Copper was named as cuprous by Romans because they obtained it from Cyprus island.

(ii) It is also found in small quantity in pea, peacock feather and animal blood.

(iii) **Occurrence** - It is found in nature in both free and combined state.

The Important ores of copper are

[1] Cuprite or ruby copper or cuprite red  $\text{Cu}_2\text{O}$

[2] Copper pyrite (Chalcopyrites)  $\text{CuFeS}_2$  or  $\text{Cu}_2\text{S} \cdot \text{Fe}_2\text{S}_3$

[3] Copper glance  $\text{Cu}_2\text{S}$

[4] Malachite  $\text{Cu}(\text{OH})_2 \cdot \text{CuCO}_3$

(e) Azurite  $\text{Cu}(\text{OH})_2 \cdot 2\text{CuCO}_3$  76% of the copper is extracted from the ore copper pyrites.

#### (iv) Indian Sources-

Bihar (Singhbhum), Andhra Pradesh, Karnataka (Mysore), Sikkim, Orissa, Rajasthan (Khetri and Dariba). In India Copper is extracted by Hindustan Copper Ltd.

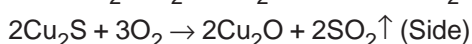
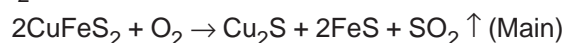
#### (v) Extraction of Copper from Copper pyrites

##### [1] Concentration -

The ore is concentrated by froth flotation method. .

##### [2] Roasting -

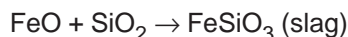
This process is done in reverberatory furnace. The Impurities of arsenic and antimony are removed as volatile oxides. Sulphur oxidises to  $\text{SO}_2$ .



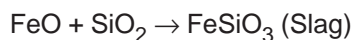
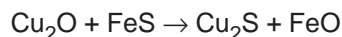


### [3] Smelting –

Coke and sand is mixed with roasted ore and it is smelted in blast furnace.  $\text{Cu}_2\text{S}$  and  $\text{FeS}$  are oxidised fastly.  $\text{FeO}$  reacts with  $\text{SiO}_2$  to give slag ferrous silicate.



$\text{Cu}_2\text{O}$  obtained in roasting reacts with  $\text{FeS}$  to give cuprous sulphide and  $\text{FeO}$ . This  $\text{FeO}$  again reacts with  $\text{SiO}_2$  to give slag  $\text{FeSiO}_3$

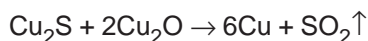
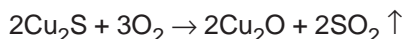


This slag is removed.

Molten  $\text{Cu}_2\text{S}$  and a small amount of  $\text{FeS}$  remains below the surface of slag. This mixture is called matte. It is taken out from the furnace.

### [4] Bessemerisation -

Molten matte *i.e.* mixture of  $\text{Cu}_2\text{S}$  and  $\text{FeS}$  is transferred to a Bessemer converter. Bessemer converter is a pear shaped furnace in which the inner lining is of  $\text{CaO}$ . or  $\text{MgO}$ . A blast of air mixed with sand is blown through the molten matte. The following reactions take place



The molten copper thus obtained is cast into ingots. It is about 98% pure copper. It is called blister copper because of blistered appearance due to escape of  $\text{SO}_2$  gas during the cooling of molten copper. This copper contains about 2% mixture of  $\text{Ag}$ ,  $\text{Au}$ ,  $\text{Ni}$ ,  $\text{Zn}$ ,  $\text{Pb}$  and  $\text{Sn}$ . etc.

**(e) Refining - (i) Poling** - The blistered copper is heated in the reverberatory furnace. Cuprous oxide present in it oxidises the impurities. The impurities of sulphur and arsenic separate as volatile oxides and the other impurities as slag. This copper still has the impurity of cuprous oxide. The molten copper is then agitated with green wood bamboos. Cuprous oxide is reduced to copper by the hydrocarbons obtained from the green wood bamboos.

### (ii) Electrolytic refining

Anode - Blistered copper

Cathode - Pure copper

Electrolyte - Aqueous solution of copper sulphate.

### On electrolysis

At cathode -  $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$

At anode -  $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$

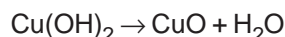
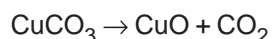
## 3. Extraction of copper from oxide or carbonate ores

### [1] Concentration-

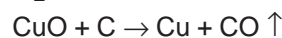
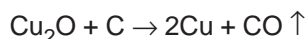
Gravity separation method is employed.

### [2] Calcination -

On calcination the volatile impurities are removed and the following reactions take place



**[3] Smelting-** Calcinated ore is smelted by mixing the suitable flux



**[4] Purification** - Electrolytic refining.

## 4. Alloys of Copper

- (i) **Brass** - Cu, 60-80% and Zn, 40-20%
- (ii) **Bronze** - Cu, 75-90% and Sn, 25-10%
- (iii) **Aluminium bronze**– Cu 90% and Al 10%
- (iv) **Monel Metal**– Cu 30%, Ni, 67% and Fe + Mn, 3%
- (v) **Bell Metal** – Cu, 80% Sn, 20%
- (vi) **Gun metal**– Cu, 87%; Sn, 10%; Zn, 3%
- (vii) **German Silver** – Cu, 50%, Zn 25%; Ni 25%
- (viii) **Phosphorus bronze**– Cu 85%, Sn 13%, P 2%

## 5. Extraction of silver

### (i) Occurrence

Silver is found in free and combined state both, In free state it is generally found in Mexico, Canada, and USA. In alluvial sand, it is found with gold and copper. Its important ores are

[1] **Argentite or silver glance**-  $\text{Ag}_2\text{S}$

[2] **Pyrargyrite or ruby silver**-  $\text{Ag}_2\text{S}$ ,  $\text{Sb}_2\text{S}_3$

[3] **Horn silver**-  $\text{AgCl}$ ,

[4] **Copper silver glance** –  $\text{Cu}_2\text{S}\cdot\text{Ag}_2\text{S}$

(e) **Stiphenite** -  $\text{Ag}_5\text{SbS}_4$

(f) **Argentiferrous galena (PbS)** - It contains about 0.01 to 0.1% silver.

(g) Silver can also be prepared from the anode mud obtained in the extraction of copper.

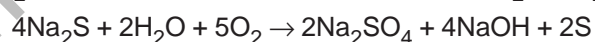
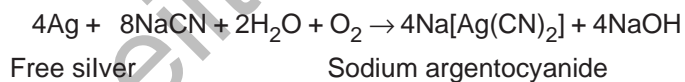
(ii) **Indian sources** - Colar and Hatti (Karnataka) and Jawar mines (Rajasthan)

(iii) **Extraction of silver from its ores** –

### [1] Cyanide process or Mac Arthur forest process

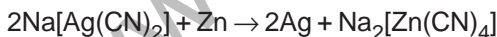
(i) **Concentration** - Froth flotation process.

(ii) Concentrated ore is reacted with dilute solution of sodium cyanide and the mixture is agitated with air. Silver forms a soluble complex,



The solution is filtered. Filtrate contains sodium argentocyanide.

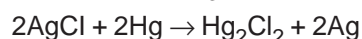
(iii) On addition of zinc powder, in sodium argentocyanide solution, silver precipitates out.



(iv) Silver precipitate is filtered and dried. It is then fused with borax or potassium nitrate for purification.

### [2] Amalgamation process

Silver ore + Salt + roasted pyrites mixture is finely powdered. Salt + roasted pyrite form ferric chloride which reacts with silver ore.



Silver chloride thus formed reacts with mercury to give silver which forms silver amalgam in the excess of mercury. On distillation of amalgam mercury distills out and silver remains in the container.

### [3] From Argentiferrous lead

The concentration of silver in argentiferrous lead can be increased by the following methods.

**(i) Parkes process -**

In the molten argentiferrous lead, a small amount of molten zinc is added. The mixture is shaken well. Silver forms an alloy with zinc which on cooling solidifies and is skimmed off while the lead still remains in the molten state. On distillation of this alloy, zinc distills out and silver remains in the container. This silver contains the impurity of lead.

**(ii) Pattinson's process -**

This method is based on phase rule. When molten argentiferrous lead is allowed to cool slowly, lead crystals separate out. This process is repeated many times until the concentration of silver in the mixture rises to 2.5% when entire mass solidifies.

From the concentrated lead silver mixture, silver is removed by cupellation.

**(iii) Cupellation -**

The impure silver is heated in a small bone-ash crucible (cupel) in a blast of air in a small reverberatory furnace. Lead gets oxidised to litharge (PbO) which is blown away.

**Purification** - Silver so obtained is further purified by electrolytic method.

Anode - Impure silver

Cathode - Pure silver

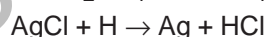
Electrolyte -  $\text{AgNO}_3$  soln. + 1 %  $\text{HNO}_3$  On passing the current -

At anode -  $\text{Ag} \rightarrow \text{Ag}^+ + \text{e}^-$

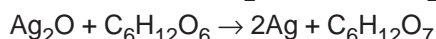
At cathode -  $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$

**6. Silver from Coins and Ornaments**

- (i) Coins and ornaments contain the impurity of Cu and Ni.
- (ii) These coins and ornaments' are treated with  $\text{HNO}_3$ . A mixture of nitrates of Ag, Cu and Ni is obtained.
- (iii) On addition of HCl to this solution, a white precipitate of AgCl is formed which is filtered out.
- (iv) This precipitate of AgCl can be converted to Ag by anyone of following methods.



[3] Reducing with alkaline glucose



Silver thus obtained is fused with borax or  $\text{KNO}_3$  for further purification. It is again purified by electrolytic method.

**7. Extraction of aluminium**

(i) Wholler prepared aluminium by the reaction of potassium metal with anhy.  $\text{AlCl}_3$  Bunsen and Deville prepared it from the reaction of  $\text{NaAlCl}_4$  with sodium and also from the electrolysis of  $\text{NaAlCl}_4$  Charles M. Hall prepared aluminium from fused cryolite.

(ii) Occurrence-Aluminium is. found in nature only in combined state. Its important ores are

[1] Felspar -  $\text{KAlSi}_3\text{O}_8$

[2] Mica (Abhrak) -  $\text{KH}_2\text{Al}_2(\text{SiO}_3)_4$

[3] Kaolin -  $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_3 \cdot 2\text{H}_2\text{O}$

[4] Corundum -  $\text{Al}_2\text{O}_3$

(e) Diaspore -  $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$

(f) Bauxite -  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$

(g) Cryolite -  $\text{Na}_3\text{AlF}_6$

(h) Alunite or alumstone -  $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 4\text{Al}(\text{OH})_3$

(i) Thrhoise -  $\text{AlPO}_4 \cdot \text{Al}(\text{OH})_3 \cdot \text{H}_2\text{O}$

(j) Gibbsite -  $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$

(k) Beryl -  $3\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$ .

Indian sources - Mainly bauxite ore is found in India. It is found in U .P., M.P. Gujrat, Tamilnadu, orissa, Bihar and

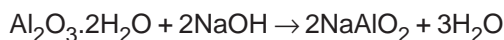


J and K. The production of aluminium is carried out by Indian aluminium company Alvai, Madras aluminium Co. Madras and Hindustan aluminium U.P.

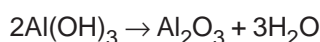
### Extraction of aluminium from bauxite Purification of bauxite

#### [1] Baeyer' process-

Finely powdered bauxite is digested with an aqueous solution of sodium hydroxide in an autoclave at 150° C and 80 atmospheric pressure. Alumina present in bauxite dissolves as sodium meta aluminate. The' other impurities remain insoluble and are filtered out.

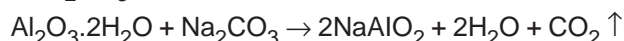


The filtrate containing sodium metaaluminate is agitated with freshly precipitated  $\text{Al}(\text{OH})_3$  for 36 hrs. Sodium meta aluminate hydrolyses to  $\text{Al}(\text{OH})_3$ ,  $\text{NaAlO}_2 + 2\text{H}_2\text{O} \rightarrow \text{NaOH} + \text{Al}(\text{OH})_3$ ,  $\text{Al}(\text{OH})_3$  thus obtained is filtered, washed, dried and heated at about 1500°C. Alumina is obtained.

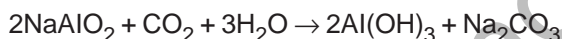


#### [2] Hall's method -

Bauxite ore is fused with  $\text{Na}_2\text{CO}_3$  and the sodium meta aluminate' formed is extracted with water.

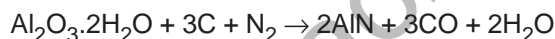


$\text{CO}_2$  gas is passed through the sodium meta aluminate solution at 50-60°C  $\text{Al}(\text{OH})_3$  gets precipitated. .



$\text{Al}(\text{OH})_3$  thus obtained is filtered, dried and heated in a furnace at about 1500°C to obtain  $\text{Al}_2\text{O}_3$

[3] Serpek's process - This process is used when bauxite contains relatively a large amount of silica as impurity. Bauxite is heated with carbon at 1800°C in the current of  $\text{N}_2$ .  $\text{AlN}$  is formed.



Aluminium nitride on hydrolysis gives  $\text{Al}(\text{OH})_3$  which on heating at 1500°C gives  $\text{Al}_2\text{O}_3$



#### (ii) Electrolytic reduction of alumina-

Pure.  $\text{Al}_2\text{O}_3$  on electrolytic reduction gives aluminium.

The melting point of  $\text{Al}_2\text{O}_3$  is about 2000°C. This is reduced by mixing fused cryolite ( $\text{Na}_3\text{AlF}_6$ ) + fluorspar ( $\text{CaF}_2$ ) to it. The melting point of this mixture is about 900°C. This mixture. is good conductor of electricity. The inner carbon lining of the cell is used as cathode and the carbon rods as anode.

The fused mixture of alumina + Cryolite + Fluorspar is taken in the cell whose temperature is maintained at about 900 to 1000°C. This mixture is covered by carbon powder which maintains the temperature of the cell. The carbon anodes are dipped in the mixture. Aluminium gets free at cathode while oxygen at anode. Aluminium thus obtained is about 99.8% pure.

#### Purification of aluminium

**Hoope's method** - Aluminium is refined electrolytically. The refining cell consists of three fused layers - (i) The bottom anode layer of impure  $\text{Al} + \text{Cu} + \text{Si}$ , (ii) The middle electrolyte layer of cryolite ( $\text{Na}_3\text{AlF}_6$ ) +  $\text{BaF}_2$  and (iii) The top cathode layer of pure aluminium. On passing the electric current, pure  $\text{Al}$  from the bottom layer rises to the upper layer.

#### Alloys of aluminium

(i) **Magnelium** -  $\text{Al}$  95%,  $\text{Mg}$  5%

(ii) **Duralium** -  $\text{Al}$  95%,  $\text{Cu}$  4%,  $\text{Mg}$  0.5%,  $\text{Mn}$  0.5%

(iii) **Y-alloy** -  $\text{Al}$  93%,  $\text{Cu}$  4%,  $\text{Ni}$  2%,  $\text{Mg}$  1%

#### 8. Extraction of iron

**(i) The important ores of iron are**

- |   |   |
|---|---|
| [1] Haematite- $\text{Fe}_2\text{O}_3$                          | [2] Magnetite- $\text{Fe}_3\text{O}_4$                                |
| [3] Limonite- $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ | [4] Siderite - $\text{FeCO}_3$  |
| (e) Iron pyrites - $\text{FeS}_2$                               | (f) Copper pyrites - $\text{CuFeS}_2$                                 |
| (g) Arsenic pyrites - $\text{FeAsS}$                            | (h) Vivianite- $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ |

**(ii) Indian sources**

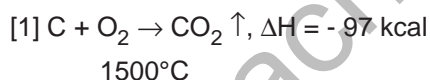
The main ores of iron is hematite in india. It is found in Singhbhum, Mysore, Durg" Chand, Mayurbhanj. Steel plants are located at Jamshedpur, Asansol, Bhadravati, Bhilai, Durgapur, Bokaro and Rourkela.

**(iii) Various forms of iron**

- [1] **Cast iron or pig iron**- It is least pure form of iron containing about 2.2 to 4.4% carbon. It is brittle and can not be hammered.
- [2] **Wrought or malleable iron** - It is the purest form of iron containing about 0.1 to 0.25% carbon. It is malleable.
- [3] **Steel**- It comes in between cast iron and wrought iron and contains about 0.25 to 2.0% carbon. It is malleable. Its properties depend upon the quantity of carbon present.

**Extraction of cast iron**

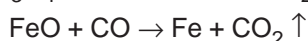
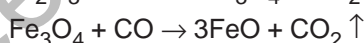
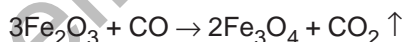
- (i) Concentration of ore – Iron ores are concentrated by magnetic separation method.
- (ii) Hematite and magnetite after concentration can be used directly. Sulphide ore is first roasted and carbonate ore is calcined.
- (iii) **Smelting**- In calcined or roasted ore, coke (reductant) and lime stone (Flux) is mixed in appropriate proportion. This mixture is smelted in a blast furnace. The following reactions take place



[3] At 400-700°C in the reduction region, the following reactions occur –

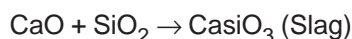


This reaction takes place in the following steps



Iron thus obtained is in solid state and becomes porous. It is known as spongy iron.

[4] At 1000°C, silica present in ore combines with CaO obtained from lime stone to give slag  $\text{CaSiO}_3$ .



(e) At 1300°C, spongy iron melts and absorb. C, P,  $\text{SiO}_2$  etc. Slag also melts at this temperature. Both fall at the bottom of the furnace. The molten metal obtained from the furnace is called pig iron. It contains 2.6-4.3% of carbon and varying amounts of Mn, Si, Sand P.

**White cast iron** - If the molten iron obtained from blast furnace is suddenly cooled, the carbon is present in the form of cementite ( $\text{Fe}_3\text{C}$ ) and the white coloured cast iron is obtained.

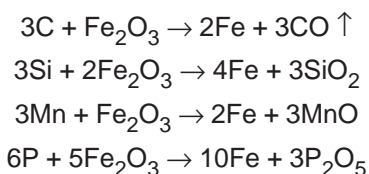
**Grey cast iron** - If the molten iron obtained from blast furnace is cooled slowly, the most part of carbon is present in the form of graphite and the grey coloured cast iron is obtained.

Cast iron is not rusted. Its melting point is about 250°C less than the pure iron.

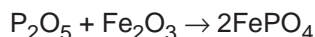
**Wrought iron**

It is obtained by purifying cast iron by the process known as puddling. The cast iron is heated on the hearth of a reverberatory furnace lined with hematite ( $\text{Fe}_2\text{O}_3$ ) or magnetite ( $\text{Fe}_3\text{O}_4$ ). The impurities of C, Si, P, Mn, etc. are oxidised.





$\text{P}_2\text{O}_5$  forms slag ferric phosphate with hematite.



After separation of slag, the iron is taken out in the form of balls and the slag squeezed out by hammering. Wrought iron thus obtained retains about 0.2% C and traces of P and Si etc. in the form of slag. The presence of slag gives strength and toughness to metal and make it resistant towards rusting.

## 9. Steel

It can be made as follows

- (i) By reducing the amount of carbon in cast iron.
- (ii) By adding some carbon to wrought iron.
- (iii) By mixing the required amounts of cast iron and wrought iron.
- (iv) Directly from ore.

Generally steel is prepared from cast iron.

### Production of steel from cast iron–

#### (i) Acidic Bessemer process

[1] The Bessemer is lined with silica.

[2] In the acidic Bessemer, hot air oxidise Mn, Si and C impurities present in the cast iron.



[3] MnO combines with  $\text{SiO}_2$  to give slag  $\text{MnSiO}_3$  which is separated. Carbon is oxidised to carbon monoxide which burns with a blue flame at the mouth of converter.

[4] When the whole of the carbon is oxidised the blue flame suddenly stops.

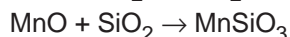
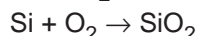
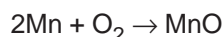
The requisite amount of carbon is then added usually in the form of an alloy of Fe + Mn + C, Called spiegel. The process is called spiegeleisen. The resulting product is manganese steel which is harder and possesses much greater tensile strength.

#### (ii) Basic Bessemer process –

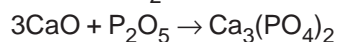
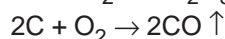
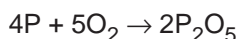
[1] This process is used when cast iron contains comparatively the higher impurity of phosphorus.

[2] The Bessemer is lined with CaO or MgO.

[3] Cast iron and lime stone are taken in the Bessemer and hot air is passed through them. Mn, Si, C and, P oxidise as



Slag



Slag

$\text{Ca}_3(\text{PO}_4)_2$  is known as Thomas slag and is used as valuable fertilizer.

[4] Iron thus obtained undergoes spiegeleisen and steel is obtained.

**(iii)** Siemen's Martin open hearth process

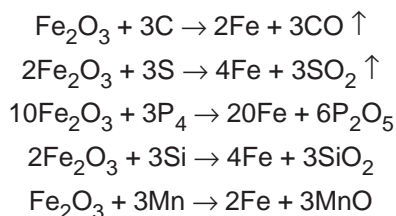
[1] Iron ore hematites used for the oxidation of impurities.

[2] Scrap steel, wrought iron of low quality is added to reduce the quantity of carbon.

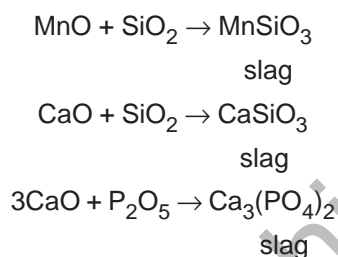
[3] Heat is reproduced for obtaining the high temperature.

[4] The hearth of the furnace is lined with silica or dolomite. (CaO. MgO) depending upon the nature of the impurities.

(e) C, S, P, Si, and Mn are oxidised by hematite as



CO and SO<sub>2</sub> come out and other oxides form slag as follows which are separated.

**10. Alloys of steel**

	Alloys	Composition
1.	Chrome steel	2-4%Cr, 98-96% Fe
2.	Tungsten steel	10-20% W, 90-80% Fe
3.	Stainless steel	12-14% Cr, 88-86% Fe or 2-4% Ni + 86-82% Fe
4.	Manganese steel	10-18% Mn, 90-82% Fe
5.	Nickel steel	3-5% Ni, 97-95% Fe
6.	Vanadium steel	0.2-1% V
7.	Invar	36% Ni, 64% Fe

**11. Heat Treatment of Steels:**

The hardness and elasticity of steel can be controlled by proper heat treatment.

**Annealing** - If steel is heated to redness and then allowed to cool slowly. it becomes malleable, soft and pliable. This operation is called annealing.

**Hardening** - If steel is heated to redness and is suddenly quenched by plunging into water or oil, it becomes extremely hard and brittle. This process is called hardening.

**Tempering** - Hard steel is heated up to 270°C and then allowed to cool slowly. It becomes' comparatively less hard and less brittle.

**12. Important Ores of various metals****Manganese**

- (i) Pyrolusite -  $MnO_2$                       (ii) Manganite -  $Mn_2O_3 \cdot H_2O$                       (iii) Braunite -  $Mn_2O_3$

**Zinc**

- (i) Zinc blende -  $ZnS$                       (ii) Calamine -  $ZnCO_3$                       (iii) Zincite -  $ZnO$   
 (iv) Franklinite -  $ZnO \cdot Fe_2O_3$

**Mercury - Cinnabar -  $HgS$** **Calcium**

- (i) Limestone -  $CaCO_3$                       (ii) Gypsum- $CaSO_4 \cdot 2H_2O$                       (iii) Fluorspar -  $CaF_2$   
 (iv) Phosphorite -  $Ca_3(PO_4)_2$

**Magnesium**

- (i) dolomite ~  $MgCO_3 \cdot CaCO_3$                       (ii) Magnesite- $MgCO_3$   
 (iii) Epsomite- $MgSO_4 \cdot 7H_2O$                       (iv) Carnallite -  $KCl \cdot MgCl_2 \cdot 6H_2O$   
 (v) Kieserite- $MgSO_4 \cdot H_2O$                       (vi) Asbestos-  $CaMg_3(SiO_3)_4$

**Lead**

- (i) Galena -  $PbS$                       (ii) Anglesite -  $PbSO_4$                       (iii) Cerussite -  $PbCO_3$

**Tin-** Cassiterite (Tin stone)- $SnO_2$ **13. Names and formulae of some Compounds-**

- |  |   |
|--|---|
| [1] Washing Soda- $Na_2CO_3 \cdot 10H_2O$ .            | [2] Baking soda- $NaHCO_3$                    |
| [3] Common salt- $NaCl$                                | [4] Glauber's salt- $Na_2SO_4 \cdot 10H_2O$   |
| (5) Hypo salt- $Na_2S_2O_3 \cdot 5H_2O$                | (6) Chili salt petre- $NaNO_3$                |
| (7) Nitre or Indian salt petre - $KNO_3$               | (8) Salt cake- $Na_2SO_4$                     |
| (9) Salammoniac (Nausadar) - $NH_4Cl$                  | (10) Rock phosphate (Bone ash) $Ca_3(PO_4)_2$ |
| (11) Mohr's salt - $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$    | (12) Calomel- $Hg_2Cl_2$                      |
| (13) Corrosive sublimate - $HgCl_2$                    | (14) Philosopher's wool- $ZnO$                |
| (15) Blue vitrol- $CuSO_4 \cdot 5H_2O$                 | (16) Green vitriol- $FeSO_4 \cdot 7H_2O$      |
| (17) Lunar caustic - $AgNO_3$                          | (18) White vitrol- $ZnSO_4 \cdot 7H_2O$       |
| (19) Litharge- $PbO$                                   | (20) White lead- $Pb(OH)_2 \cdot 2PbCO_3$     |
| (21) Red lead- $Pb_3O_4$                               | (22) Chrome red - $PbO \cdot PbCrO_4$         |
| (23) Chrome yellow- $PbCrO_4$ .                        | (24) Chrome alum - $KCr(SO_4)_2 \cdot 12H_2O$ |
| (25) Plaster of Paris- $CaSO_4 \cdot \frac{1}{2} H_2O$ | (26) Lithopone- $BaSO_4 + ZnS$                |
| (27) Microcosmic salt- $Na(NH_4)HPO_4 \cdot 4H_2O$     | (28) Hydrolith - $CaH_2$                      |
| (29) Pink salt - $(NH_4)_2SnCl_6$                      | (30) Laughing gas- $N_2O$                     |
| (31) Spodumene - $LiAl(SiO_3)_2$                       | (32) Nitrolium - $CaCN_2$                     |
| (33) Ferric alum- $NH_4Fe(SO_4)_2 \cdot 12H_2O$        |   |

**1. IMPORTANT ORES**

<b>Oxide Ore</b>	ZnO	Zincite
	MnO <sub>2</sub>	Pyrolusite
	SnO <sub>2</sub>	Cassiterite
	Cu <sub>2</sub> O	Cuprite
	Fe <sub>2</sub> O <sub>3</sub>	Hematite
	Al <sub>2</sub> O <sub>3</sub> .2H <sub>2</sub> O	Bauxite
	FeO.Cr <sub>2</sub> O <sub>3</sub>	Chromite
	Fe <sub>3</sub> O <sub>4</sub>	Magnetite
	Fe <sub>2</sub> O <sub>3</sub> .3H <sub>2</sub> O	Lymonite
	3BeO.Al <sub>2</sub> O <sub>3</sub> .6SiO <sub>2</sub>	Beryl
<b>Sulphide Ore</b>	ZnS	Zinc Blende
	HgS	Cinabar
	PbS	Galena
	Ag <sub>2</sub> S	Argentite or Silver glance
	FeS <sub>2</sub>	Iron pyrites
	CuFeS <sub>2</sub> .CuS.FeS	Copper pyrites
	Cu <sub>2</sub> S. Ag <sub>2</sub> S	Copper silver glance
	Ag <sub>2</sub> S.Sb <sub>2</sub> S <sub>3</sub>	Pyrargyrites, Rubi silver
	Ag <sub>5</sub> .SbS <sub>4</sub>	Stifenite
	FeAsS	Arsenickel Pyrites
<b>Halide Ore</b>	NaCl	Rock Salt
	AgCl	Horn Silver
	CaF <sub>2</sub>	Flour Spar
	AlF <sub>3</sub> .3NaF	Cryolite
	KCl MgCl <sub>2</sub> .6H <sub>2</sub> O	Camelite
<b>Carbonate Ore</b>	MgCO <sub>3</sub>	Magnesite
	CaCO <sub>3</sub>	Lime stone
	MgCO <sub>3</sub> .CaCO <sub>3</sub>	Dolomite
	ZnCO <sub>3</sub>	Calamine
	PbCO <sub>3</sub>	Cerussite
	FeCO <sub>3</sub>	Siderite
	CuCO <sub>3</sub> .Cu(OH) <sub>2</sub>	Malachite
	2CuCO <sub>3</sub> .Cu(OH) <sub>2</sub>	Azurite
	SrCO <sub>3</sub>	Strontianite
	<b>Sulphate Ore</b>	BaSO <sub>4</sub>
PbSO <sub>4</sub>		Anglisite
CaSO <sub>4</sub> .2H <sub>2</sub> O		Gypsum
MgSO <sub>4</sub> .7H <sub>2</sub> O		Eypsomite
SrSO <sub>4</sub>		Celestine
K <sub>2</sub> SO <sub>4</sub> .Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .24H <sub>2</sub> O		Alum
K <sub>2</sub> SO <sub>4</sub> .Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> .4Al(OH) <sub>3</sub>		Alunite or Alumstone

<b>Silicate Ore</b>	$\text{LiAl}(\text{SiO}_3)_2$	Spodumene	
	$\text{KAlSi}_3\text{O}_8$	Felsper	
	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$		Caolin
		(or China-Clay)	
	$3\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$	Beryl	
	$\text{CaO} \cdot 3\text{MgO} \cdot 4\text{SiO}_2$	Asbestos	
	$\text{K}_2\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 2\text{H}_2\text{O}$	Mica	
	$\text{KH}_2\text{Al}_3(\text{SiO}_3)_4$		
<b>Nitrate Ore</b>	$\text{NaNO}_3$	Chili-Salt Peter	
	$\text{KNO}_3$	Salt peter or Indian salt peter	
<b>Phosphate Ore</b>	$\text{Ca}_3(\text{PO}_4)_2$	Rock Phosphate	
	$\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$	Vivianite	
	$\text{AlPO}_4 \cdot \text{Al}(\text{OH})_3 \cdot \text{H}_2\text{O}$	Terguise	

## 2. FAMOUS PROCESS AND RELATED METAL

Poling	Cu
Perkes Process	Ag
Pattinson process	Ag
Cupellation process	Ag
Baeyer's Process	Al
Serpek's process	Al
Hall's process	Al
Siemens Martin open halth furnace	Fe
L.D. Process	Fe
Temperine	Fe

## CHIEF ORES OF ALUMINIUM

Bauxite	$\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$
Diaspore	$\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$
Cryolite	$\text{AlF}_3 \cdot 3\text{NaF}$ or $\text{Na}_3\text{AlF}_6$
China clay/Caolin	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$
Mica	$\text{K}_2\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 2\text{H}_2\text{O}$
Felspar	$\text{KAlSi}_3\text{O}_8$
Corundum/Ruby/Sapphire/emerald / Topaz	$\text{Al}_2\text{O}_3$
Gibbsite	$\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$
Aunite or Alum stone	$\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 4\text{Al}(\text{OH})_3$
Turquoise	$\text{AlPO}_4 \cdot \text{Al}(\text{OH})_3 \cdot \text{H}_2\text{O}$
Beryl	$3\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$

## ELECTROCHEMICAL SERIES

1. The series of elements obtained by arranging them in an decreasing order of reduction potential is known as electrochemical series. ( $M^{+n} + ne^- \rightarrow M$ )

**Table – 1** standard electrode potential (reduction potential) at 25°C

S.No.	Metal ion	Potential in volts
1.	$Li^+ + e^- \rightarrow Li$	- 3.05
2.	$K^+ + e^- \rightarrow K$	- 2.93
3.	$Ca^{+2} + 2e^- \rightarrow Ca$	- 2.90
4.	$Na^+ + e^- \rightarrow Na$	- 2.71
5.	$Mg^{+2} + 2e^- \rightarrow Mg$	- 2.37
6.	$Al^{+3} + 3e^- \rightarrow Al$	- 1.66
7.	$Zn^{+2} + 2e^- \rightarrow Zn$	- 0.76
8.	$Cr^{+3} + 3e^- \rightarrow Cr$	- 0.74
9.	$Fe^{+2} + 2e^- \rightarrow Fe$	- 0.44
10.	$Ni^{+2} + 2e^- \rightarrow Ni$	- 0.23
11.	$Sn^{+2} + 2e^- \rightarrow Sn$	- 0.14
12.	$Pb^{+2} + 2e^- \rightarrow Pb$	- 0.13
13.	$Fe^{+3} + 3e^- \rightarrow Fe$	- 0.04
14.	$H^+ + e^- \rightarrow H$ or $\frac{1}{2} H_2$	- 0.00 (Reference)
15.	$Cu^{+2} + 2e^- \rightarrow Cu$	+ 0.34
16.	$Hg^{+2} + 2e^- \rightarrow Hg$	+ 0.79
17.	$Ag^+ + e^- \rightarrow Ag$	+ 0.80
18.	$Pt^{+4} + 4e^- \rightarrow Pt$	+ 0.86
19.	$Au^+ + e^- \rightarrow Au$	+ 1.69

### Some Important Alloy

1.	$\alpha$ - Iron	-	Fe (100%)
2.	Bronze	-	Cu(75–90%) + Sn (10 – 25%)
3.	Brass	-	Cu (60 – 80%) + Zn (20 – 40%)
4.	Aluminium Bronze	-	Cu(90%) + Al (10%)
5.	Gun metal	-	(Cu + Zn + Sn) (87 : 3 : 10)
6.	German Silver	-	Cu + Zn + Ni (2 : 1 : 1)
7.	Bell metal	-	Cu (80%) + Sn (20%)
8.	Monel Metal	-	Cu : Ni : (Fe + Mn) (30 : 67 : 3)
9.	Nichrome	-	(Ni + Cr + Fe) (24 : 26 : 28)
10.	Alnico	-	(Al, Ni, Co)
11.	Britania Metal	-	(Sn + Pb)
12.	Babbitt metal	-	Sn + Pb + Cu
13.	Munz metal	-	Cu + Zn (60 – 62%) – (68 – 40%)
14.	Type metal	-	Pb + Sn + Sb
15.	Alloys of steel		
	[1] Vanadium steel		V (0.2 – 1%)
	[2] Chromium steel		Cr (2 – 4%)



	[3] Nickel Steel		Ni (3 – 5%)
	[4] Manganese steel Mn (10 – 18%)		Mn (10 – 18%)
	(e) Stainless steel		Cr (12 – 14%) & Ni (2 – 4%)
	(f) Tungston steel		W (10–20%)
	(g) Invar		Ni (36%)
16.	14 Carat Gold	-	54% Au + Ag (14 to 30%) + Cu (12–28%)
17.	24 Carat Gold	-	100% Au
18.	Genny Gold or coil of Gold	-	Au + Cu (11 : 1)
19.	Solder	-	Pb + Sn
20.	Delta metal	-	Cu + Zn + Fe
21.	Coin of Silver	-	Ag (92.5%) + Cu (7.5%)
22.	Coin of aluminium	-	Mg + Al
23.	Coin of Steel	-	3.5% Ni in steel
24.	Magnellium	-	Mg (10%) + Al(90%)
25.	Duralumin	-	(Al + Mn + Cu)
26.	Y-alloy	-	Al(93%) + Cu(4%) + Ni(2%) + Mg (1%)
27.	Dutch metal	-	Cu (80%) + Zn (20%)
28.	Artificial Gold	-	Cu(90%) + Al(10%)
29.	Constantan	-	Cu(60%) + Ni(40%)
30.	Rinman Green	-	CoZnO <sub>2</sub>
B.	% of Carbon in different type of Iron		
	Name		% of C
[1]	Wrought iron/Meleable		0.1 to 0.25
[2]	Steel		0.25 to 2.0
[3]	Pig Iron		2.3 to 4.6
[4]	Cast Iron		2.6 to 4.3

### SUM IMPORTANT COMPOUNDS/ MINERALS/ MIXTURE & THERE FORMULA'S

1.	Epsom salt	-	MgSO <sub>4</sub> .7H <sub>2</sub> O
2.	Gypsom salt	-	CaSO <sub>4</sub> .2H <sub>2</sub> O
3.	Glober's salt	-	Na <sub>2</sub> SO <sub>4</sub> .10H <sub>2</sub> O
4.	Lime water	-	Ca(OH) <sub>2</sub> (slaked lime)
5.	Quick lime	-	CaO
6.	Washing soda	-	Na <sub>2</sub> CO <sub>3</sub> .10H <sub>2</sub> O
7.	Crystal carbonate	-	Na <sub>2</sub> CO <sub>3</sub> .10H <sub>2</sub> O
8.	Soda ash	-	Na <sub>2</sub> CO <sub>3</sub>
9.	Baking Soda	-	NaHCO <sub>3</sub>
10.	Baking powder	-	NaHCO <sub>3</sub> Tartaric acid
11.	Plaster of pairs	-	2CaSO <sub>4</sub> .H <sub>2</sub> O or CaSO <sub>4</sub> .1/2 H <sub>2</sub> O
12.	Chile salt petre	-	NaNO <sub>3</sub>
13.	Indian salt petre	-	KNO <sub>3</sub>
14.	Brine or table salt or rock salt -		NaCl
15.	Potash ash or pearl ash	-	K <sub>2</sub> CO <sub>3</sub>
16.	Nitre or Indian salt petre or chemical refrigerator	-	KNO <sub>3</sub>
17.	Norwegian salt petre	-	Ca(NO <sub>3</sub> ) <sub>2</sub>

18.	Salt Cake	-	$K_2SO_4$
19.	Carnalite	-	$KCl, MgCl_2 \cdot 6H_2O$
20.	Hypo	-	$Na_2S_2O_3 \cdot 5H_2O$
21.	Borax ) or Tineal	-	$Na_2B_4O_7 \cdot 10H_2O$
22.	Barytes or Heavy spar or Barium meal	-	$BaSO_4$
23.	Baryta	-	$Ba(OH)_2$
24.	Magnesia	-	$MgO$
25.	Microcosmic salt	-	$NaNH_4HPO_4 \cdot 4H_2O$
26.	Nitrolim	-	$CaCN_2$
27.	Hydrolith	-	$CaH_2$
28.	Fusion mixture	-	$Na_2CO_3 + K_2CO_3$
29.	Gun powder	-	$KNO_3$
30.	Pink salt	-	$(NH_4)_2SnCl_6$
31.	Laughing gas	-	$N_2O$ (Nitous oxide)
32.	Red Lead	-	$Pb_3O_4$
33.	Blue vitreol	-	$CuSO_4 \cdot 5H_2O$
34.	Green vitreol	-	$FeSO_4 \cdot 7H_2O$
35.	White vitreol	-	$ZnSO_4 \cdot 7H_2O$
36.	Phiiosopher's wool	-	$ZnO$
37.	Oil of Vitreol	-	$H_2SO_4$
38.	Mohr's salt (Ferrous ammonium sulphate)	-	$FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$
39.	Lunar Caustic	-	$AgNO_3$
40.	Calomel	-	$Hg_2Cl_2$
41.	Corrosive sublimate	-	$HgCl_2$
42.	Potash alum	-	$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$
43.	Chrom alum	-	$K_2SO_4 \cdot Cr_2(SO_4)_3 \cdot 24H_2O$
44.	Ferric alum	-	$Fe_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$
45.	Chrome lemon	-	$PbCrO_4$
46.	Pyrolusite	-	$MnO_2$
47.	Cementite (Iron Carbide)	-	$Fe_3C$
48.	Nessler's reagent	-	$K_2HgI_4$
49.	Lead Sugar	-	$(CH_3COO)_2Pb$
50.	White lead	-	$Pb(OH)_2 \cdot 2PbCO_3$
51.	Rock Phosphate	-	$Ca_3(PO_4)_2$
52.	Rochelle salt (Sodium potassium tartrate)	-	$CH(OH)COONa$   $CH(OH)COOK$
53.	Flour spar	-	$CaF_2$
54.	Anhydrone	-	$Mg(ClO_4)_2$
55.	Asbestos	-	$CaMg_3(SiO_3)_4$
56.	Sorel's cement	-	$MgCl_2 \cdot 5HgO \cdot H_2O$
57.	Magnesia alba	-	$MgCO_3 \cdot Mg(OH)_3 \cdot 3H_2O$

			(used in tooth powders and tooth paste)
58	Lithopone	-	$\text{BaSO}_4 + \text{ZnS}$
59.	Witherite	-	$\text{BaSO}_4$
60.	Tough pitch Copper	-	99.5% pure Cu
61.	Oxone	-	$\text{Na}_2\text{O}_2$

**2. [1] PARAMAGNETIC COMPLEX ION, HYBRIDIZATION AND GEOMETRY**

[1]	$[\text{Cr}(\text{H}_2\text{O})]^{+3}$ ( $d^2sp^3$ )	(Octahedral)
[2]	$[\text{Cr}(\text{CN})_6]^{-3}$ ( $d^2sp^3$ )	(Octahedral)
[3]	$[\text{CoF}_6]^{-3}$ ( $sp^3d^2$ )	(Octahedral)
[4]	$[\text{Ni}(\text{H}_2\text{O})_6]^{+2}$ ( $sp^3d^2$ )	(Octahedral)
(5)	$[\text{NiCl}_4]^{-2}$ ( $sp^3$ )	(Tetrahedral)
(6)	$[\text{Cu}(\text{NH}_3)_4]^{+2}$ ( $dsp^2$ )	(Tetrahedral) or $[\text{Zn}(\text{NH}_3)_4]^{+2}$
(7)	$[\text{CoF}_6]^{-3}$ ( $sp^3d^2$ )	(Octahedral)

**[2] DIAMAGNETIC COMPLEX AND HYBRIDISATION & GEOMETRY**

[1]	$[\text{Ni}(\text{Co})_4]$ ( $sp^3$ )	(Tetrahedral)
[2]	$[\text{Ni}(\text{CN})_4]^{-2}$ ( $dsp^3$ )	(Square Planer) or $[\text{Pt}(\text{NH}_3)_4]^{+2}$
[3]	$[\text{Co}(\text{NH})_5]^{+3}$ ( $d^2sp^3$ )	(Octahedral)
[4]	$[\text{Co}(\text{H}_2\text{O})_6]^{+3}$ ( $d^2sp^3$ )	(Octahedral)
(5)	$[\text{Co}(\text{NO})_2]^{-3}$ ( $d^2sp^3$ )	(Octahedral)
(6)	$[\text{Co}(\text{CN})_6]^{-3}$ ( $d^2sp^3$ )	(Octahedral)
(7)	$[\text{Fe}(\text{CN})_6]^{-4}$ ( $d^2sp^3$ )	(Octahedral)