Extraction of Metal from the concentrated ore.
Metal is extracted from the concentrated ore by the following steps

a) Conversion of the concentrated ore into its oxide :
the production of metal from the concentrated ore. mainly involves reduction process. This can be usually done by 2 processes known as calcination and roasting. The method depends upon the nature of the ore

(b) conversion of oxide to metal by reduction process

(a) Conversion of ore into Metal oxide :
these are briefly discussed below :

i) Calcination : it is the process of heating the concentrated ore in the absence of air
the calcination process is used for the following changes:
- to convert carbonate ores into metal oxide..
- to remove water from the hydrated ores
- to remove volatile impurities from the ore.

For example:

$$\underset{\text{calamine}}{ZnCO_3(s)} \xrightarrow{\text{calcination}} \underset{\text{Zinc oxide}}{ZnO(s)} + \underset{\text{carbon di oxide}}{CO_2(g)}$$

$$\underset{\text{siderite}}{FeCO_3(s)} \xrightarrow{\text{calcination}} \underset{\text{Iron(II) oxide}}{FeO(s)} + \underset{\text{carbon di oxide}}{CO_2(g)}$$

ii) Roasting : It is the process of heating the concentrated ore strongly in the presence of excess air.

This process is used for converting sulphide ores to metal oxide. In this process, the following changes take place

- the sulphide ores undergo oxidation to their oxides
- moisture is removed
- volatile impurties are removed

For example:

$$2ZnS(s) + 3O_2(g) \xrightarrow{Roasting} 2ZnO(s) + 2SO_2(g)$$

Zinc blende Oxygen (from air) Zinc oxide sulphur oxide

$$4FeS_2(s) + 11O_2(g) \xrightarrow{Roasting} 2Fe_2O_3(s) + 8SO_2(g)$$

Iron pyrites oxygen ferric oxide sulphur dioxide

Note: calcination is used for hydrated and carbonate ores and roasting is used for sulphide ore

b) conservation of metal oxide into Metal:
the metal oxide formed after calcination or roasting is converted into metal by reduction. The method used for reduction of metal oxides depends upon the nature and chemical reactivity of metal

The metals can be grouped into the following three categories on the basis of their reactivity:

- Metals of low reactivity
- Metals of medium reactivity
- Metals of high reactivity

these different categories of metals are extracted by different techniques. The different steps involved in separation are as follows:

i) Reduction by heating: Metals placed low in the reactivity series are very less reactive. They can be obtained from their oxides by simply heating in air.

$$2HgS(s) + 3O_2(g) \xrightarrow{Roasting} 2HgO(s) + 2SO_2(g)$$

Mercury sulphide oxygen mercuric oxide sulphur oxide

$$2HgO(s) \xrightarrow{heat} 2Hg(l) + O_2(g)$$

mercuric oxide mercury metal oxygen.

ii) chemical Reduction (for metals in the middle of the reactivity series):

A) Reduction with carbon: the oxides of moderately reactive metals (occuring in the middle of reactivity series) like zinc, copper, nickel, tin, lead etc. can be reduced by using carbon as reducing agent.

$$ZnO(s) + C(s) \xrightarrow{heat} Zn(s) + CO(g)$$

Zinc oxide carbon (R.A.) Zinc carbon monoxide

$$Fe_2O_3(s) + 3C(s) \longrightarrow 2Fe(s) + 3CO(g)$$

ferric oxide iron metal carbon monoxide

$$PbO(s) + C(s) \longrightarrow Pb(s) + CO(g)$$

lead oxide carbon lead metal

One disadvantage of using carbon as reducing agent is that small traces of carbon are added to metal as impurity. Therefore, it contimates the metals

* Note :
coke is very commonly used as reducing agent because it is cheap

B) Reduction with carbon monoxide : Metals can be obtained from oxides by reduction with carbon monoxide in the furnace

$$Fe_2O_3(s) + 3CO(g) \xrightarrow{heat} 2Fe(s) + 3CO_2(g)$$
ferric oxide carbon-dioxide iron carbon di-oxide

b) Reductⁿ by Aluminium or Gold schmidt alumino-thermic process : In this process those metal oxide will be reduced which required high temperature and at high temp. carbon react with metal to form metal carbide.
In this process we use aluminium as a reducing agent due to
i) Al has greater affinity towards oxygen as it forms most stable oxide (Al_2O_3)
ii) This reaction is highly exothermic in nature and once it start it will continue till at the metal oxide is reduced into metal
For Cr, Mn, Fe

$$Cr_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Cr$$
$$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$$

iv) Electrolytic reduction
this process is mainly used for the extraction of highly electropositive metals. IA, II A, & Al
Electrolysis is carried out in a large cell and a small amount of another suitable

electrolyte is added which :

a) lowers the melting point of the main electrolyte
b) enhances its conductivity
c) reduces corrosion troubles

eg :- manufacture of metallic sodium (Down's process)

Molten NaCl containing a little $CaCl_2$ is electrolysed between graphite anode and iron cathode. The various reactions that take place are :

On fusion : $NaCl \rightleftharpoons Na^+ + Cl^-$ (Ions become mobile)

On electrolysis : At cathode : $Na^+ + e^- \longrightarrow Na$ (redn)

At anode : $2Cl^- \longrightarrow Cl_2(g) + 2e^-$

Hall heroult process :

This process is used for extraction of Al from alumina. The extraction of Al from Al_2O_3 is quite difficult because

i) Fusion ~~of~~ temp. of Alumina is quite high (2050°c) Even more than boiling point of Al (1150°c)

ii) It is bad conductor of electricity. To overcome these difficulties we mix some amount of neutral flux $[Na_3AlF_6 + CaF_2]$. Neutral flux provides free ion to the soln which decreases the fusion temp. of Alumina from 2050°c to 950°c.

i) From cryolite → $AlF_3 \longrightarrow Al^{+3} + 3F$

At cathode : $Al^{+3} + 3e^- \longrightarrow Al$ (redn)

At anode : $2F^- - 3e^- \longrightarrow \frac{3}{2}F_2$

F_2 reacts with Al_2O_3 $3F_2 + Al_2O_3 \rightarrow 2AlF_3 + \frac{3}{2}O_2$

so at anode O_2 gas is liberated which graphite anode convert into CO_2 + destroy the anode

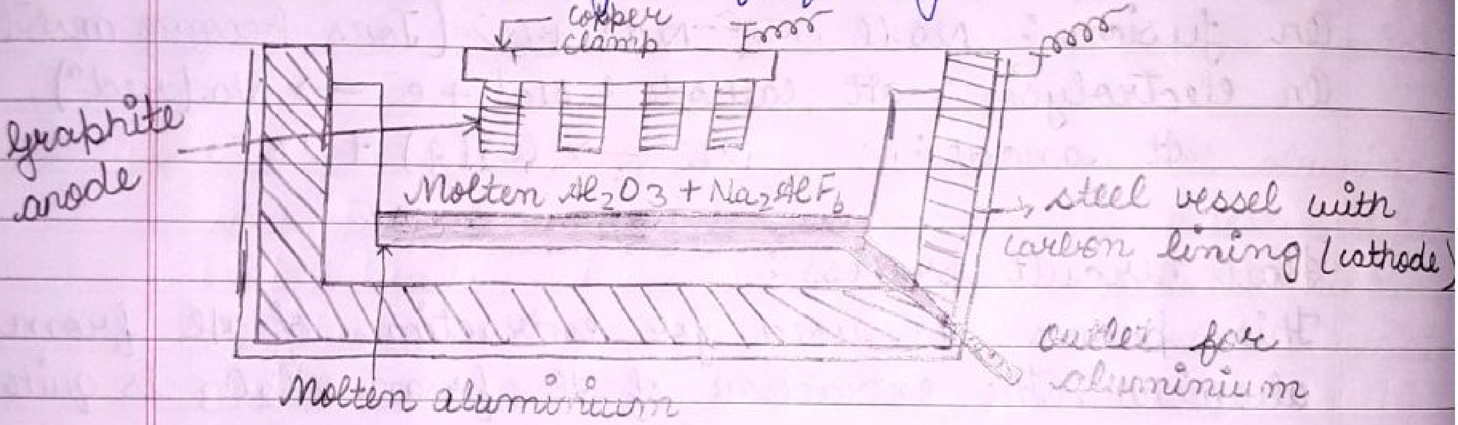
$$C + O_2 \longrightarrow CO_2 \uparrow$$

ii) From Al_2O_3

At cathode : $Al^{+3} + 3e^- \rightarrow Al$ (redⁿ)

At anode : $C(s) + 2O^{-2} \rightarrow CO_2(g) + 4e^-$

The main drawback of this process is that anode should be changed frequently.



(III) Metal displacement method : In this method, compound is reacted with a more electropositive + more reactive metal which displaces, the metal from the solⁿ.

$$CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu.$$

Kroll's process

$$TiCl_4 + Mg \longrightarrow 2MgCl_2 + Ti$$ (Mg acts as reducing agent)

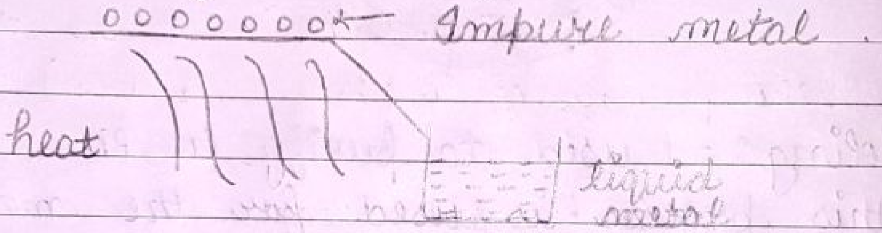
REFINING OF METALS

Metals obtained by the reduction of its compound still contains some objectionable substance and have to be refined. Depending upon the nature of the metal and impurities, the following methods are used for purification of the metals.

(I) Physical Process

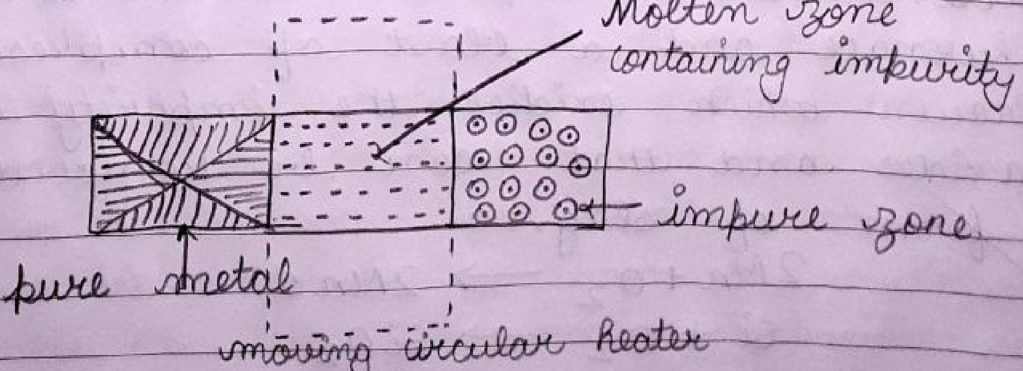
i) Liquation : this method is used for the refining of metals having low melting point and are associated with high melting impurities
Ex : Pb, Sn, Sb and Bi

the impure metal is heated on the sloping hearth of a furnace. The pure metal flows down leaving behind the non-fusible impurities on the hearth.



ii) Distillation : Metals having low boiling point are refined by this method, for example, Zinc, cadamium and mercury

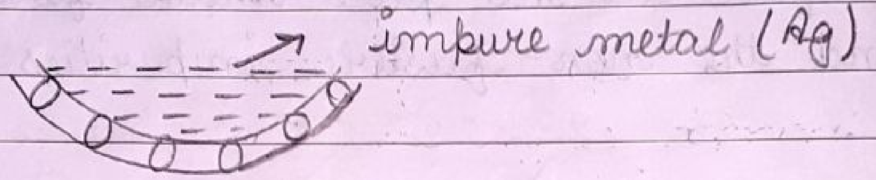
iii) Zone refining : Metals of very high purity are obtained by zone refining this refining method is based on the fact that impurities tend to remain dissolved in molten metal.
Ge, Si, and Ga used as semiconductors are refined in this manner.



chemical process :-

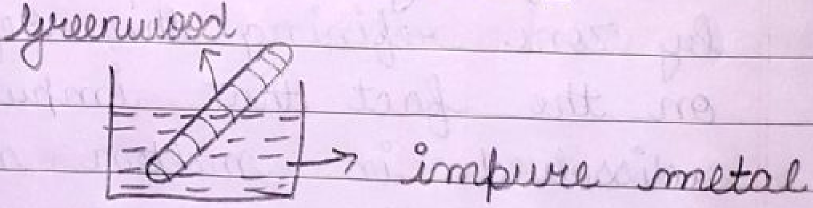
Cupellation : this process is used to purify silver containing the impurities of Pb. This process is used when impurity have greater affinity towards O_2 while metal does not have.

impure metal + O_2 —
- impurity + O_2 → volatile oxid
- metal + O_2



Poling :- used to purify Cu, Pb
this process is used for the metal having the impurity of their own oxide. In this process a green wooden pole is heated with molten metal, which provide C and H to metal oxide which reduce impurity of metal oxide to metal

$$2Cu + O_2 \rightarrow Cu_2O \uparrow$$
$$2Cu_2O + CH_4 \rightarrow 6Cu + CO + 2H_2 \uparrow$$



Bessemerisation : impure metal is heated in a furnace and a blast of compressed air is blown which oxidise the impurity into their oxides and that can be removed in the form of slag.

$$2Mn + O_2 \rightarrow 2MnO$$
$$Si + O_2 \rightarrow SiO_2$$

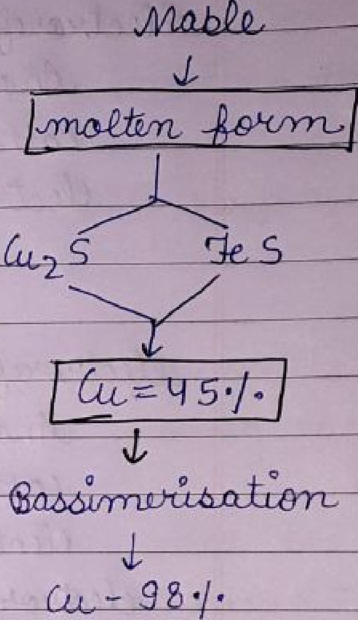
Bassmerization :- the process of farther heating of mollen Matte in the presence of flux is called

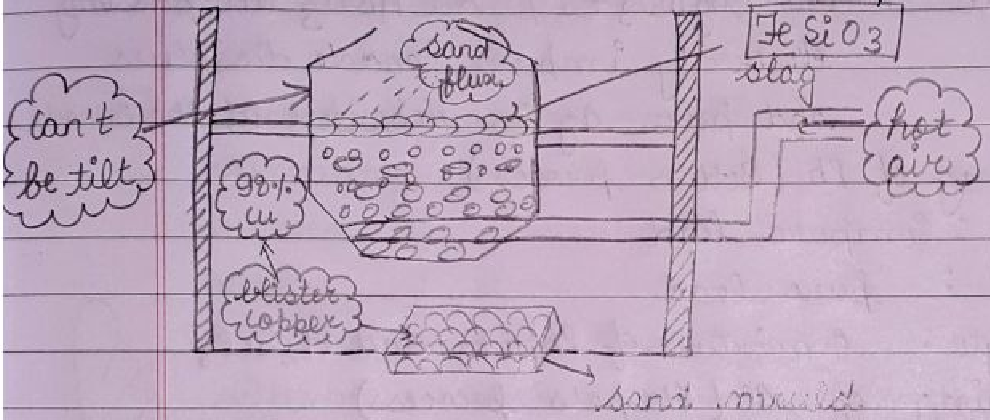
$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2$$

$$FeO + SiO_2 \longrightarrow FeSiO_3 \text{ (slag)}$$

$$Cu_2S + O_2 \longrightarrow Cu_2O + SO_2$$

$$2Cu_2O + Cu_2S \longrightarrow \underset{98\%}{\boxed{6Cu}} + SO_2$$





Bassimer
⇓
Shape
⇓
pear like

Cu_2S → cupperous sulphite
FeS → ferrous sulphide
FeO → " oxide
Cu_2O → copperous oxide

(III) Electro refining of metals :

metals such as Cu, Ag, Zn, Sn, Pb, Al, Ni, Cr are refined by this method

The impure metal is made the anode of an electrolytic cell, while cathode is thin plate of pure metal. Electrolyte is the solⁿ of a salt of the metal.

On passing the electric current pure metal from the anode dissolves and gets deposited at the cathode. The soluble impurities go into the solution while insoluble or less electropositive impurities settle down below the anode as anode mud or sludge.

For example :-

→ Electrorefining of copper

Anode : Blister copper (98%)
cathode : pure copper
electrolyte : An aq. sol^n of $CuSO_4$ (15%) + 5% dil H_2SO_4

Electrorefining of silver

Anode : impure silver
cathode : pure silver
electrolyte : Aq. $AgNO_3$ + 1% dil HNO_3 on passing electricity impure anode dissolves and pure Ag is deposited at the cathod

electrorefining of Pb (Bett's process)

Anode : impure lead
cathode : pure lead.
electrolyte : A mixture of $PbSiF_6$ and H_2SiF_6

electrorefining of Al (Hoope's process)

Anode : impure Al
cathode : pure Al
electrolyte : a mixture of Na_3AlF_6 + CaF_2.

(IV) Vapour phase refining (thermal decomposition)

i) Van-Arkel process:

this method is very useful for removing all the Oxygen + nitrogen present in the form of impurity

i) employed to get metal in very pure form of small quantities

ii) In this method, the metal is converted into a volatile unstable compound (eg. iodide) and impurities are not affected during compound formation

iii) The compound thus obtained is decomposed to get the pure metal.

iv) Employed for purification of metals like titanium and zirconium

$$\underset{\text{impure}}{Ti}(s) + 2I_2(g) \xrightarrow{523K} TiI_4(g)$$

$$TiI_4(g) \xrightarrow{1800K} Ti(s)(pure) + 2I_2(g)$$

ii) Mond's process :-

i) Nickel is purified by using CO gas. This involves the formation of nickel tetracarbonyl

$$Ni(impure) + 4CO \xrightarrow[350K]{330K} [Ni(CO)_4] \xrightarrow[470K]{450K} Ni(pure) + 4CO\uparrow$$

iii) chromatographic methods :-

chromatography is the most modern and versatile method of separation, purification and testing the purity of elements and their compounds.

The method is based upon the principle that the different components of a mixture are absorbed to different extents of an adsorbent.