

## Iron and steel:

Though materials like plastics & other polymers have created their usefulness importance, iron & steel remained its importance. In this unit we are going to study iron manufacture and its different forms useful for mankind.

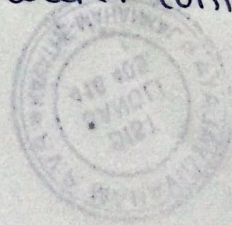
\* Occurance:- About 4.5% of earth crust is constituted by iron. which indicates there is huge abundance of iron in earth crust.

It is found in soil, rocks, minerals, green plants, haemoglobin.

Important minerals of iron are oxides, carbonate and sulphides of iron:-

Oxides:- In this type of minerals iron is present in the form of oxide.

1. Haematite:- Its chemical formula is  $Fe_2O_3$ . in which iron is in +3 oxidation state. It is called as ferric oxide ore. It is reddish brown in colour. It contains about 70% iron.
2. Magnetite:- Its chemical formula is  $Fe_3O_4$ . It is called as ferrous ferric oxide ( $FeO \cdot Fe_2O_3$ ). Iron has +2 as well as +3 oxidation state. It is black in colour. It contains about 73% iron.
3. Limonite:- Its chemical formula is  $FeO(OH) \cdot nH_2O$  or  $2Fe_2O_3 \cdot 3H_2O$ . It is yellowish brown in colour. Its percentage of iron depends on presence of water content.



Carbonate:- In this type of mineral iron is present in the form of carbonate.

Siderite:- It is also called as spathic iron, its formula is  $FeCO_3$ . This mineral contains about 48% of iron. generally process of calcination is employed for purification.

Sulphides:- In this type of minerals iron is present in the form of sulphides. that are Iron sulphid

1. Pyrites ( $FeS_2$ ) here ~~is~~ Iron is present in the form of sulphide. 2. Copper Pyrites - ( $CuFeS_2$ ) it is also called as copper iron pyrites or chalcopyrites 3. Arsenical

4. Pyrites: ~~FeAsS~~  $FeAsS$

commercial value of mineral to act as ore depends not only on percentage of iron in mineral but also presence or absence of objectionable impurities. such as arsenic, titanium sulphur and phosphorus.

In india distribution of iron is very large specially it is found in Karnataka, Maharashtra, Madhya Pradesh. Production of iron and steel is profitable as all raw materials are easily available.

\* Definition of some terms:-

\* Metallurgy:- The process of extraction of metal from its ore is known as metallurgy. It involves the concentration of ore and reduction of an ore to free metal.

\* Mineral:- Any substance that contains metal either in free state or combined state obtained from earth crust is known as mineral.

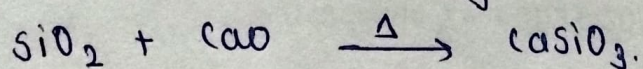
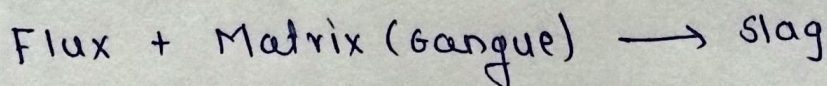
\* Ores:- The mineral from which metal can be extracted on commercial scale eg. Bauxite, Haematite

Here note that all ores are minerals but all minerals are not ore.

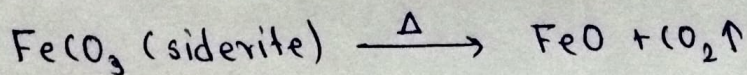
\* Gangue:- Any unwanted impurity associated with metal in its ore is called gangue or matrix.

\* Flux:- The substance which is added to convert gangue of an ore into slag is called flux. There are three types of fluxes acidic fluxes eg.  $\text{SiO}_2$ ,  $\text{P}_2\text{O}_5$  etc. basic fluxes eg.  $\text{CaO}$ ,  $\text{MgO}$  etc and amphoteric fluxes eg.  $\text{Al}_2\text{O}_3$ .

\* Slag:- The easily fusible mass formed due to action of flux on gangue during smelting of ore

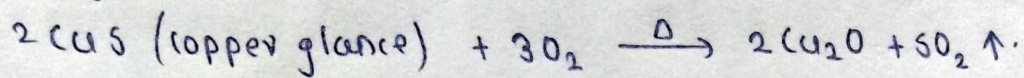


\* Calcination:- It is the process of heating the concentrated ore below its melting point in the absence or limited supply of air or  $\text{O}_2$ .



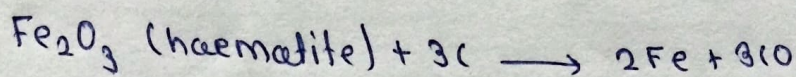
Commonly ores free from P, As, S etc and carbonate and hydrated ores are calcined.

\* Roasting:- The process of heating the concentrated ore below its melting point in excess of air or  $O_2$



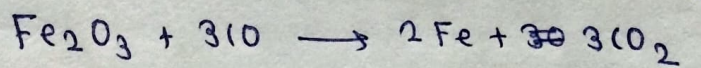
generally sulphide ores, or ores containing impurities like S, P, As, Sb are roasted.

\* Smelting:- It is the process of separation of fused metal from its calcined or roasted ore by heating and melting it in presence of suitable reducing agent and flux.

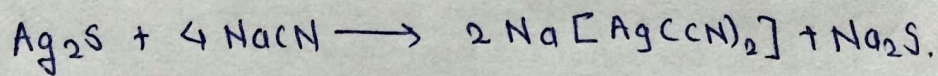


Thus ~~is~~ smelting involves calcination or ~~and~~ Roasting and reduction.

\* Reduction:- Extraction of Metal from their ore is generally called reduction. It can be carried out by using suitable chemical agent which ~~dissolves the metal & keep gangue as it is~~ like coke, or CO, hydrogen metals like Mg, Al, Ca etc.



\* Leaching:- It is the process of concentrating the metal from its ore by reacting with suitable agent which dissolves the metal and keep the gangue as it is



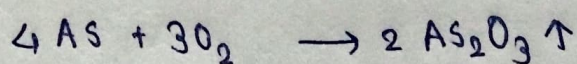
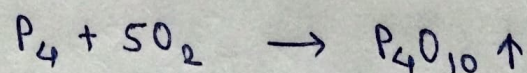
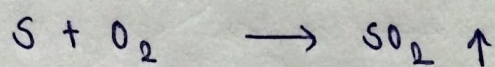
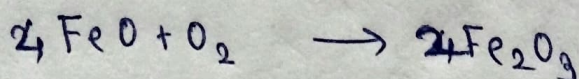
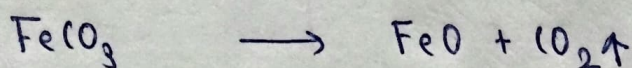
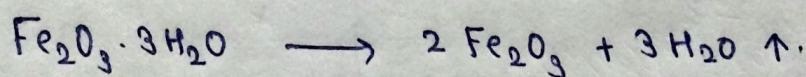
\* Types of Iron:- The chief varieties of iron are cast iron, wrought iron and steel. Cast or pig iron contains 2.5-4.5% percent of carbon and other impurities. While steel contains 0.25 to 2.5 percent carbon content and wrought iron contains 0.12 to 0.25% percent carbon. Thus purest form of iron is wrought iron.

## \* Extraction of Iron by Blast furnace :-

Extraction of iron from its ores involves two important steps ① preliminary treatment ② smelting or reduction

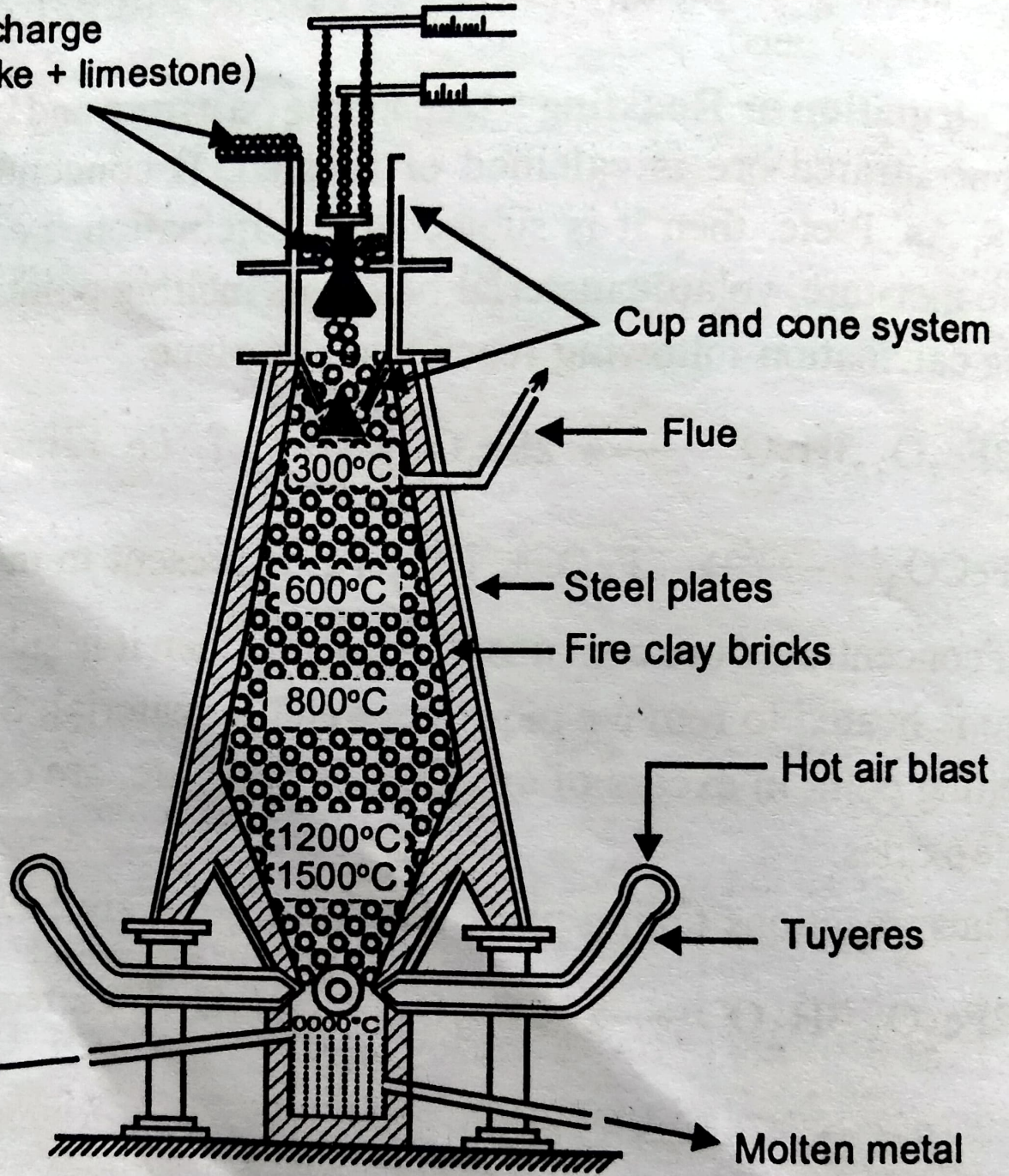
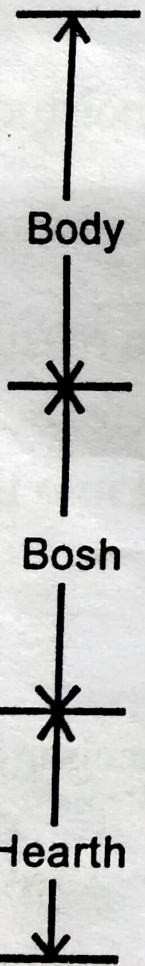
1. Preliminary treatment :- The ore is ~~is~~ crushed and converted to fine powder. Then it is washed under stream of water to remove clay, sand and other water soluble impurities. The ore is subjected to gravity separation to remove lighter impurities. Then powdered ore is subjected to magnetic separation to remove non magnetic impurities.

Preliminary treatment. Calcination or Roasting: Depending on nature and type of impurity the concentrated ore is calcined or roasted. If concentrated ore is free from S, As, P etc then it is subjected to calcination otherwise process of Roasting is done. The following reactions takes place during process of calcination / Roasting



2. Smelting (Reduction) :- The smelting is carried out in blast furnace. Blast furnace is tall cylindrical and made by steel and lined inside with firebricks. To facilitate the proper flow of material it is slightly narrower at the top and bottom. as shown in figure.

Furnace charge  
(Ore + coke + limestone)

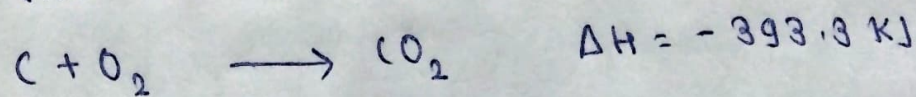


It has cup and cone arrangement at the top which prevent the exit of gases during the charging. The upper longer part of furnace is called body, middle part is Bosh and lower part is Hearth. The body is provided with outlet for flue gases. At the base of Bosh there is water jacketed pipes which are used to admit hot blast of air called tuyeres or bustles. Hearth has two outlets upper one is used to remove molten slag and lower one is used to remove molten iron.

Working:- The charge consisting of calcined or roasted ore (8 parts) and coke (4 parts) and limestone (1 part) is admitted into blast furnace. While hot blast of air about  $800^{\circ}\text{C}$  is introduced into furnace through tuyeres. Added coke acts as reducing agent as well as fuel while limestone acts as basic flux.

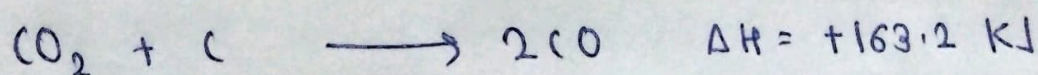
Reactions taking place in blast furnace:- The chemical reactions taking place in different zones of blast furnace are as follows.

(a) zone of combustion:- Near the tuyeres the portion of blast furnace is called zone of combustion. In this zone the combustion of coke takes place, to produce  $\text{CO}_2$



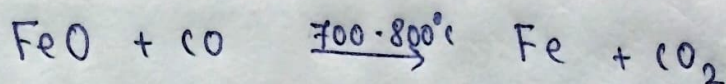
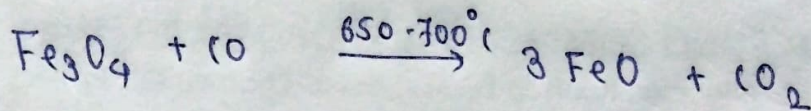
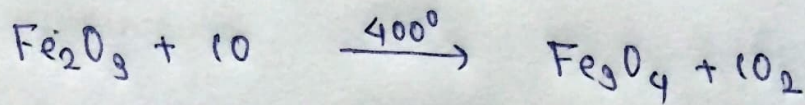
as this reaction is exothermic, a lot of heat is evolved and temperature raises up to  $1500^{\circ}\text{C}$

(b) zone of heat absorption ( $800-1200^{\circ}\text{C}$ ) :-  $\text{CO}_2$  formed in zone of combustion rises up in the furnace it meets fresh coke to produce CO



Since this reaction is endothermic there is decrease in temperature from bottom to top takes place

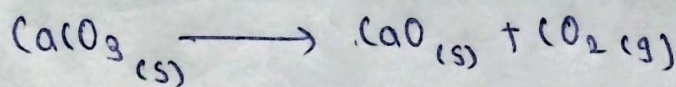
(c) zone of reduction: - At temperature range about  $300^{\circ}\text{C}$  to  $800^{\circ}\text{C}$  in upper part of Furnace. Ferric oxide is reduced to spongy iron by carbon monoxide.



Overall reaction is

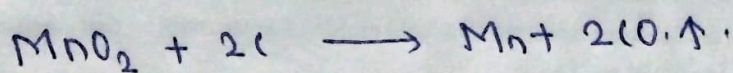


(d) zone of slag formation: - In this zone the temperature is about  $900^{\circ}\text{C}$  where limestone gives  $\text{CaO}$  which acts as a flux and reacts with impurity like silica to produce calcium silicate slag.



calcium silicate slag.

(e) zone of fusion: - (about  $1200-1500^{\circ}\text{C}$ ) In this zone spongy iron melts. impurities like  $\text{MnO}_2$  and  $\text{Ca}_3\text{PO}_4$  are reduced to elementary form and get mixed with melted iron.



Due to presence of impurities iron along with slag melts at  $1200^{\circ}\text{C}$  to  $1300^{\circ}\text{C}$  which are collected in well. Slag flows over molten iron so it is removed from upper outlet while iron from lower outlet of well.

## \* Products of Blast Furnace:-

The products of blast furnace are pig iron, slag, furnace gases.

i. Pig or cast iron:- It is impure, weak variety and could not be shaped into different articles on hammering. The cast or pig iron contains Fe (92-95%), C (2.6-4.3%), Si (0.7-3%), P, Mn & S in small proportion.

When molten iron is cooled suddenly, white crystalline cast iron is obtained ( $Fe_3C$ ) it is harder, brittle and rustless variety. When molten iron is slowly cooled most of carbon get separated it is called grey cast iron it is softer and low tensile strength.

ii. Slag:- commonly it is calcium silicate and lighter than molten metal. so it floats over molten metal and protect the metal from oxidation by hot blast of air.

It is used in road making, as a filler for railroads, in the manufacture of cement.

iii. Furnace gases:- The waste gases leaving from flue of the furnace are called flue gases. Approximately mixture of furnace gases contains.

$CO$  : 25-30%,  $N_2$  : 58-60%,  $CO_2$  : 10%,  $H_2$  : 4-5%.  
hydrocarbons 1-2%.

## \* Steel :-

Steel is the alloy of iron with carbon content intermediate between cast iron and wrought iron. It is most important commercial form of iron can be obtained by removing C, P, S and Si from cast iron or adding required quantity of ~~iron~~ carbon to wrought iron.

Types of steel :- Based on chemical composition steel may be divided into two classes namely (a) carbon steel and (b) alloy steel

\* Carbon steel :- Basis of quantity of carbon present in steel carbon steel is divided into three types mild steel, medium carbon steel and high carbon steel.

1. Mild steel :- This type of steel contains less than 0.2 percent of carbon content. It is quite tough, ductile weldable by forging can be permanently magnetised. It is used in place of wrought iron. It is used in boiler plates, rivets etc.
2. Medium Carbon Steel :- This type of steel contains 0.2 to 0.6% carbon content. It is tougher and harder than mild steel. It is used for making rails, structural elements such as grinder beams. It is also called structural steel.
3. High carbon steel :- This type of steel contains larger quantity of carbon content ranging from 0.6 to 1.5 percent. It is also called as cast steel or high carbon steel. It can be hardened or tempered easily. It cannot be easily forged and can withstand shocks and vibrations much better. It is used for making tools, files, surgical instruments, razors drills and so on.

In general increase in carbon content increases hardness and decreases ductility, weldability of the steel.

Alloy steel:- Steel when alloyed with at least one other element than carbon to give special property is called alloy steel. Some times more than one element is used in the production of alloys. Generally they are added to molten steel in electric furnace.

On the basis of chemical composition physical & mechanical properties alloy steels are further divided into large number of sub types:-

● Manganese steel:- This type of steel contains 1.2 to 17 percent manganese. It has high strength and extra-ordinary resistance to wear. It is used for making rail road switch points, jaws of road crushing machinery, burglar proof safes etc.

● Nickel steel:- Nickel steel contains about 2.5 to 10 percent nickel. It has greatest toughness, heat resistivity and elasticity. It is used in making crankshafts, gears, heavy guns, aeroplane parts.

● Invar steel:- Nickel steel containing about 35% of nickel with little manganese and carbon is called invar. Its coefficient of expansion is very small and hence used for preparation of pendulum rods, balance wheels of watches.

Stainless steel:- Stainless steel contains about 16 to 20% chromium. It is extremely tough hard and corrosion resistant hence it is used to make cutting tool, ball bearings, armour plates and 8-10% nickel. It is resistant to action of organic acids. It is used to make stainless cutlery, cycle automobile parts.

Brittle steel:- Steel containing phosphorus or sulphur in excess is called brittle steel. The phosphorus steel is cold short. and sulphur steel is hot short.

\* Conversion of cast iron into steel :-  
conversion of cast iron into steel takes place by different methods such as- Bessemer process, L.D. Process, Open hearth process, Electric arc process

Bessemer Process :- This process proposed by Sir. Henry Bessemer in 1856 and is used in manufacture of steel. This process is carried out in large egg shaped vessel called Bessemer converter, which is made up of steel plates and lined with silicious material and lined with silicious material.

When acidic impurities are to be removed a basic lining such as dolomite ( $\text{CaCO}_3$  and  $\text{MgCO}_3$ ) is used so it is Basic Bessemer process. When basic impurities are to be removed acidic lining of  $\text{SiO}_2$  is used so the process is called acid Bessemer process.

To admit hot blast of air number of holes are provided to the base of converter. The converter is mounted on trunion so that it can be tilted into different positions according to requirement.

Working :- The Bessemer converter is tilted to horizontal position and about 15 to 20 tons of molten cast iron from the blast furnace is run into converter. Then it is tilted to vertical position and hot blast of air is blown from the converter the temperature rises up to  $1900^\circ\text{C}$ . The impurities are first oxidized and then removed as a slag.



- Disadvantages:-
- ① It is not continuous process
  - ② Low grade steel is obtained.

L. D. Process:- This method of steel making was developed by Robert Durrer in 1948 and used in Linz and Donawitz in Austria. In this process high purity oxygen is blown from the top of the converter through copper lance with high pressure.

The furnace is an egg shaped steel vessel lined from inside with basic lining ( $\text{CaCO}_3$ ) and supported on side arms called trunnion.

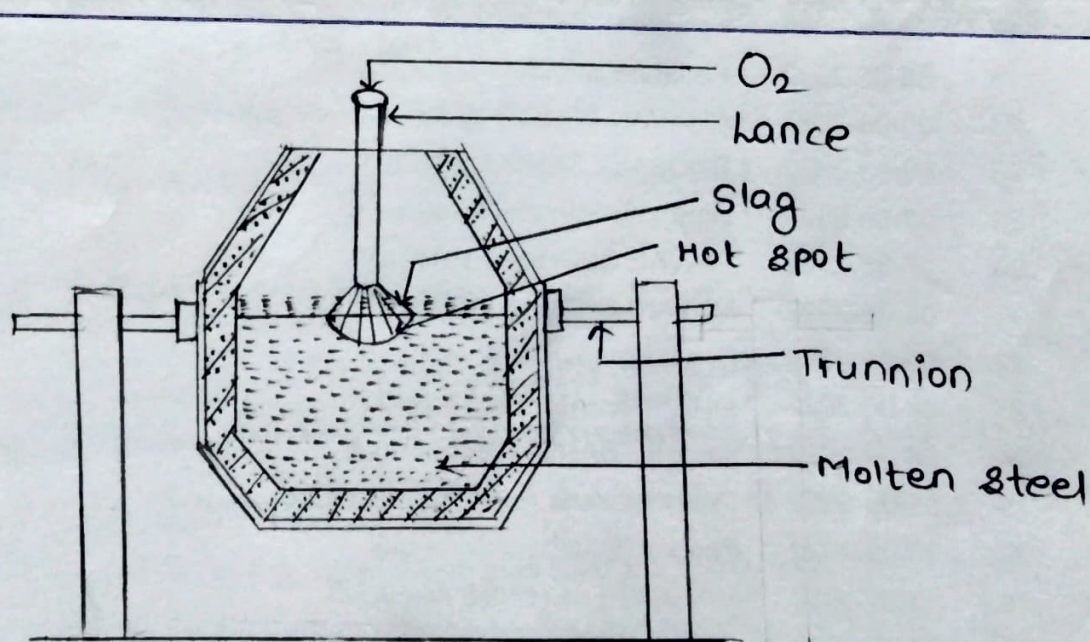
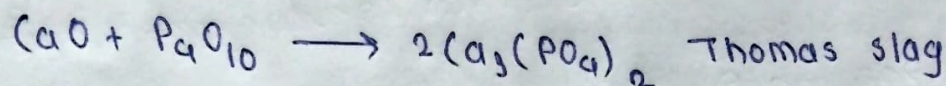
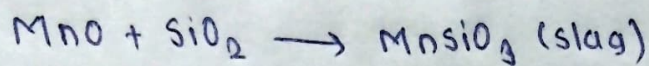
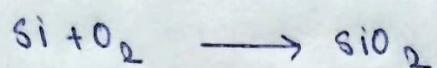


Fig. L. D. Converter.

Workings:- The converter is charged with the scrap, limestone pig iron. The pure and dry oxygen is introduced into molten mass through copper lance under high pressure. The impurities like Si, Mn, P, C are oxidised by oxygen and removed as a slag. A convectional current is developed in converter and entire metal gets purified.

The reactions occurring during the process are



Advantages :-

1. Its capital expenditure is less
2. low energy is required
3. Manufacturing cost is low
4. The process is rapid
5. About 20 to 60 tons of steel is obtained in 45 minutes.

Heat treatment on steel :-

The physical & chemical properties of steel not only depends on chemical composition but also on heat treatment.

The process of heating steel and cooling under specific condition of temperature so as to modify their physical properties without changing chemical composition is known as heat treatment on steel.

These methods are as follows.

1. Annealing :- The process of heating steel to a bright red hot and then cooling it slowly is known as annealing. Then steel becomes soft and pliable by annealing.

Annealing are of two types :-

Low temperature annealing :- In this process the steel is heated below its lower critical temperature and then cool slowly. Due to this shock resistivity & ductility increases &

hardness decreases.

High temperature annealing:- In this process steel is heated above its upper critical temperature cooled slowly due to this steel becomes softer and its ductility toughness increases

2. Hardening:- The process of heating steel to bright redness and then cooling suddenly by plunging in oil or water is called as hardening. Due to this steel becomes hard & brittle.

3. Tempering:- The process of heating the hardened steel to a temperature much below redness and cooling it slowly is known as tempering. The product is neither so hard nor so brittle.

4. Surface treatment of steel:-

Case hardening:- The process of giving a thin coating of hardened steel to a flexible, strong mild steel by heating it in contact with charcoal and quenching in oil is called. case hardening such steel become resistant to wear and tear such steel is used in locomotive axles.

Nitriding:- The process of heating the steel in the atmosphere of ammonia, when the surface is coated with iron nitride is known as nitriding.

Cyaniding:- The process of immersing the steel in molten salt containing KCN or NaCN about  $870^{\circ}\text{C}$  and quenching in water or oil called cyaniding.

5. Forging:- The process of heating the steel to red hotness and hammering or subjecting to load to give various mechanical properties.