# METALLURGY

## ❑ INTRODUCTION :

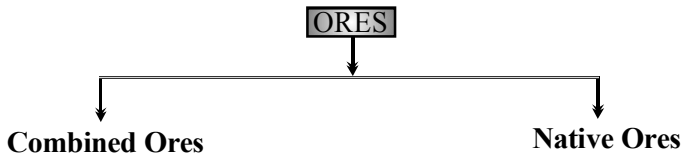
The compound of a metal found in nature is called a **mineral**.

The minerals from which metal can be economically and conveniently extracted are called **ores**.

An ore is usually contaminated with earthy or undesired materials known as **gangue**.

***Note :*** All minerals are not ores but all ores are minerals.

Ores may be classified mainly into following two classes.




***(a)*** ***Native ores :*** Silver, gold, platinum etc, occur as native ores.

***(b)*** ***Combined ores :*** They contain the metal in combined form.

***(i)*** ***Oxidised ores :*** Oxide ores , Carbonate ores, Sulphate ores, Phosphate ores, Silicate ores.

***(ii)*** ***Sulphurised ores :*** These ores consist of sulphides of metals like iron, lead, zinc, mercury etc.

***(iii)*** ***Halide ores :*** These ores consist of halides of metals

## ❑ METALLURGY :

The scientific and technological process used for the extraction/isolation of the metal from its ore is called as metallurgy.

The isolation and extraction of metals from their ores involve the following major steps:

(A) Crushing of the ore.

(B) Dressing or concentration of the ore.

(C) Isolation of the crude metal from its ore

(D) Purification or refining of the metal.

***(A) Crushing and Grinding :*** The ore is first crushed by crushers and ground to a powder.

***(B) Concentration of the ore :*** The removal of unwanted, useless impurities from the ore is called ***dressing, concentration or benefaction of ore***.

There are several steps for the concentration of Ores.

***(I) By physical separation***

***(a) Gravity separation (Levigation)***

***(b) Froth Floatation method***

***(c) Magnetic separation***

***(i) Gravity separation or Levigation method :***

It is based on the difference in the densities of the gangue and ore particles. This method is generally used for the concentration of oxide and native ores.

***(ii) Electromagnetic separation :***

It is based on differences in magnetic properties of the ore components.

It is used when either the ore or the impurities associated with it are magnetic in nature.

***Examples :***

Chromite ore($FeO.Cr_2O_3$) is separated from non–magnetic silicious impurities and cassiterite ore($SnO_2$) is separated from magnetic Wolframite ($FeWO_4 + MnWO_4$).

***(iii) Froth floatation process :*** This process is based on differential wetting of the ore by oil and gangue by water.

***Examples :*** Galena, PbS (ore of Pb) ; copper pyrites $Cu_2S.Fe_2S_3$ or $CuFeS_2$ (ore of copper) ; zinc blende, ZnS (ore of zinc) etc.

***(a) Frothers :*** Oil like pine oil, camphor oil etc., are used as frothers.

***(b) Frothers stablizer :*** Aneline & Cressol

***(c) Collectors :*** Potassium or sodium ethyl xanthate is used as a collector.

***(d) Activating and depressing agents :*** For example galena (PbS) usually contains the minerals namely zinc blende (ZnS) and pyrites ($FeS_2$) as impurities. Floatation is carried out by using potassium ethyl xanthate (used as a collector) along with NaCN and $Na_2CO_3$ (used as depressing agent).

***(II) By Chemical separation***

Some of the ores are concentrated by means of chemical treatment.

***Leaching :*** It involves the treatment of the ore with a suitable reagent. as to make it soluble while impurity remain insoluble. The ore is recovered from the solution by suitable chemical method.

**(i) Bayer's process**

**(ii) Cyanide process**

## ❑ CALCINATION

Calcination is a process in which ore is heated, generally in the **absence of air**, to expel water from a hydrated oxide or carbon dioxide from a carbonate at temperature below their melting points.

***For Example***

(i) $CaCO_3 \longrightarrow CaO + CO_2$

(ii) $Al_2O_3.\ 2H_2O \longrightarrow Al_2O_3 + 2H_2O$

## ROASTING

The removal of the excess sulphur contained in sulphide ores by heating **in an excess of air** is called roasting.

(Metal sulphides $\xrightarrow{+O_2}$ Metal oxide + $SO_2$)

(iii) $2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + SO_2\uparrow$

## THERMODYNAMICS OF REDUCTION PROCESSES (ELLINGHAM DIAGRAM)

The extraction of metals from their oxides using carbon or other metals, and by thermal decomposition, involves a number of points which merit detailed discussion.

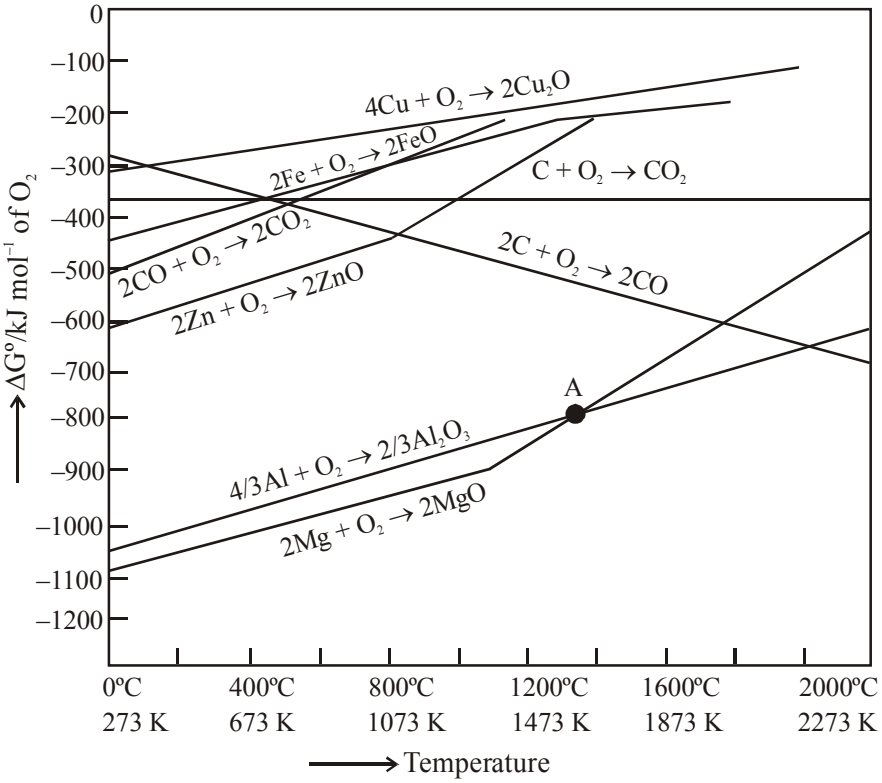
For a spontaneous reaction, the free energy change $\Delta G$ must be negative.

$$\Delta G = \Delta H - T\Delta S$$

$\Delta H$ is the enthalpy change during the reaction, T is the absolute temperature, and $\Delta S$ is the change in entropy during the reaction. Consider a reaction such as the formation of an oxide:

$$M + O_2 \rightarrow MO$$

Dioxygen is used up in the course of this reaction. Gases have a more random structure (less ordered) than liquids or solids. Consequently gases have a higher entropy than liquids or solids. In this reaction S the entropy or randomness decreases, the hence $\Delta S$ is negative. Thus if the temperature is raised then $T\Delta S$ becomes more negative. Since $T\Delta S$ is subtracted in the equation, then $\Delta G$ becomes less negative. Thus the free energy changed increases with an increase of temperature.




The free energy changes that occur when one gram molecule of a common reactant (in this case dioxygen) is used may be plotted graphically against temperature for a number of reactions of metals of their oxides. This graph is shown in figure and is called an Ellingham diagram (for oxides). Similar diagrams can be produced for one gram molecule of sulphur, giving an Ellingham diagram for sulphides, and similarly for halides.

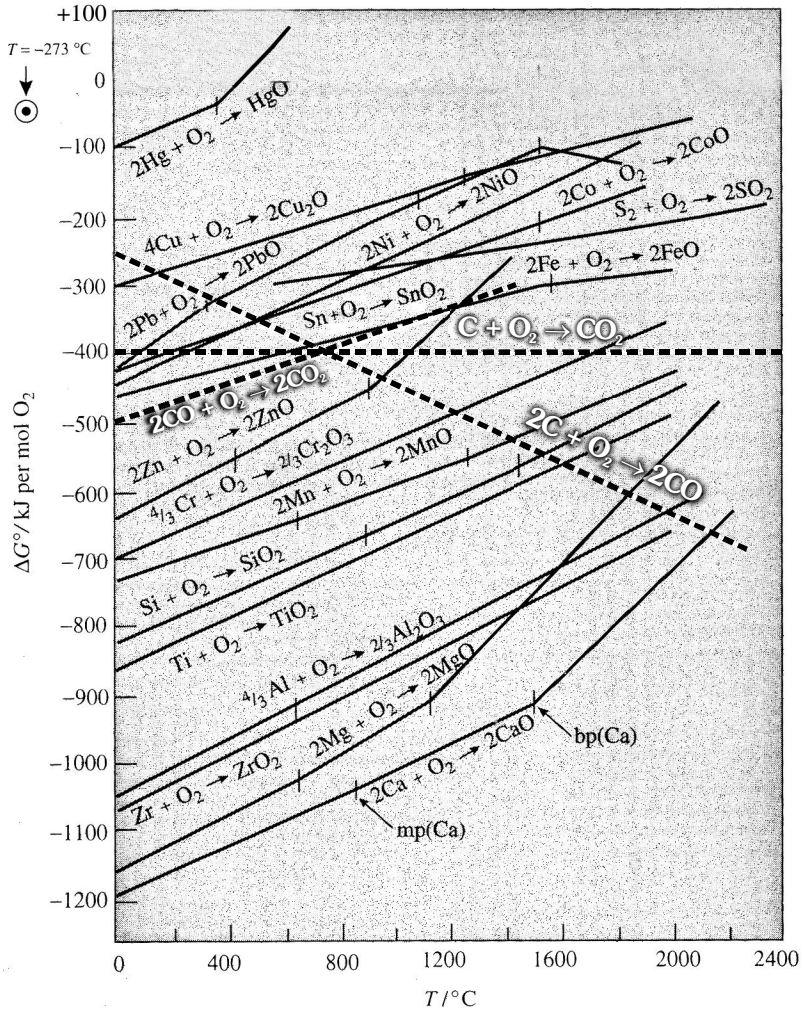
***The Ellingham diagram for oxides shows several important features:***

**(i)** The graph for metal oxide all slope upwards, because the free energy change increases with an increase of temperature as discussed above.

**(ii)** The free energy changes all follows a straight line unless the materials metal or vaporize.

**(iii)** When the temperature is raised, a point will be reached where the graph crosses the $\Delta G = 0$ line. Below this temperature the free energy of formation of the oxide is negative, so the oxide is stable. Above this temperature the free of formation of the oxide is positive, and the oxide becomes unstable, and should decompose into the metal and dioxygen.

**(iv)** Any metal will reduce the oxide of other metals which lie above it in the Ellingham diagram because the free energy will become more negative by an amount equal to the different between the two graphs at that particular temperature.




***Limitations of Ellingham Diagram***

**(i)** The graph simply indicates whether a reaction is possible or not i.e., the tendency of reduction with a reducing agent is indicated. This is so because it is based only on the thermodynamic concepts. It does not say about the kinetics of the reduction process (Cannot answer questions like how fast it could be ?).

**(ii)** The interpretation of $\Delta G^{\Theta}$ is based on K($\Delta G^{\Theta} = -$ RT lnK). Thus it is presumed that the reactants of products are in equilibrium.

## ❑ REDUCTION OF ORE TO THE METAL

The calcined or roasted ore is then reduced to the metallic state in either of the following ways.

***(i) Reduction by Carbon (Smelting)***

- Concentrate ore (ore + gangue) + R.A. (carbon) + Flux [$\therefore$ R.A. $\Rightarrow$ Reducing agent]

$\downarrow$

Metal + Slag + gases

$PbO + C \longrightarrow Pb + CO$

$Fe_2O_3 + 3C \longrightarrow Fe + 3CO$

Acidic impurity + Flux $\longrightarrow$ slag

$P_2O_5 + 3CaO \longrightarrow Ca_3(PO_4)_2$

Basic impurity + Flux $\longrightarrow$ slag

$MgCO_3 + SiO_2 \longrightarrow MgSiO_3 + CO_2 \uparrow$

$FeO + SiO_2 \longrightarrow FeSiO_3$

***(ii) Self Reduction***

Sulphides of certain metals are reduced to metal without using any additional reducing agent. ores of Cu, Pb, Hg etc.

***Self Reduction for Pb***

$2PbS + 3O_2 \xrightarrow{\text{Roasting}} 2PbO + 2SO_2 \uparrow$

(Galena) (air)

$PbS + 2PbO \xrightarrow[\text{Absence of air}]{\text{High temp}} 3Pb + SO_2 \uparrow$

(unroasted ore) (roasted ore) (Self reduction)

***(iii) Metal Displacement Method***

$2Na[Au(CN)_2] + Zn \longrightarrow Na_2[Zn(CN)_4] + 2Au$

$2Na[Ag(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2Ag$

Sodium tetra cyanozincate

***(iv) Electrolytic Reduction***

This process is mainly used for the extraction of **highly electropositive metals.**

**Ex.** Na, K, Mg, Ca, Al, etc.

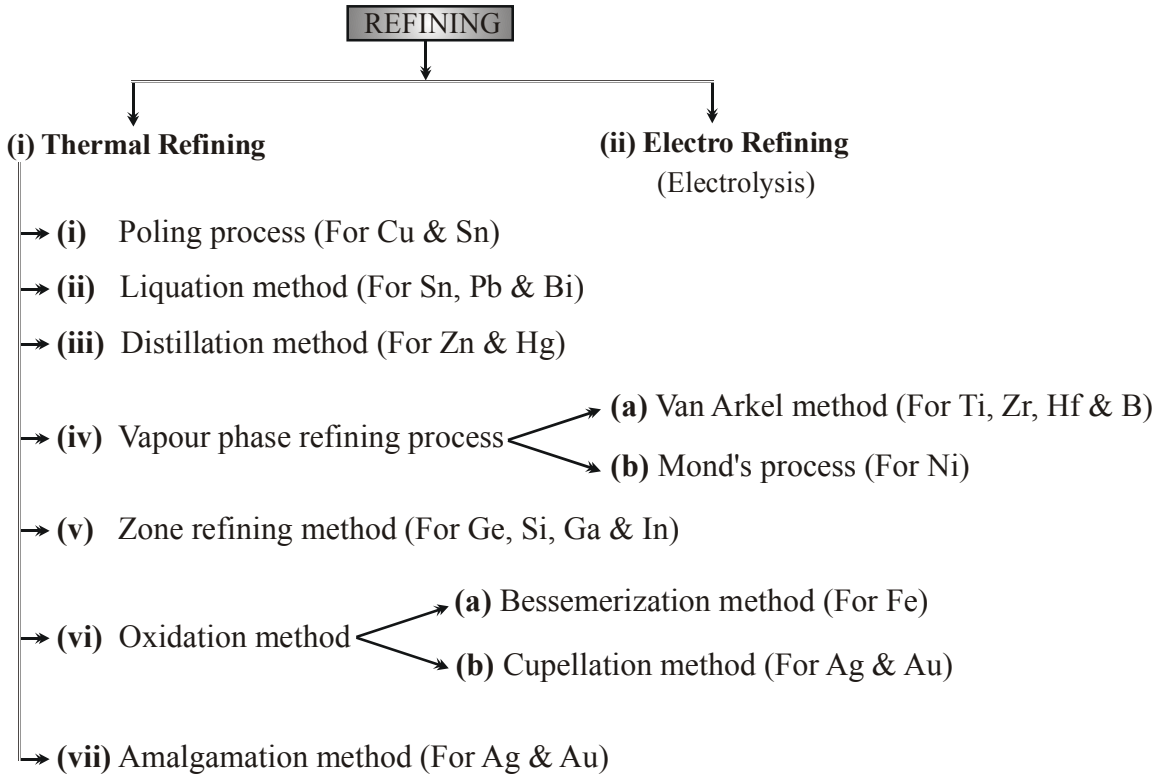
***(v) Thermite Reduction or Thermite Process***

Al is used as reducing agent in this process. This process is employed in the case of those metals which have very high melting points and are to be extracted from their oxides

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

$3Mn_3O_4 + 8Al \longrightarrow 9Mn + 4Al_2O_3$

## ❑ REFINING OF METALS

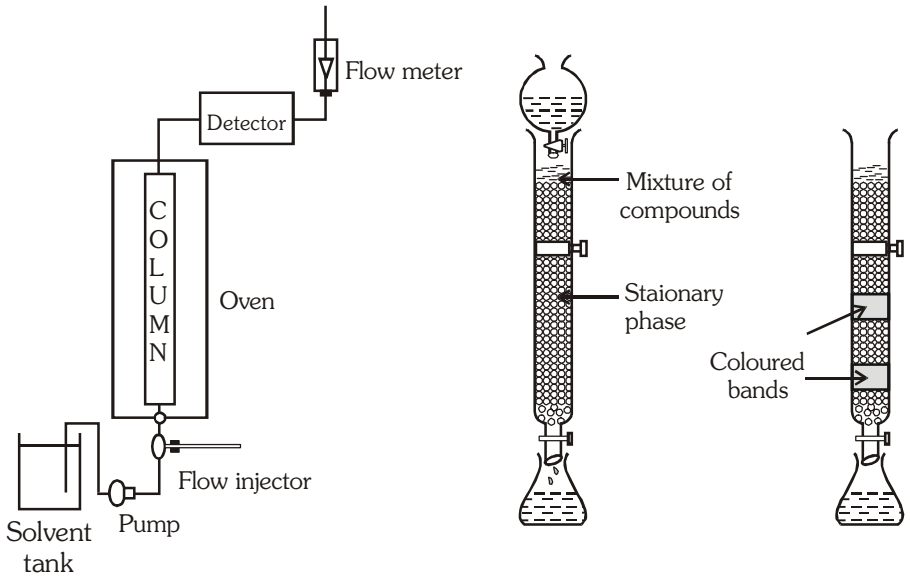



## ❑ OTHER METHOD : BY CHROMATOGRAPHIC METHOD

This method is based on the principle that different components of a mixture are differently adsorbed on an adsorbent. The mixture is put in a liquid or gaseous medium which is moved through the adsorbent.

Different components are adsorbed at different levels on the column. Later the adsorbed components are removed (eluted) by using suitable solvent (eluant). Depending upon the physical state of the moving medium and the adsorbent material and also on the process of passage of the moving medium, the chromatographic method is given the name. In one such method the column of $Al_2O_3$ is prepared in a glass tube and the moving medium containing a solution of the components is in liquid form.

This is an example of column chromatography. This is very useful for purification of the elements which are available in minute quantities and the impurities are not very different in chemical properties from the element to be purified. There are several chromatographic techniques such as paper chromatography, column chromatography, gas chromatography, etc. Procedures followed in column chromatography have been depicted in the following figures.




**(a) Industrial method** **(b) Laboratory method**

**Fig. Schematic diagrams showing column chromatography**

## EXTRACTION OF SOME INDIVIDUAL METALS

### ❑ EXTRACTION OF COPPER

**(1) Extraction of copper :**

**Occurrence :** Copper occurs in free as well as in combined state. The main ores are as follows.

(i) Copper pyrites $CuFeS_2$ or $Cu_2S.Fe_2S_3$

(ii) Cuprite (Ruby copper) $Cu_2O$

(iii) Copper glance $Cu_2S$

(iv) Malachite $Cu(OH)_2.CuCO_3$

(v) Azurite $2Cu(OH)_2.CuCO_3$

**Extraction :**

Copper is extracted from the ores (sulphide) by two process.

**(A) Pyrometallurgical Process :**

This is a dry process and applied to high grade ores (containing 4% or more copper).

**(B) Hydrometallurgical Process :**

This is a wet process and applied to low grade ores.

**(A) Extraction from pyrites by pyrometallurgical process (Smelting Process)**

**(i) Concentration :**

The finely powdered ore is concentrated by froth floatation process.

**(ii) Roasting :**

The concentrated ore is heated strongly in presence of air.

Sulphur, arsenic, and antimony are removed in form of their volatile oxides while the ore is converted into a mixture of cuprous and ferrous sulphides.

These sulphides are partially oxidised to oxides.

(a) $S + O_2 \rightarrow SO_2 \uparrow$

(b) $2As_2S_3 + 9O_2 \rightarrow 2As_2O_3\uparrow + 6SO_2 \uparrow$

(c) $2Sb_2S_3 + 9O_2 \rightarrow 2Sb_2O_3 \uparrow + 6SO_2 \uparrow$

(d) $2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$

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

**(iii) Smelting**

The roasted ore is mixed with sand (flux) and coke (fuel) and then heated in a reverberatory furnace water jacketed blast furnace called smelter. The oxidation of ferrous sulphide which started during roasting now goes a step further. Ferrous oxide formed, reacts with sand to form ferrous silicate (slag).

Here some FeS reacts with $Cu_2O$ to form $Cu_2S$ again.

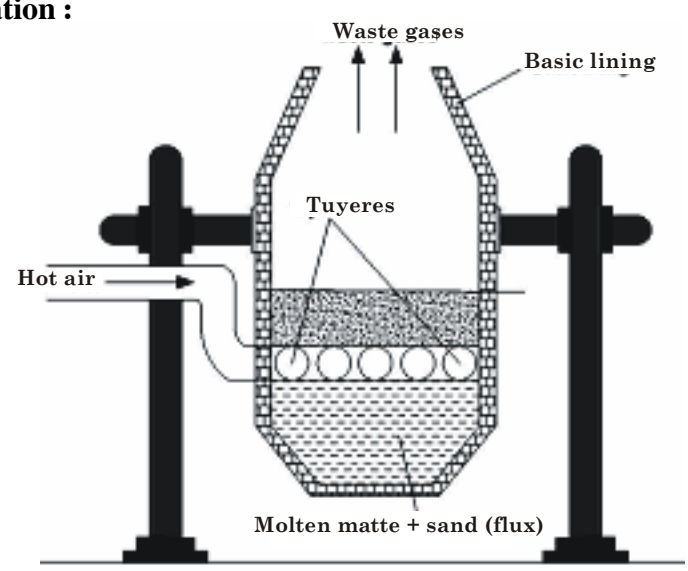
(a) $FeO + SiO_2 \rightarrow FeSiO_3$ (Slag)

(b) $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

(c) $Cu_2O + FeS \rightarrow Cu_2S + FeO$

Slag (forming upper layer) and molten mass consisting of $Cu_2S$ and a little FeS **(forming lower layer and commonly called matte)** are removed from separate holes.

**(iv) Bessemerisation :**




Molten matte is heated in a Bessemer converter and a blast of air mixed with sand is blown through the molten mass.

Here iron (FeS) is completely removed as slag, a part of $Cu_2S$ is oxidised to $Cu_2O$ and a part of $Cu_2S$ reduces $Cu_2O$ to metallic copper.

**(a)** $2FeS + 3O_2 \rightarrow 2FeO + 2SO_2 \uparrow$

$FeO + SiO_2 \rightarrow FeSiO_3$

**(b)** $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2 \uparrow$

$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2\uparrow$

The molten copper is poured off into moulds. As it cools it gives up the dissolved sulphur dioxide which forms blister on the surface of the metal. Hence the metal thus obtained is called blister copper and contains 98 percent copper.

**(v) Refining of copper :**

**(a) Poling :**

The molten blister copper is heated in pressure of air and stirred with green wood **poles**. S and As are oxidised to their volatile oxides.

Iron is oxidised and forms a scum or slag which is **skimmed** off.

The cuprous oxide is reduced to Cu by CO and $CH_4$ from green wood.

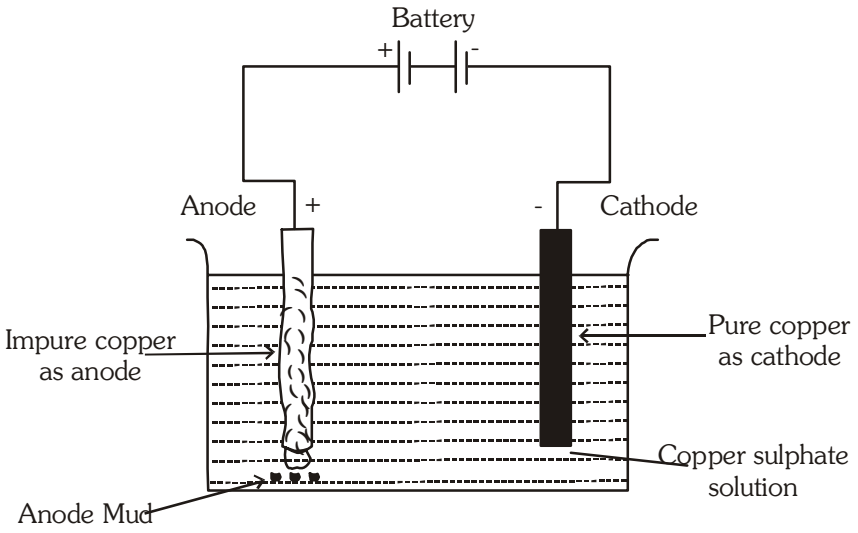
$Cu_2O + CO \rightarrow 2Cu + CO_2\uparrow$

$4Cu_2O + CH_4 \rightarrow 8Cu + 2H_2O + CO_2$

**(b) Electrolytic refining :**

The electrolytic bath contains an acidified solution of copper sulphate. Impure copper acts as anode while cathode is of the pure copper strip. When electric current is passed, there is transfer of pure copper from anode to cathode which gradually grows in size.

**The impurities** like Fe, Zn, Ni, Co etc. dissolve in the solution as sulphates and others like Au and Ag settle down below the anode as **anode mud.** The cathode is removed and copper of about 99.99% purity is obtained.




**Electrolytic refining of copper**

**(B) Hydrometallurgical Process :**

Crushed and powdered low grade ore is exposed to air and water then copper sulphide is oxidised to copper sulphate. Some iron sulphate and sulphuric acid is also produced. The process is completed in about a year.

(a) $CuFeS_2 + 4O_2 \rightarrow CuSO_4 + FeSO_4$
(Copper pyrite)

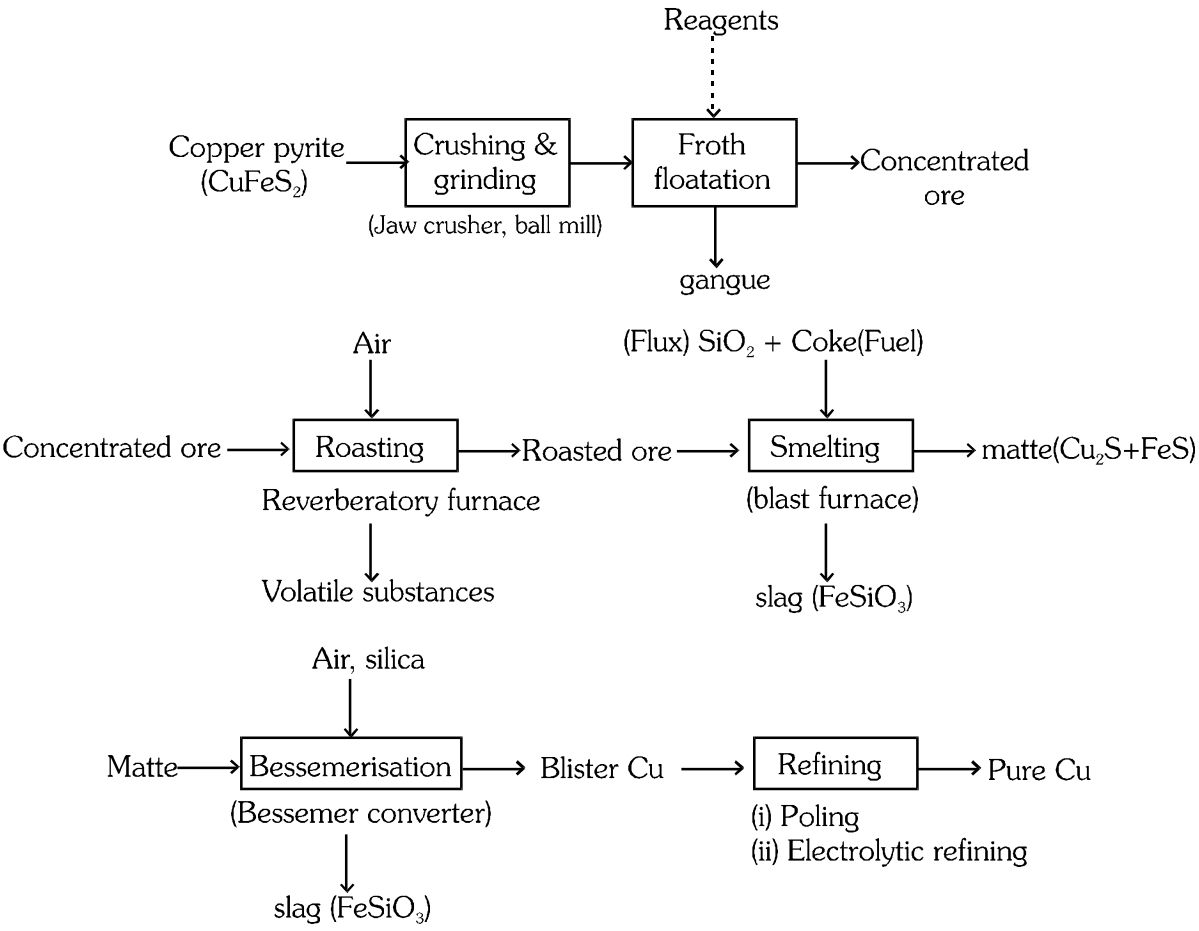
(b) $2Cu_2S + 5O_2 \rightarrow 2CuSO_4 + 2CuO$
(Copper glance)

(c) $CuCO_3.Cu(OH)_2 + 2H_2SO_4 \rightarrow 2CuSO_4 + CO_2 \uparrow + 3H_2O$
(malachite)

The pale green liquor draining from the bottom of the heaps is $CuSO_4$ which is collected in pans and treated with iron scraps which precipitate out copper.

$CuSO_4 + Fe/Zn/H_2 \rightarrow FeSO_4/ZnSO_4/H_2SO_4 + Cu$ (red ppt.) $\downarrow$

**Process in brief :**




**Uses :**

Copper is the second most useful metal (the first being Iron) because of its stability in air and water and excellent conductivity.

It is used :–

1. In the manufacture of electrical wires, cables etc.
2. For electroplating.
3. As a coinage metal and in ornaments and jewellery.
4. For the manufacture of alloys like brass (Cu + Zn), bronze (Cu + Sn) German silver (Cu + Zn + Ni) bell metal (Cu + Sn) gun metal (Cu + Sn + Zn), coppper coins (Cu + Zn + Sn) etc.

## EXTRACTION OF LEAD

**(2) Extraction of lead :**

***Main Ore : Galena (PbS) :*** There are mainly two types of process used in the extraction of Lead.

***Ore -*** **Galena PbS** → **(a) Carbon reduction process**
**Galena PbS** → **(b) Self reduction process**

***(a) Carbon reduction process (When impurity content is high) :***

(i) Crushing & Grinding

(ii) Concentration by Forth floatation method

(iii) Roasting process with Lime stone ($CaCO_3$). Roasting in air to give PbO and $SO_2$ .

$$2PbS(s) + 3O_2(g) \xrightarrow{\Delta} 2PbO(s) + 2SO_2$$

(iv) Smelting (Carbon reduction method with coke + $Fe_2O_3$). Then reduction with coke or CO in a blast furnace take place.

$$2PbO(s) + C \xrightarrow{\Delta} 2Pb(\ell) + CO_2(g)$$

***(b) Self reduction process :*** (When the impurity content is less)

(i) Crushing & Grinding

(ii) Concentration by Forth floatation method

(iii) Self reduction process : PbS is partially oxidized by heating and blowing air through it. After some time the air is turned off and heating is continued. The mixture undergoes self reduction as given below.

$$PbS + O_2 \longrightarrow PbO + SO_2$$

$$PbS + 2PbO \longrightarrow 3Pb + SO_2$$

Parallel reaction

$$PbS + 2O_2 \longrightarrow PbSO_4$$

$$PbS + PbSO_4 \longrightarrow 2Pb + 2SO_2$$

***(c) Refining process :***

*(a) Liquation*

*(b) Bett's electrorefining*

Anode → Impure Pb

Cathode → Pure Pb

Electrolyte → $Pb[SiF_6] + H_2SiF_6$ + Gelatin (to adjust viscosity)

on the electrolysis Pb is deposited at cathode which give 99.95% pure metal.

## EXTRACTION OF ZINC

**(2) Extraction of zinc :**

**Occurrence :** Its important minerals are :-

(i) Zinc blende or black jack ZnS

(ii) Zincite ZnO

(iii) Calamine $ZnCO_3$

**Extraction :**

**Electrolytic Process :**

**(i) Concentration :**

The powdered ore ZnS is concentrated by froth floatation method.

**(ii) (a) Roasting :**

Concentrated ZnS is roasted at $700^0$C. A mixture of ZnO and $ZnSO_4$ is obtained

$ZnS + 2O_2 \rightarrow ZnSO_4$

$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

$$ZnS \xrightarrow{\text{concentration}} ZnS \xrightarrow{\text{roasting}} ZnO + SO_2$$

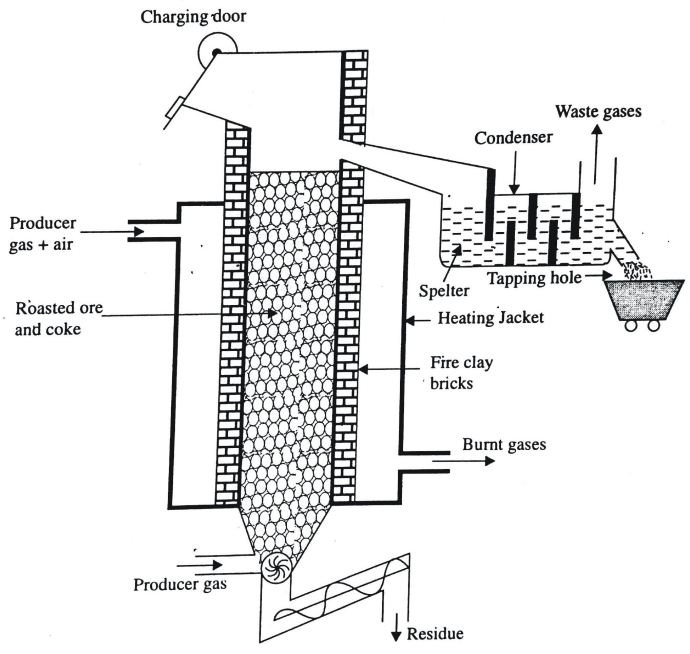
**(b) Calcination Process**

$$ZnCO_3 \xrightarrow{\text{concentration}} ZnCO_3 \xrightarrow{\text{calcination}} ZnO + CO_2$$

**(iii) Carbon Reduction (Extraction of zinc from zinc oxide) :-**

The reduction of zinc oxide is done using coke. The temperature in this case is higher than that in case of copper. For the purpose of heating, the oxide is made into brickettes with coke and clay.

$$ZnO + C \text{ (coke)} \xrightarrow{1673K} Zn + CO$$




Vertical retort process for the reduction of ZnO to Zn-metal.

The metal is distilled off and collected by rapid chilling is called **zinc spelter**.

**(iv) Electrolysis** (Electrolytic refining) **:**

Anode → Impure Zn

Cathode → Thin Al-rod

Electrolyte → Solution of $ZnSO_4 + H_2SO_4$ (dil.)

on the electrolysis zinc is deposited at cathode. The metal is scrapped off and melted to give 99.95% pure metal.

***Uses :***

(i) In making alloys e.g. brass, german silver, elektron (Alloy of Mg with smaller amount of Al, Y, Ag, Gd, Zn) etc.

(ii) In the extraction of silver and gold by cyanide process.

(iii) It is also used in large quantities in batteries and dry cells for making cathode container.

(iv) Zn–Cu couple, Zn- Hg, zinc dust etc. are used as reducing agent in organic reactions.

(v) large amount of zinc is used for galvanizing iron. Zinc is deposited on the surface of iron articles. This process is called galvanization.

(vi) It is also used in large quantities in batteries, as a constituent of many alloys, e.g., brass, (Cu 60%, Zn 40%) and german silver (Cu 25-30%, Zn 25-30%, Ni 40–50%).

(vii) Zinc dust is used as a reducing agent in the manufacture of dye-stuffs, paints, etc.

## EXTRACTION OF TIN

**Extraction of tin from cassiterite :**

**Main Ore :** Cassiterite or Tinstone ($SnO_2$) + Major impurities

[(i) $SiO_2$, (ii) Sulphides of Fe & Cu, (iii) $FeWO_4 + MnWO_4$]

Some following steps are involved :

**(i) Crushing and concentration :**

The ore is crushed and washed with a stream of running water to remove the lighter earthy and silicious impurities.

**(ii) Electromagnetic separation :**

The concentrated ore is subjected to the electromagnetic separation to remove magnetic impurity of Wolframite.

**(iii) Roasting :**

The ore is then heated in presence of air, when volatile impurities (S as $SO_2$, As as $As_2O_3$ and Sb as $Sb_2O_3$) are removed.The impurities of pyrites of copper and iron are converted into their respective oxides and sulphates

$CuS + 2O_2 \rightarrow CuSO_4$ ; $FeS + 2O_2 \rightarrow FeSO_4$

**(iv) Leaching :**

Sulphates of copper and iron are dissolved in water.

**(v) Washing :**

The ore is washed with running water to remove the fine iron oxide produced in roasting. Thus obtained ore contains 60 – 70% $SnO_2$ and is called as black tin.

**(vi) Carbon reduction method :** Coke & Lime stone (flux) is used.

**Smelting :**

The black tin is mixed with anthracite coal and heated to about 1500K in a reverberatory furnace. If $SiO_2$ is present as impurity then CaO is added as flux.

$SnO_2 + C \rightarrow SnO + CO\uparrow$

$SnO + SiO_2 \rightarrow SnSiO_3$ ; $CaO + SiO_2 \rightarrow CaSiO_3$

$SnSiO_3 + CaO + C \rightarrow Sn + CaSiO_3 + CO\uparrow$

or use scrap iron $SnSiO_3 + Fe \rightarrow Sn + FeSiO_3$

***Refining method :***

(a) Poling (b) Electrorefining

Anode → Impure Sn

Cathode → Pure Sn

Electrolyte → ($SnSO_4$ solution + dil. $H_2SO_4$)

## EXTRACTION OF IRON

**(1) Extraction of Iron :**

***Main Ore :*** *Haematite ($Fe_2O_3$)*

Some following steps are involved :

***(i) Crushing & Grinding :***

***(ii) Concentration :*** By gravity separation method.

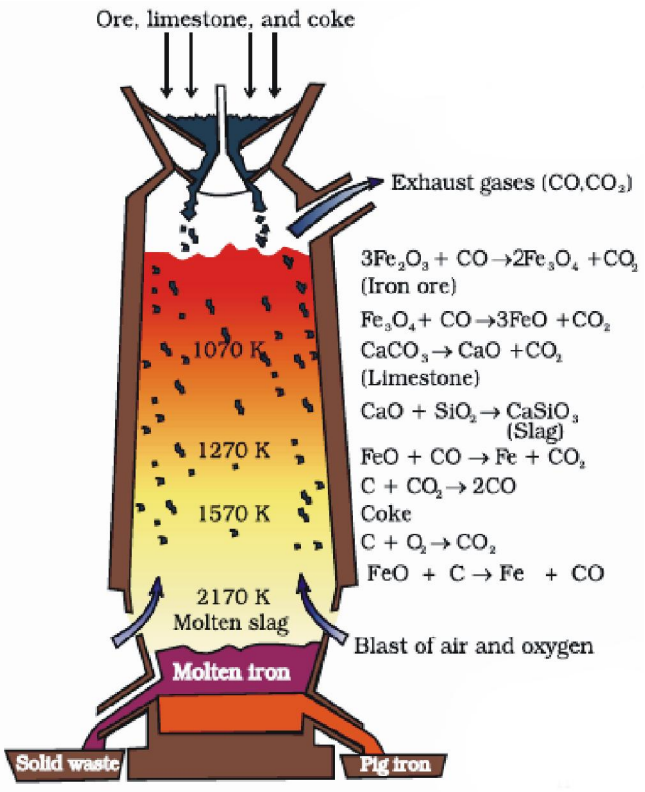
***(iii) Roasting :***

***(iv) Carbon reduction (Blast furnace) :*** Pig iron is obtained from this process

**Smelting or reduction :**

The calcined ore (8 parts) mixed with coke, a reducing agent (4 parts) and lime stone a flux (1 part) is reduced in a blast furnace.

Since the blast furnace has different temperatures at different zones, different reactions take place at different zones.



**(a) Zone of combustion (1500 -1600$^0$C)**

This zone is near at the bottom of the furnace and little above the tuyers. It increases temp. of the furnace because of exothermic reactions.

$2C + O_2 \rightarrow 2CO$ $\quad C + O_2 \rightarrow CO_2$

**(b) Zone of fusion (1200- 1300$^0$C)**

It is just above the zone of combustion. Here the iron melts and trickles down in the hearth while the slag being lighter floats over the molten metal and thus prevents oxidation of Fe by blast of air.

**(c) Zone of heat absorption or slag formation (800- 1000$^0$C)**

This is the middle part of the furnace. Here rising $CO_2$ is reduced to carbon monoxide.

$CO_2 + C \rightarrow 2CO$

The reaction being endothermic, lowers the temperature of the zone.

Limestone decomposes forming CaO which reacts with $SiO_2$ forming slag.

$CaCO_3 \rightarrow CaO + CO_2$ $\quad CaO + SiO_2 \rightarrow CaSiO_3$ (Slag)

**(d) Zone of reduction (400-700$^0$C)**

It is near the top of the furnace. Here the calcined ore is reduced to Fe by rising CO.

$Fe_2O_3 + CO \rightleftharpoons 2FeO + CO_2 \uparrow$

$Fe_3O_4 + CO \rightleftharpoons 3FeO + CO_2 \uparrow$

$FeO + CO \rightarrow Fe + CO_2 \uparrow$

To retard the backward reaction, supply of excess of CO is maintained by the following reaction.

$CO_2 + C \rightarrow 2CO$

Since the temperature of this zone is too low to melt iron, the metal produced is known as spongy iron.

**Refining :**

Purification of Fe can be done by different method which are as follows :

(a) Puddling Process

(b) Bessemerisation Process

(c) Open hearth Process

(d) L. D. Process

Thus we got pure iron.

***Types of Iron***

***Cast iron or pig iron***

It is most impure form of Iron and contains the highest proportion of carbon (2.5 - 4 % ) along with traces of S, P, Mn and Si. Cast iron contain 2.5 to 4.3 & pig iron contain 2.5 to 5%.

***Wrought iron (Fibrous iron) or malleable iron***

It is the purest form of iron and contains minimum amount of carbon (0.12 - 0.25%) and less than 0.5% of other impurities.

***Steel***

It is the most important form of iron and finds extensive applications. As far as carbon content (impurity) is concerned it is mid-way between cast iron and wrought iron, it contains 0.25- 2% carbon.

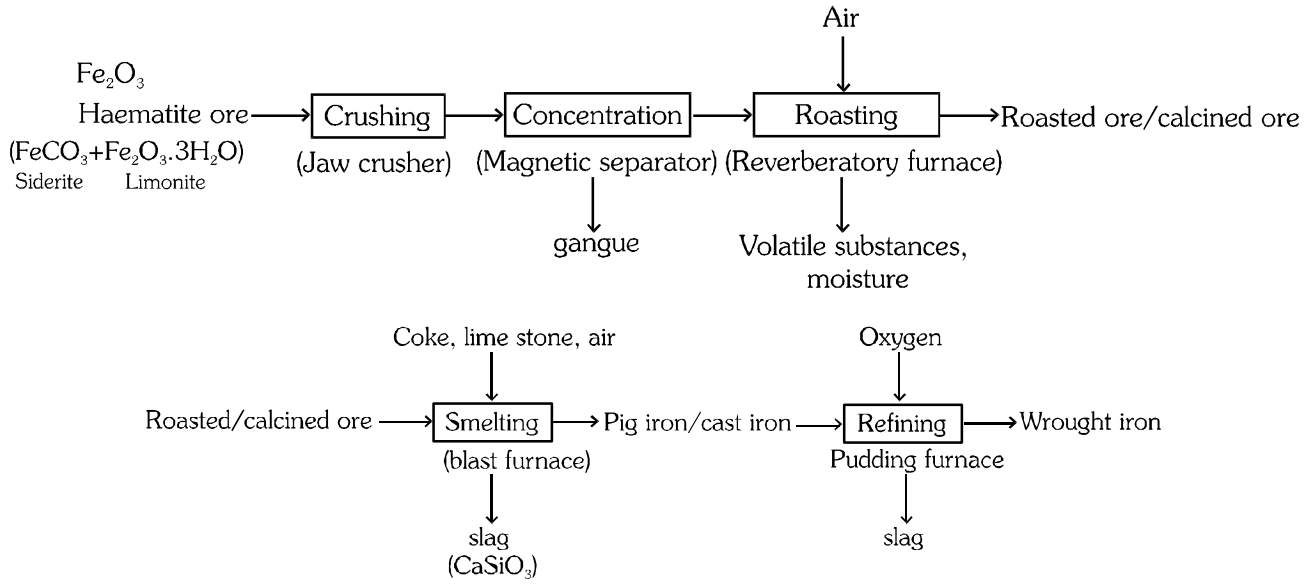
Thus all the three forms of iron differ in their carbon contents, both iron and steel are obtained from cast iron.

Order of M.P. Wrought Iron > Steel > Cast Iron or Pig Iron

***% of Carbon in different type of Iron***

| | *NAME* | *% of C* |
|---|---|---|
| (1) | Wrought iron | 0.1 to 0.25 |
| (2) | Steel | 0.25 to 2.0 |
| (3) | Cast Iron | 2.6 to 4.3 |
| (4) | Pig Iron | 2.3 to 4.6 |

**Process in brief :**




***Manufacture of Steel :*** The addition of different desired impurities into molten pure iron is known as steel making

**Bessemer process :**

This process involves the use of a large pear- shaped furnace (vessels) called Bessemer converter. This is made of steel plates lined with silica ($SiO_2$) or magnesia (MgO) depending upon the nature of impurities. If the impurities are acidic e.g. $P_4O_{10}$ or $SiO_2$, basic lining of lime (CaO) or magnesia is used (Basic process). If the impurities are basic e.g. MnO, lining of silica bricks is used (acid process). Silicon and manganese (in acidic process) or phosphorus (in basic process) are oxidised to their oxides and thus removed as slag.

**Acid process :** $Si + O_2 \rightarrow SiO_2$ ; $2Mn + O_2 \rightarrow 2MnO$ ; $MnO + SiO_2 \rightarrow MnSiO_3$ (Slag)

**Basic process :** $P_4 + 5O_2 \rightarrow P_4O_{10}$ $P_4O_{10} + 6CaO \rightarrow 2Ca_3(PO_4)_2$ (Thomas slag)

**Properties of Steel :**

Steel combines the useful properties of cast iron and wrought iron. It is hard and elastic. The properties of steel depend upon its carbon content. With the increase in carbon content, the hardness of steel increases while its ductility decreases.

(i) Low carbon or soft steel contain C upto 0.25%.

(ii) Medium carbon steel or mild steel contain 0.25–0.5% C.

(iii) High carbon or hard steel contain 0.5–1.5% C.

***Heat Treatment of Steel***

*(i)* ***Quenching or hardening :*** Steel is heated to red hot temperature (700 to 800°C) and is then cooled suddenly by plunging into either cold water or oil. It makes steel hard and brittle.

*(ii)* ***Annealing :*** The steel is heated to red hot temperature (700 to 800°C) and then cooled slowly. It makes steel soft.

*(iii)* ***Tempering :*** If quenched steel is heated to temperature between 500 to 575 K and then cooled slowly, it becomes quite hard but brittleness disappears. The process is called tempering.

***Surface treatment of steel***

*(i)* ***Nitriding*** : Process of heating steel at 1000 K in an atmosphere of $NH_3$.
This gives hard coating of iron nitride on the surface.

*(ii)* ***Case hardening :*** Process of giving a thin coating of hardened steel, by heating steel in contact with charcoal followed quenching in oil.
– It is used for axles of railway wagons.

***Uses***

*(i)* ***Cast iron :*** It is the most important form of iron, is used for casting stoves, railway sleepers, gutter pipes , toys, etc.

*(ii)* It is used in the manufacture of wrought iron and steel.

*(iii)* ***Wrought iron :*** It is used in making anchors, wires, bolts, chains and agricultural implements.

*(iv)* ***Steel finds a number of uses :*** Alloy steel is obtained when other metals are added to it. Nickel steel is used for making cables, automobiles and aeroplane parts, pendulum, measuring tapes, chrome steel for cutting tools and crushing machines, and stainless steel for cycles, automobiles, utensils, pens, etc.

## ❑ EXTRACTION OF SILVER & GOLD

**(1) Extraction of silver :**

**Occurrence :**

Ag found in free and combined state in nature.

Its main ore is Argentite $Ag_2S$.

Other ores are

| | | |
|---|---|---|
| Copper silver glance | – | $Cu_2S$ . $Ag_2S$ |
| Horn silver | – | AgCl |
| Argentiferrous lead | – | PbS(0.01 – 0.1% Ag) |

**Steps of Metallurgy :**

**(A) From Argentite ($Ag_2S$)**

**(i) Concentration :** As it is a sulphide ore, so froth floatation process is used.

**(B) Leaching and reduction (Mac Arther cyanide process)**

**(a) Formation of cyanide complex :**

**(a)** $Ag_2S + 4NaCN \rightleftharpoons 2Na[Ag(CN)_2] + Na_2S \xrightarrow{+O_2+H_2O} Na_2SO_4 + 'S' + 2NaOH$

[$\because$ $O_2$ is used to make reaction irreversible which remove $Na_2S$ as $Na_2SO_4 + S$]

$Na_2SO_4$ does not reacts with sod. Argento cyanide.

**(b) Displacement of Ag metal :–**

$2Na[Ag(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2Ag$

Sodium tetra cyanozincate (black ppt) .

$Ag \xrightarrow[KNO_3]{\Delta}$ Ag (Solid) Shining silver (impure)

**(C) Purification by electrolytic method :**

Pure Ag — Cathode

Impure Ag — Anode

Electrolyte — $AgNO_3$

+ 1% $HNO_3$ — To increase ionisation and to avoid hydrolysis of $AgNO_3$ by common ion effect

**(D) Ag from Argentiferrous lead (PbS – Galena) :**

Galena has a little amount of silver

**(1) Concentration :** (PbS) by froth floatation process

**(E) Reduction of metal :**

**(a) Parke's process :** Based on distribution law.

**(i)** Molten Ag is more soluble in molten zinc.

Pb (molten) → Zn(molten)

(Ag)

**(ii)** Melting point of Zn/Ag alloy is greater than lead, so Zn/Ag freezes first.

**(iii)** Density of Zn/Ag is less than Pb so Zn/Ag forms the upper layer and Pb form lower layer.

**(iv)** Upper layer taken out.

**(v)** Ag is separated by using distillation method. (Vapourisation of Zn)

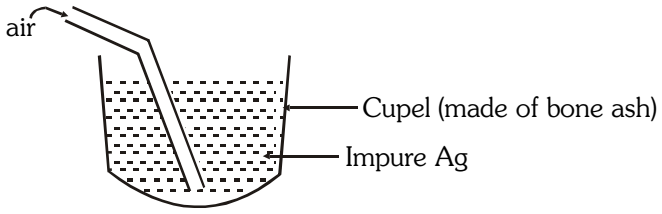
**(b) Pattinson method :–**

**(i)** It is based upon fractional crystallisation.

**(ii)** Ag/Pb is melted then cooled, the process is repeated again & again, concentration of Ag increases. Pb separate out in crystalline form.

**(F) Purification :**

**(a) Cupellation :**




Pb impurities separate (oxidised) out in the form of litharge.

**(b) Electrolytic process :–** As discussed earlier.

**Uses**

(i) It is used in silver plating.

(ii) Silver foils are used in medicine.

(iii) Silver amalgam is used for dental filling.

(iv) Compounds of silver are used in silvering of mirrors ($AgNO_3$ + HCHO + Red Pb), in photography, as laboratory reagents etc.

(v) Silver is easily alloyed with copper, so it is used in making coins, ornaments, silver ware etc.

(vi) It gives black spot on skin due to decomposition so it is also used as hair dye and ink.

***Extraction of Gold :***

***Occurrence :*** Au found in free (native) state in nature.

***Same steps as are involved in the extraction of Silver metal.***

***(i) Crushing & Grinding :***

***(ii) Leaching process :*** Gold are extracted by the cyanide process (Mc Arthur - Forest process).

***Reaction involved :***

$$4Au + 8NaCN + O_2 + 2H_2O \rightleftharpoons 4Na[Au(CN)_2] + 4NaOH$$

$$2Na[Au(CN)_2] + Zn \longrightarrow Na_2[Zn(CN)_4] + 2Au$$

***(iii) Refining Process :***

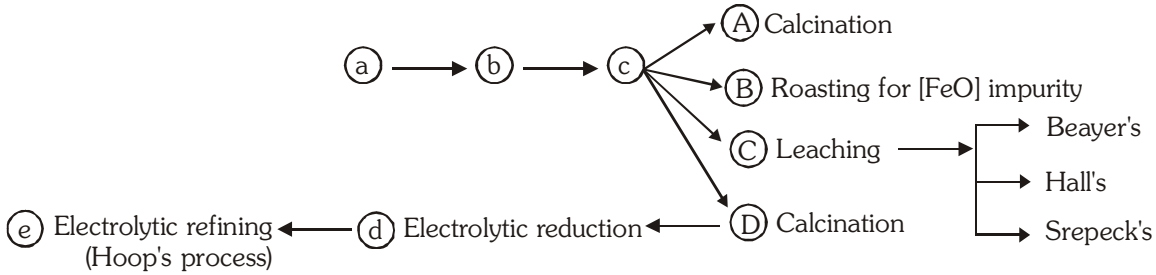
| | | |
|---|---|---|
| Anode | → | Impure Au |
| Cathode | → | Pure Au |
| Electrolyte | → | ($AuCl_3$ solution + dil. HCl) |

## ❑ EXTRACTION OF ALUMINIUM :

### *Ore - Bauxite $AlO_x(OH)_{3-2x}$ (where $O < x < 1$)*

**Extraction of Aluminium :**

**Short chart of Al from $Al_2O_3.2H_2O$ (Bauxite)**




**BAUXITE**

↓

***Step-1: Concentration of Bauxite ore***

**(a) Baeyer's process :** (Used for red bauxite in which main impurity is iron oxide)

Bauxite ore $\xrightarrow{\text{Roasted}}$ as to convert FeO into $Fe_2O_3$

Roasted ore + NaOH solution $\xrightarrow[8\text{ atm}]{150^\circ C}$ $NaAlO_2$ $\xrightarrow{\text{Hydrolysis}}$ $Al(OH)_3$ + NaOH in presence ppt. of little $Al(OH)_3$

**(b) Hall's Process :** (Red bauxite)

Bauxite ore + $Na_2CO_3$ $\xrightarrow{\text{Fused}}$ $NaAlO_2$

↓ extracted with water

Solution

↓ warmed 50° – 60° C

$CO_2$ is circulated

↓

$Al(OH)_3 + Na_2CO_3$

**(c) Serpeck's process :** (Used for white bauxite in which main impurity is silica)

$$\text{Bauxite ore + coke} \xrightarrow{1800^\circ C} AlN \xrightarrow{H_2O} Al(OH)_3 + NH_3$$

$$+ \qquad\qquad\qquad\qquad\qquad\qquad \text{ppt.}$$

$$\text{(Nitrogen) } N_2 \qquad\qquad C + SiO_2 \text{ (gangue)} \rightarrow CO_2\uparrow + Si\uparrow$$

$$\downarrow$$

***Step-2:*** **CALCINATION**

$$Al(OH)_3 \xrightarrow{1500^\circ C} Al_2O_3$$

$$\downarrow$$

***Step-3 :*** **Electrolytic Reduction**

Electrolyte $Al_2O_3$ dissolved in $Na_3AlF_6$ and $CaF_2$

**Cathode**–Carbon lining

**Anode –** Graphite rods

**Electrolytic reduction (Hall-Heroult process) :**

The purified $Al_2O_3$ is mixed with $Na_3AlF_6$ (cryolite) or $CaF_2$ (fluorspar) ) which lowers the melting point of the mixture and brings conductivity. The fused matrix is electrolysed. Steel cathode and graphite anode are used. The graphite anode is useful here for reduction to the metal. The overall reaction may be taken as :

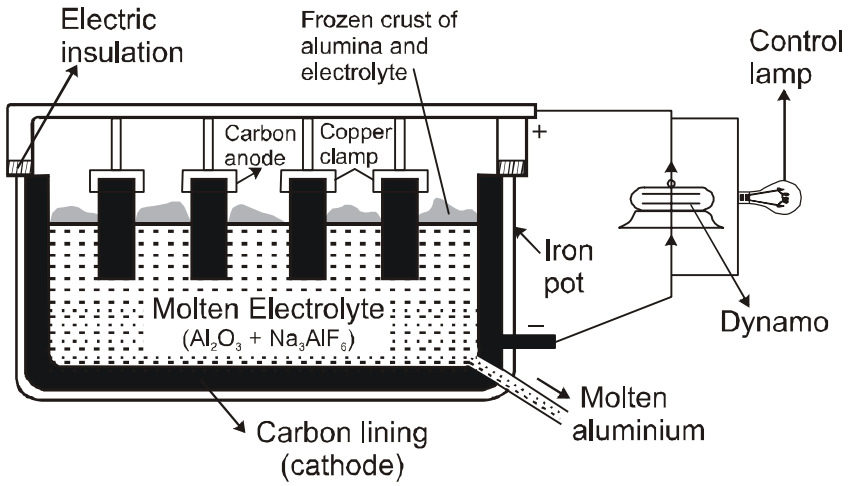
$$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$$

The electolysis of the molten mass is carried out in an electrolytic cell using carbon electrodes. The oxygen liberated at anode reacts with the carbon of anode producing CO and $CO_2$. This way for each kg of aluminium produced, about 0.5 kg of carbon anode is burnt away. The electrolytic reactions are :

**Cathode :** $Al^{3+}$ (melt) + $3e^- \longrightarrow$ Al(l)

**Anode :** $C(s) + O^{2-}(melt) \longrightarrow CO(g) + 2e^-$

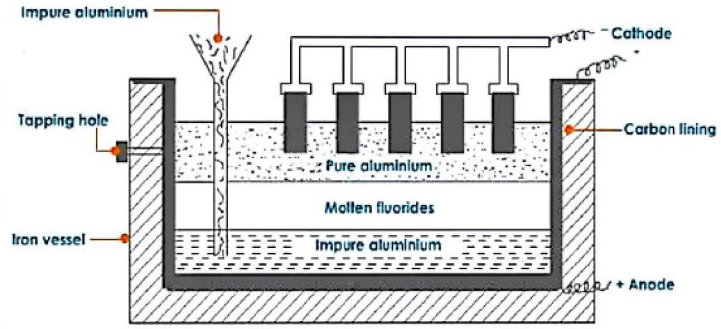
$$C(s) + 2O^{2-}(melt) \longrightarrow CO_2(g) + 4e^-$$




$$Al_2O_3 \xrightarrow[950^\circ C]{\text{Electrolysis}} Al + O_2$$

$$\downarrow \quad 99.8\% \text{ pure}$$

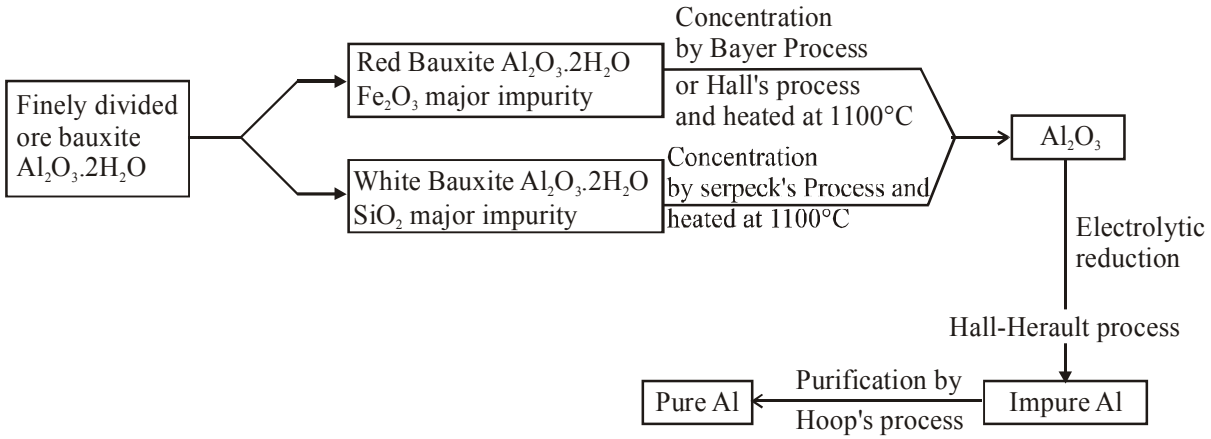
***Step-4 :*** **Electrolytic Refining**




(Hoop's process)

Pure Al (99.98 % pure)

***Flow chart of Al from $Al_2O_3.2H_2O$ (Bauxite)***




**Important points :**

(a) Useful gas $NH_3$ is evolved in the leaching of bauxite by serpeck's process.

(b) In the electrolytic reduction of $Al_2O_3$ cryotite ($Na_3AlF_6$) is added along with $CaF_2$ (fluorspar) to–
– decrease m.p. of $Al_2O_3$
– decrease viscocity of electrolyte ($CaF_2$ is used)
– increase conductivity

(c) In the electrolytic reduction graphite anode get corrode or finishe due to reaction with $O_2$ liberates at anode, hence it had to be changed periodically.

(d) In the electrolytic refining (4th step) no electrodes are used. In the Hoop's process molten pure Al is used as cathode and molten impure Al is used as anode.

(e) In the Hoop's process carbon dust is sprayed over molten Al to
– avoid heat lose
– minimise metallic lusture (glaze) which is harmful for the eyes.

***Uses***

(i) Aluminium foils are used as wrappers for chocolates.

(ii) The fine dust of the metal is used in paints and lacquers.

(iii) Aluminium, being highly reactive, is also used in the extraction of chromium and manganese from their oxides.

(iv) Wires of aluminium are used as electricity conductors.

(v) Alloys containing aluminium, being light, are very useful.

## ❑ EXTRACTION OF MAGNESIUM :

**(1) Extraction of Magnesium :**

***(i) From Carnallite :*** Carnallite $KCl.MgCl_2.6H_2O$

The ore is dehydrated in a current of hydrogen chloride and the mixture of fused chlorides is electrolysed.

***(ii) From Magnesite :***

The concentrated ore is calcined at higher temperature

$$MgCO_3 \xrightarrow[\text{Strongly}]{\text{Heated}} MgO + CO_2$$

The calcined ore is heated with coke in a current of dry chlorine gas.

$$MgO + C + Cl_2 \xrightarrow{\Delta} MgCl_2 + CO$$

The magnesium chloride is fused and then electrolysed.

$$MgO + C \text{ (Other reducing agents like Si, Al can be used)} \xrightarrow[\text{Vaccume}]{2000^\circ C} Mg + CO$$

***(iii) From Sea water (Dow's process) :***

Sea water contains 0.13% magnesium as chloride and sulphate. It involves following steps.

***(a)*** *Precipitation of magnesium as magnesium hydroxide by slaked lime :*

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 \downarrow + CaCl_2$$

***(b)*** *Preparation of hexahydrated magnesium chloride*

$$Mg(OH)_2 + 2HCl(aq) \longrightarrow MgCl_2 + 2H_2O$$

The solution on concentration and crystallisation gives the crystals of $MgCl_2.6H_2O$

***(c)*** *Preparation of anhydrous magnesium chloride*

$$MgCl_2.6H_2O \xrightarrow[\text{Dry HCl(g)}]{\Delta\text{(calcination)}} MgCl_2 + 6H_2O$$

It is not made anhydrous by simple heating because it gets hydrolysed

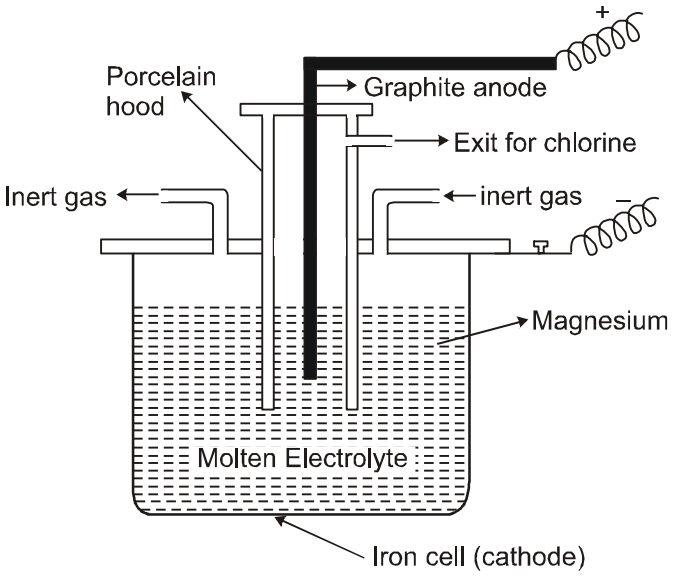
$$MgCl_2.\ 6H_2O \xrightarrow{\Delta} MgO + 5H_2O + 2HCl$$

***(d)*** *Electrolysis of fused anhydrous $MgCl_2$*

(i) Electrolyte : Molten $MgCl_2 + NaCl + CaCl_2$

(ii) Anode : Graphite electrode

(iii) Cathode : Iron cell (steel container)



Magnesium chloride obtained by any of the above methods is fused and mixed with sodium chloride and calcium chloride in the temperature range of 973 – 1023 K. The molten mixture is electrolysed. Magnesium is liberated at the cathode (iron pot) and chlorine is evolved at graphite anode.

Reaction occurs :

The molten mixture is electrolysed. Magnesium is liberated at the cathode (iron pot) and chlorine is evolved at graphite anode.

$MgCl_2 \rightleftharpoons Mg^{2+} + 2Cl^-$

***At cathode :*** $Mg^{2+} + 2e^- \longrightarrow Mg(99\%\ pure)$ ;

***At anode :*** $2Cl^- \longrightarrow Cl_2 + 2e^-$

A stream of coal gas is passed through the pot to prevent oxidation of magnesium metal. The magnesium obtained in liquid state is purified by distillation under reduced pressure. (1 mm of Hg at 873 K).

***(iv) From Dolomite : In the Pidgeon Process Mg is Produced.***

The concentrated ore is calcined at higher temperature

$CaCO_3 . MgCO_3 \xrightarrow{\Delta} CaO. MgO + 2CO_2$

It is then reduced by ferrosilicon at 1273 K under reduced pressure.

$2CaO. MgO + Fe–Si \xrightarrow{1150°C} 2Mg\uparrow + Fe + Ca_2SiO_4$

**Extraction of Na :**

The fused mixture of NaCl and $CaCl_2$ is taken in Down's cell which consists of circular iron cathode and carbon anode. On passing the electric current the following reactions take place :

Ionisation of NaCl : $NaCl \rightleftharpoons Na^+ + Cl^-$

Collection of Na at cathode : $Na^+ + e^- \rightarrow Na$(Reduction).

Collection of $Cl_2$ at anode : $Cl^- + e^- \rightarrow Cl$ (Oxidation), $Cl + Cl \rightarrow Cl_2$ .

| | | | |
|---|---|---|---|
| Aluminium | 1. Bauxite, $Al_2O_3$. x $H_2O$<br>2. Cryolite, $Na_3AlF_6$ | Electrolysis of $Al_2O_3$ dissolved in molten $Na_3AlF_6$ | For the extraction, a good source of electricity is required. |
| Iron | 1. Haematite, $Fe_2O_3$<br>2. Magnetite, $Fe_3O_4$ | Reduction of the oxide with CO and coke in Blast furnace | Temperature approaching 2170 K is required. |
| Copper | 1. Copper pyrites, $CuFeS_2$<br>2. Copper glance, $Cu_2S$<br>3. Malachite, $CuCO_3.Cu(OH)_2$<br>4. Cuprite, $Cu_2O$ | Roasting of sulphide partially and reduction | It is self reduction in a specially designed converter. The reduction takes place easily. Sulphuric acid leaching is also used in hydrometallurgy from low grade ores. |
| Zinc | 1. Zinc blende or Sphalerite, ZnS<br>2. Calamine, $ZnCO_3$<br>3. Zincite, ZnO | Roasting followed by reduction with coke | The metal may be purified by fractional distillation. |

# GENERAL PRINCIPLES & PROCESSES OF ISOLATION OF ELEMENTS

## EXERCISE # O-1

*ONLY ONE OPTION IS CORRECT.*

*ORES*

**1.** Which of the following does not contain Mg:

(A) magnetite (B) magnesite (C) asbestos (D) carnallite

**ML0001**

**2.** Which of the following is not an ore:

(A) malachite (B) calamine (C) stellite (D) cerussite

**ML0002**

**3.** Carnallite does not contain

(A) K (B) Ca (C) Mg (D) Cl

**ML0003**

**4.** Among the following statements, the incorrect one is

(A) calamine and siderite are carbonate ores (B) argentite and cuprite are oxide ores

(C) zinc blende and pyrites are sulphide ores (D) malachite and azurite are ores of copper

**ML0004**

**5.** Select the correct statement :

(A) Magnetite is an ore of manganese (B) Pyrolusite is an ore of lead

(C) Siderite is carbonate ore of iron (D) $FeS_2$ is rolled gold

**ML0005**

**6.** "Fool's gold" is

(A) iron pyrites (B) horn silver (C) copper pyrites (D) bronze

**ML0006**

**7.** **Assertion :** Platinum and gold occur in native state in nature.

**Reason :** Platinum and gold are noble metals.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

**ML0007**

*CONCENTRATION METHODS*

**8.** $Ag_2S + NaCN + Zn \longrightarrow Ag$

This method of extraction of Ag by complex formation and then its displacement is called:

(A) Parke's method (B) McArthur-Forest method

(C) Serpeck method (D) Hall's method

**ML0008**

**9.** Which one of the following is not a method of concentration of ore?

(A) gravity separation (B) froth floating process

(C) electromagnetic separation (D) smelting

**ML0009**

**10.** Chemical leaching is useful in the concentration of:

(A) copper pyrites (B) bauxite (C) galena (D) cassiterite

**ML0010**

**11.** In froth-floatation process, pine oil functions as

(A) activator (B) frother (C) collector (D) agitator

**ML0011**

**12.** Collectors are the substances which help in attachment of an ore particle to air bubble in froth. A popular collector used industrially is

(A) sodium ethyl xanthate (B) sodium xenate

(C) sodium pyrophosphate (D) sodium nitroprusside

**ML0012**

**13.** In the cyanide process involving extraction of silver, zinc is used industrially as a(an)

(A) oxidising agent (B) reducing agent

(C) solvent (D) solvating agent

**ML0013**

**14.** During initial treatment, preferential wetting of ore by oil and gangue by water takes place in

(A) Levigation (gravity separation) (B) Froth floatation

(C) Leaching (D) Bessemerisation

**ML0014**

**15.** An non-magnetic ore containing the impurity of $FeCr_2O_4$ is concentrated by

(A) magnetic-separation (B) gravity separation

(C) froth-floatation method (D) electrostatic method

**ML0015**

**16.** The beneficiation of the sulphide ores is usually done by

(A) Electrolysis (B) Smelting process

(C) Metal displacement method (D) Froth flotation method

**ML0016**

**17.** The process of the isolation of a metal by dissolving the ore in aqueous solution of suitable chemical reagent followed by precipitation of the metal by a more electropositive metal is called:

(A) hydrometallurgy (B) electrometallurgy

(C) zone refining (D) electrorefining

**ML0017**

**18.** Froth floatation process for concentration of ores is an illustration of the practical application of:

(A) Adsorption (B) Absorption

(C) Coagulation (D) Sedimentation

**ML0018**

**19.** **Assertion :** Sulphide ores are concentrated by froth floatation process.

**Reason :** Pine oil acts as a frothing agent in froth floatation process.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

**ML0019**

**20.** **Assertion :** Wolframite impurities are separated from cassiterite by electromagnetic separation.

**Reason :** Cassiterite being magnetic is attracted by the magnet and forms a separate heap.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

**ML0020**

## *CALCINATION/ROASTING*

**21.** Calcination is the process of heating the ore:

(A) in inert gas (B) in the presence of air

(C) in the absence of air (D) in the presence of CaO and MgO

**ML0021**

**22.** When roasting is carried out :

(i) Sulphide ore is converted into oxide and sulphate

(ii) remove water of hydration

(iii) the ore melts

(iv) arsenic and sulphur impurities are removed

Of these statements:

(A) (i), (ii) and (iii) are correct (B) (i) and (iv) are correct

(C) (i), (ii) and (iv) are correct (D) (ii), (iii) and (iv) are correct

**ML0022**

## *REDUCTION PROCESS*

**23.** In the alumino thermite process, Al acts as

(A) An oxidising agent (B) A flux

(C) A reducing agent (D) A solder

**ML0023**

**24.** **Assertion :** Al is used as a reducing agent in aluminothermy.

**Reason :** Al has a lower melting point than Fe, Cr and Mn.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

**ML0024**

**25.** Formation of metallic copper from the sulphide ore in the commercial thermo-metallurgical process essentially involves which one of the following reaction:

(A) $Cu_2S + \frac{3}{2}O_2 \longrightarrow Cu_2O + SO_2$ ; $CuO + C \longrightarrow Cu + CO$

(B) $Cu_2S + \frac{3}{2}O_2 \longrightarrow Cu_2O + SO_2$ ; $2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$

(C) $Cu_2S + 2O_2 \longrightarrow CuSO_4$ ; $CuSO_4 + Cu_2S \longrightarrow 3Cu + 2SO_2$

(D) $Cu_2S + \frac{3}{2}O_2 \longrightarrow Cu_2O + SO_2$ ; $Cu_2O + CO \longrightarrow 2Cu + CO_2$

**ML0025**

**26.** The element which could be extracted by electrolytic reduction of its oxide dissolved in a high temperature melt is:

(A) sodium (B) magnesium (C) fluorine (D) aluminium

**ML0026**

**27.** In which of the following isolations no reducing agent is required:

(A) iron from haematite (B) Tin from cassiterite

(C) mercury from cinnabar (D) zinc from zinc blende

**ML0027**

## *PURIFICATION METHODS*

**28.** A metal has a high concentration into the earth crust and whose oxides cannot be reduced by carbon. The most suitable method for the extraction of such metal is

(A) Alumino thermite process (B) Electrolysis process

(C) Van-Arkel's process (D) Cupellation

**ML0028**

**29.** **Assertion :** Alkali metals can not be prepared by the electrolysis of their chlorides in aqueous solution

**Reason :** Reduction potentials of alkali metals cations is much lower than that of $H_2O$.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

**ML0029**

**30.** **Assertion :** Magnesium can be prepared by the electrolysis of aq. $MgCl_2$.

**Reason :** The reduction potential of $Mg^{2+}$ is much lower than that of $H_2O$.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

**ML0030**

**31.** Bessemerisation is carried out for

I : Fe, II : Cu, III : Al, IV : silver

(A) I , II (B) II, III (C) III, IV (D) I, III

**ML0031**

**32.** In the extraction of nickel by Mond process, the metal is obtained by:

(A) electrochemical reduction (B) thermal decomposition

(C) chemical reduction by aluminium (D) reduction by carbon

**ML0032**

**33.** Formation of $Ni(CO)_4$ and subsequent its decomposition into Ni and CO (recycled) makes basis of Mond's process

$$Ni + 4CO \xrightarrow{T_1} Ni(CO)_4 \xrightarrow{T_2} Ni + 4CO$$

$T_1$ and $T_2$ are:

(A) 100°C, 50°C (B) 50°C, 100°C (C) 50°C, 230°C (D) 230°C, 50°C

**ML0033**

**34.** Zone refining is based on the principle of

(A) fractional distillation (B) fractional crystallisation

(C) partition coefficient (D) chromatographic separation

**ML0034**

**35.** Si and Ge used for semiconductors are required to be of high purity and hence purified by

(A) zone-refining (B) electrorefining

(C) Van-Arkel's process (D) cupellation process

**ML0035**

**36.** Which process of purification is represented by the following equation :

$$Ti\ (Impure) + 2I_2 \xrightarrow{250°C} TiI_4 \xrightarrow{1400°C} Ti\ (Pure) + 2I_2$$

(A) Cupellation (B) Poling (C) Van-Arkel Process (D) Zone refining

**ML0036**

**37.** Which of the following employ(s) thermal decomposition of volatile iodide compounds?
(A) Thermite process (B) Hall's process (C) Van-Arkel's process (D) Mond's process

**ML0037**

**38.** The method of zone refining of metals is based on the principle of:
(A) Greater mobility of the pure metal than that of impurity.
(B) Higher melting point of the impurity than that of the pure metal.
(C) Greater noble character of the solid metal than that of the impurity
(D) Greater solubility of the impurity in the molten state than in the solid

**ML0038**

**39.** **Assertion :** Titanium is purified by Van-Arkel method.
**Reason :** Ti reacts with $I_2$ to form volatile $TiI_4$ which decomposes at 1673 K to give pure Ti.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

**ML0039**

**40.** **Assertion :** Nickel is purified `by the thermal decomposition of nickel tetracarbonyl.
**Reason :** Nickel is a transition element.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

**ML0040**

**41.** Refining of silver is done by:
(A) liquation (B) poling (C) cupellation (D) van Arkel method

**ML0041**

**42.** Mercury is purified by:
(A) Passing through dilute $HNO_3$ (B) Distillation
(C) Distribution (D) Vapour phase refining

**ML0042**

**43.** **Assertion :** Lead, tin and bismuth are purified by liquation method.
**Reason :** Lead, tin and bismuth have low m.p. as compared to impurities.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

**ML0043**

**44.** When an impurity in a metal has greater affinity for oxygen and is more easily oxidised than the metal itself. Then, the metal is refined by

(A) cupellation (B) zone-refining (C) distillation (D) electrolytic process

**ML0044**

## *EXTRACTION OF METALS*

**45.** Which of the following process is not associated with recovery of the silver -

(A) As a side product in electrolytic refining of copper

(B) Parke's process in which Zn is used to extract silver by solvent extraction from molten lead

(C) By reaction of silver sulphide with KCN and then reaction of soluble complex with Zn

(D) By boiling $Na[Ag(CN)_2]$ aq.

**ML0045**

**46.** Blister Cu is about:

(A) 60% Cu (B) 90% Cu (C) 98% Cu (D) 100% Cu

**ML0046**

**47.** Iron obtained from blast furance is:

(A) wrought iron (B) cast iron (C) pig iron (D) steel

**ML0047**

**48.** Which of the following term is not related to Al-extraction

(A) Serpek's process (B) Hall-Heroult process

(C) Thermite process (D) Hoop's process

**ML0048**

**49.** Dow's process

(A) involves purification of copper (B) involves extraction of magnesium

(C) gives metal chloride as product (D) gives pure Na as product

**ML0049**

**50.** Silica is added to roasted copper ores during extraction in order to remove

(A) cuprous sulphide (B) ferrous oxide (C) ferrous sulphide (D) cuprous oxide

**ML0050**

**51.** Addition of high proportions of manganese makes steel useful in making rails of railroads, because manganese

(A) gives hardness to steel (B) helps the formation of oxides of iron

(C) can remove oxygen and sulphur (D) can show highest oxidation state of +7

**ML0051**

**52.** In the commercial electrochemical process for aluminium extraction the electrolyte used is

(A) $Al(OH)_3$ in NaOH solution (B) an aqueous solution of $Al_2(SO_4)_3$

(C) a molten mixture of $Al_2O_3$ ,$Na_3AlF_6$ & $CaF_2$ (D) a molten mixture of $Al_2O_3$ and $Al(OH)_3$

**ML0052**

**53.** Blister copper is refined by stirring molten impure metal with green logs of wood because such a wood liberates hydrocarbon gases (like $CH_4$). This process X is called _____ and the metal contains impurities of Y is _____.

(A) X = cupellation, Y = $CuO_2$ (B) X = poling, Y = $Cu_2O$

(C) X = poling, Y = CuO (D) X = cupellation, Y = CuO

**ML0053**

**54.** A piece of steel is heated until redness and then plunged into cold water or oil. This treatment of steel makes it

(A) soft and malleable (B) hard but not brittle

(C) more brittle (D) hard and brittle

**ML0054**

**55.** Modern method of steel manufacturing is

(A) open hearth process (B) L.D. Process

(C) Bessemerisation (D) Cupellation

**ML0055**

**56.** During electrolytic reduction of alumina, two auxiliary electrolytes X and Y are added to increase the electrical conductance and lower the temperature of melt in order to making fused mixture very conducting. X and Y are

(A) cryolite and flourspar (B) cryolite and alum

(C) alum and flourspar (D) flourspar and bauxite

**ML0056**

**57.** For extraction of sodium from NaCl, the electrolytic mixture NaCl + KCl + $CaCl_2$ is used. During extraction process, only sodium is deposited on cathode but K and Ca do not because

(A) Na is more reactive than K and Ca

(B) Na is less reactive than K and Ca

(C) NaCl is less stable than $Na_3AlF_6$ and $CaCl_2$

(D) the discharge potential of $Na^+$ is less than that of $K^+$ and $Ca^{2+}$ ions.

**ML0057**

**58.** Railway wagon axles are made by heating iron rods embedded in charcoal powder. This process is known as:

(A) Sherardising (B) Annealing (C) Tempering (D) Case hardening

**ML0058**

**59.** In the extraction of copper from its sulphide ore the metal is formed by the reduction of $Cu_2O$ with:

(A) FeS (B) CO (C) $Cu_2S$ (D) $SO_2$

**ML0059**

**60.** Carnallite on electrolysis gives:

(A) Ca and $Cl_2$ (B) Na and $CO_2$ (C) Al and $Cl_2$ (D) Mg and $Cl_2$

**ML0060**

*MISCELLANEOUS*

**61.** Which of the following statement is correct regarding Cu-extraction
(A) In the smelting step carbon reduction takes places
(B) During partial roasting $Cu_2S$ remains almost unaffected
(C) In Bessemer converter, only self reduction occur, not slag formation
(D) Blister forms in the blister Cu is due to dissolved $CO_2$

**ML0061**

**62.** Refractory materials are generally used in furnaces because
(A) they are chemically inert
(B) they can withstand high temperature
(C) they do not contain impurities
(D) they decrease melting point of ore

**ML0062**

**63.** Which of the following statements is correct regarding the slag formation during the extraction of a metal like copper or iron.
(A) The slag is lighter and has lower melting temperature than the metal
(B) The slag is heavier and has lower melting temperature than the metal
(C) The slag is lighter and has higher melting temperature than the metal
(D) The slag is heavier and has higher melting temperature than the metal

**ML0063**

**64.** **Assertion :** Generally in smelting, roasted/cacinated ore is heated with powdered coke in presence of a flux.
**Reason :** Oxides are reduced to metals by C or CO. Impurities are removed as slag.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

**ML0064**

**65.** **Assertion :** Magnesia and quick lime are used as basic flux.
**Reason :** MgO and CaO can withstand very high temperatures.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

**ML0065**

**66.** **Assertion :** Wolframite impurity is separated from $SnO_2$ by magnetic separation
**Reason :** Tin stone is ferromagnetic, therefore attracted by magnet.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D) Statement-1 is false, statement-2 is true.

**ML0066**

## EXERCISE # O-2

### *ONE OR MORE THAN ONE OPTION MAY BE CORRECT*

**1.** Which of the following is(are) sulphide ores?

(A) Argentite (B) Galena (C) Anglesite (D) Copper glance

**ML0067**

**2.** Which of the following is (are) regarded as iron ores?

(A) Haematite (B) Magnetite (C) Limonite (D) Copper pyrites

**ML0068**

### *CONCENTRATION*

**3.** Which of the following ores is(are) concentrated by froth floatation?

(A) haematite (B) galena (C) copper pyrite (D) azurite

**ML0069**

**4.** Which of the following ores is (are) concentrated industrially by froth floatation?

(A) Copper pyrites (B) Galena (C) Dolomite (D) Carnallite

**ML0070**

**5.** Leaching is used for the concentration of:

(A) Red bauxite (B) Haematite (C) Gold ore (D) Silver ore

**ML0071**

### *CALCINATION/ROASTING*

**6.** Calcination and roasting processes of ores to form their oxides are beneficial

(A) to convert ores into porous form so that their reduction becomes easier

(B) as impurities like S, As, Sb, are removed

(C) as organic impurities are removed.

(D) as the ores are converted into oxide form which makes the reduction easier

**ML0072**

**7.** Which of the following reaction(s) occur during calcination?

(A) $CaCO_3 \rightarrow CaO + CO_2$ (B) $4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$

(C) $2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O$ (D) $CuS + CuSO_4 \rightarrow 2Cu + 2SO_2$

**ML0073**

**8.** Which of the following is true for calcination of a metal ore?

(A) It makes the ore more porous

(B) The ore is heated to a temperature when fusion just begins

(C) Hydrated salts lose their water of crystallisation

(D) Impurities of S, As and Sb are removed in the form of their volatile oxides.

**ML0074**

**9.** Roasting can be performed in

(A) blast furnace (B) reverberatory furnace

(C) electric furnace (D) None of these

**ML0075**

### *REDUCTION*

**10.** Carbon reduction method is employed for commercial extraction of metal from amongst these :
(A) haematite (B) cassiterite (C) iron pyrite (D) corundum

**ML0076**

**11.** Auto reduction process is used in extraction of
(A) Cu (B) Hg (C) Al (D) Fe

**ML0077**

**12.** Which of the following reduction reactions are actually employed in commerical extraction of metals?
(A) $Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$
(B) $Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$
(C) $2Na[Au(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2Au$
(D) $Cu_2S + Pb \rightarrow Cu + PbS \downarrow$

**MΛ0078**

### *PURIFICATION*

**13.** In the manufacturing of metallic sodium by fused salt-electrolysis method (Down's process), small amount of $CaCl_2$ that added is known as auxiliary electrolyte and is used to
(A) improve the electrical conductance (B) decrease the melting point of electrolyte
(C) stabilise the metallic sodium (D) increase the temperature of electrolysis

**ML0079**

**14.** Poling is employed in refining of
(A) iron (B) copper (C) tin (D) lead

**ML0080**

**15.** Zone refining is used for purification of
(A) Ge (B) Si (C) Ga (D) In

**ML0081**

**16.** Metal(s) which does/do not form amalgam is/are
(A) Fe (B) Pt (C) Zn (D) Au

**ML0082**

**17.** Metals which can be commercially extracted by smelting process
(A) Pb (B) Fe (C) Zn (D) Mg

**ML0083**

### *EXTRACTION OF METALS*

**18.** Hoop's process of purification of aluminium involves formation of layers during electrolysis. It involves
(A) the three layers have same densities but different materials.
(B) the three layers have different densities
(C) the upper layer is of pure aluminium which acts as a cathode
(D) the bottom layer is of impure aluminium which acts as an anode and middle layer consists of cryolite and $BaF_2$.

**ML0084**

**19.** Metallurgical process of zinc involves roasting of zinc sulphide followed by reduction. Metallic zinc distills over as it is volatile and impurities like Cu, Pb and Fe gets condensed. The crude metal obtained is called spelter, which may be purified by

(A) electrolysis process (B) fractional distillation

(C) polling (D) heating with iodine

**ML0085**

**20.** Which of the following process (es) are used for purification of Bauxite ore?

(A) Hall's process (B) Serpeck's process (C) Baeyer's process (D) Mond's process

**ML0086**

**21.** Common impurities present in Bauxite are

(A) CuO (B) ZnO (C) $Fe_2O_3$ (D) $SiO_2$

**ML0087**

**22.** Calcium silicate slag formed in extraction of iron

(A) prevents the reoxidation of molten iron.

(B) catalyses the combustion of carbon.

(C) reduces $CO_2$ to CO at the bottom of the furnace.

(D) is used in cement industry.

**ML0088**

**23.** Amphoteric nature of aluminium is employed in which of the following process for extraction of aluminium?

(A) Baeyer's process (B) Hall's process

(C) Serpec's process (D) Dow's process

**ML0089**

**24.** The chief reaction(s) occuring in blast furnace during extraction of iron from haematite is(are)

(A) $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (B) $FeO + SiO_2 \rightarrow FeSiO_3$

(C) $Fe_2O_3 + C \rightarrow 2Fe + 3CO$ (D) $CaO + SiO_2 \rightarrow CaSiO_3$

**ML0090**

**25.** Which of the following are true for electrolytic extraction of aluminium

(A) cathode material contains graphite

(B) anode material contains graphite

(C) cathode reacts away forming $CO_2$

(D) anode reacts away forming $CO_2$

**ML0091**

**26.** During extraction of copper, it is obtained in the form of molten *matte*. Which of the following is **not true**?

(A) *matte* is further treated in Bessemer's coverter

(B) molten *matte* is electrolysed

(C) It is treated with a blast of air and sand

(D) It is dissolved in $CuSiF_6$ and crystallised.

**ML0092**

**27.** The major role of fluorspar ($CaF_2$) which is added in small quantities in the electrolytic reduction of alumina dissolved in fused cryolite ($Na_3AlF_6$) is

(A) as a catalyst

(B) to make the fused mixture very conducting

(C) to lower the melting temperature of the mixture

(D) to decrease the rate of oxidation of carbon at the anode.

**ML0093**

**28.** Which of the following reaction does not occur in blast furance during extraction of iron :

(A) $CaO + SiO_2 \longrightarrow CaSiO_3$

(B) $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

(C) $FeO + SiO_2 \longrightarrow FeSiO_3$

(D) $FeO \longrightarrow Fe + \frac{1}{2}O_2$

**ML0094**

## *MISCELLANEOUS*

**29.** Which of the following employ downward movement of ore due to gravity?

(A) Gravity separation

(B) Froth floatation

(C) Blast furnace

(D) Bessemer's coverter

**ML0095**

**30.** The **CORRECT** statements are :

(A) generally the calcination and roasting is done in blast furance

(B) the sandy and rocky materials associated with ore are called matrix

(C) froth floatation process is suitable for sulphide ores

(D) substance that reacts with gangue to form fusible mass is called slag

**ML0096**

## EXERCISE # S-1

**1.** Find the number of ore which are concentrated by magnetic sepration method.
Haemetite, Cassiterite, Copper Glance, Chromite, Cinnabar

**ML0097**

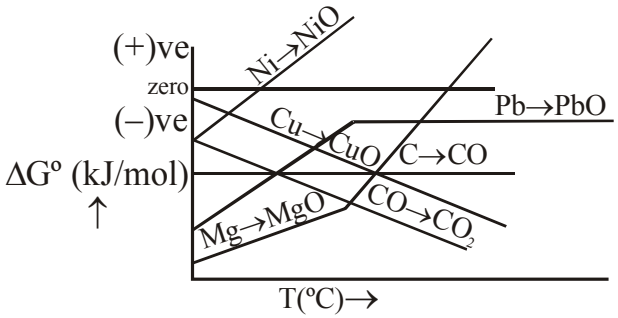
**2.** Find the number of metals which are commercially extracted by carbon reduction method
Pb, Fe, Zn, Mg, Al, Na, Au, Ag

**ML0098**

**3.** The number of following pairs is correctly matched
(i) Van Arkel method – Zirconium
(ii) Mond Process – Titanium
(iii) Froth Floatation Method – Cerussite
(iv) Distillation method – Zinc
(v) Poling Process – Copper
(vi) amalgamation – Gold

**ML0099**

**4.** Find the number of curves which are wrongly presented in the Ellingham diagram.




**ML0100**

**5.** How many of the following minerals containing Mg.
Magnetite, Carnallite, Epsom salt, Siderite

**ML0101**

**6.** Find out the number of minerals given below contain iron as Fe(II).
Haematite, Magnetite, Limonite, Siderite, Chromite, Wolframite

**ML0102**

**7.** Amongst the following ores, the total number of oxide ores are
Siderite, Magnetite, Haematite, Malachite, Zincite, Cuprite

**ML0103**

**8.** Amongst the following, total number of sulphide ores are
Calamine, Sphalertie, Copper pyrites, Copper glance, Iron pyrites, Bauxite

**ML0104**

**9.** How many of the following ores of silver ?
Hornsilver, Cerrusite, Chalcopyrite, Galena, Anglesite, Argentite

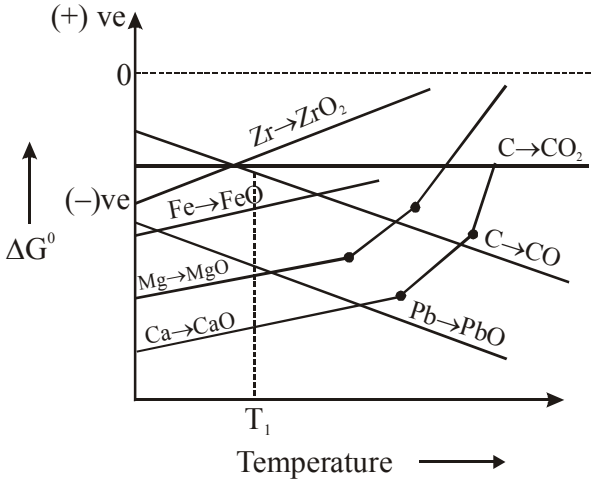
**ML0105**

# EXERCISE # S-2

## COMPREHENSION AND MATCH THE COLUMN

## ELLINGHAM DIAGRAM

***Paragraph for 1 to 3***




**1.** Which of the above curve is wrongly presented -

(A) $C \rightarrow CO_2$ (B) $Pb \rightarrow PbO$ (C) $Zr \rightarrow ZrO_2$ (D) $Mg \rightarrow MgO$

**ML0106**

**2.** Which of the above metal oxide is having minimum thermal decomposition temperature.

(A) CaO (B) FeO (C) $ZrO_2$ (D) MgO

**ML0106**

**3.** Which of the following metal's oxide can be reduced by Fe as reducing agent at temperature ($T_1$)

(A) Zr (B) Ca (C) Mg (D) None of these

**ML0106**

***PURIFICATION METHOD***

***Paragraph for 4 to 5***

At high temperature carbon reacts with water to produce a mixture of carbon monoxide, CO and hydrogen, $H_2$.

$$C + H_2O \xrightarrow{\text{red heat}} CO + H_2$$

CO is separated from $H_2$ and then used to separate nickel from cobalt by forming a volatile compound, nickel tetracarbony, $Ni(CO)_4$.

$$Ni + 4CO \longrightarrow Ni(CO)_4$$

**4.** How many moles of $Ni(CO)_4$ could be obtained from the CO produced by the reaction of 75.0g of carbon ? Assume 100% reaction and 100% recovery in both steps.

(A) 6.25 (B) 1.563 (C) 3.125 (D) 25.0

**ML0107**

**5.** Formation of volatile $Ni(CO)_4$ and its subsequent heating gives pure Ni. Process is called -

(A) Hall (B) Dow (C) Serpeck (D) Mond

**ML0107**

## *MISCELLANEOUS*

***Match Column***

**6.** Match **Column-I** with **Column-II**

| | **Column-I (Metals)** | | **Column-II (Method used for refining)** |
|---|---|---|---|
| (A) | Iron & copper | (P) | Poling |
| (B) | Zirconium & Titanium | (Q) | Bessemerisation |
| (C) | Lead & Tin | (R) | Van-Arkel |
| (D) | Copper & Tin | (S) | Liquation |

**ML0108**

**7.** Match the following choosing one item from column X and the appropriate item from column Y.

| | **Column -X** | | **Column-Y** |
|---|---|---|---|
| (A) | Zinc from $ZnCO_3$ | (P) | Calcination |
| (B) | Lead from PbS | (Q) | Removal of iron |
| (C) | Cu from $CuFeS_2$ | (R) | Froth floatation process |
| (D) | Tin from cassiterite | (S) | Poling |

**ML0109**

**8.** Match column (I) (process) with column (II) (electrolyte)

| | **Column (I) (process)** | | **Column (II) (electrolyte)** |
|---|---|---|---|
| (A) | Downs cell | (P) | fused $MgCl_2$ |
| (B) | Dow's sea water process | (Q) | fused ($Al_2O_3 + Na_3AlF_6 + CaF_2$) |
| (C) | Hall-Heroult | (R) | fused (40% NaCl + 60% $CaCl_2$) |
| | | (S) | ($A\ell N + C + N_2$) |

**ML0110**

**9.** Match column - I with column - II

| | **Column - I (Property)** | | **Column - II (Element/compound)** |
|---|---|---|---|
| (A) | Explosive | (P) | Cu |
| (B) | Self-reduction | (Q) | $Fe_3O_4$ |
| (C) | Ferrimagnetic material | (R) | $Cu(CH_3COO)_2.Cu(OH)_2$ |
| (D) | Verdigris | (S) | $Pb(NO_3)_2$ |

**ML0111**

**10.** Match column - I and column - II and select the correct answer using the codes given below the lists:

| | **Column - I** | | **Column - II** |
|---|---|---|---|
| (A) | Cyanide process | (P) | Ultrapure Ge |
| (B) | Floatation process | (Q) | Dressing of HgS |
| (C) | Electrolytic reduction | (R) | Extraction of Al |
| (D) | Zone refining | (S) | Extraction of Au |

**ML0112**

**11.** Match the items of Column I with items of Column II and assign the correct code :

| | **Column I** | | **Column II** |
|---|---|---|---|
| (P) | Blistered Cu | (1) | Aluminium |
| (Q) | Blast furnace | (2) | $2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$ |
| (R) | Reverberatory furnace | (3) | Iron |
| (S) | Hall-Heroult process | (4) | $FeO + SiO_2 \rightarrow FeSiO_3$ |
| | | (5) | $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$ |

**Code :**

(A) P → (2) ; Q → (3) ; R → (4) ; S → (1) (B) P → (1) ; Q → (2) ; R → (3) ; S → (5)

(C) P → (5) ; Q → (4) ; R → (3) ; S → (2) (D) P → (4) ; Q → (5) ; R → (3) ; S → (2)

**ML0113**

Answer Q.12, Q.13 and Q.14 by appropriately matching the information given in the three columns of the following table.

| **Column - I Extraction of metal** | **Column - II Methods for Reduction** | **Column - III Refining Method** |
|---|---|---|
| (1) $SnO_2 \rightarrow Sn$ | (i) Carbon Reduction | (P) Poling |
| (2) $Al_2O_3 \rightarrow Al$ | (ii) Hydrometallurgic Reduction | (Q) Electrolytic Refining |
| (3) $Cu_2S \rightarrow Cu$ | (iii) Electrolytic Reduction | (R) Distillation |
| (4) $ZnS \rightarrow Zn$ | (iv) Self-Reduction | (S) Puddling Process |

**12.** Which of the following is **NOT** correctly matched?

(A) (1), (iv), (S) (B) (3), (iv), (P) (C) (4), (i), (R) (D) (2), (iii), (Q)

**ML0114**

**13.** Which of the followong match is the **CORRECT** reduction and purification methods for Zn

(A) (i), (R) (B) (iv), (S) (C) (iv), (P) (D) None of these

**ML0114**

**14.** Which of the following set of code shows the **CORRECT** similarity with the extraction processes for Pb?

(A) (1), (ii), (S) (B) (4), (iii), (P) (C) (2), (iii), (Q) (D) (3), (iv), (Q)

**ML0114**

## EXERCISE # JEE-MAINS

**1.** Aluminium is extracted by the electrolysis of :- **[AIEEE-2002]**

(1) Bauxite (2) Alumina

(3) Alumina mixed with molten cryolite (4) Molten cryolite

**ML0115**

**2.** Pyrolusite is a/an :- **[AIEEE-2002]**

(1) Oxide ore (2) Sulphide ore (3) Carbide ore (4) Not an ore

**ML0116**

**3.** Which one of the following ores is best concentrated by froth-flotation method : **[AIEEE-2004]**

(1) Galena (2) Cassiterite (3) Magnetite (4) Malachite

**ML0117**

**4.** Which of the following factors is of no significance for roasting sulphide ores to the oxides and not subjecting the sulphide ores to carbon reduction directly ? **[AIEEE-2008]**

(1) Metal sulphides are thermodynamically more stable than $CS_2$

(2) $CO_2$ is thermodynamically more stable than $CS_2$

(3) Metal sulphides are less stable than the corresponding oxides

(4) $CO_2$ is more volatile than $CS_2$

**ML0118**

**5.** Which method of purification is represented by the following equation : **[AIEEE-2012]**

$$Ti(s) + 2I_2(g) \xrightarrow{523K} TiI_4(g) \xrightarrow{1700K} Ti(s) + 2I_2(g)$$

(1) Van Arkel (2) Zone refining (3) Cupellation (4) Poling

**ML0119**

**6.** The substance used as froth stabilisers in froth-floatation process is : **[J-Mains-2012 (On line)]**

(1) Copper sulphate (2) Aniline

(3) Sodium cyanide (4) Potassium ethyl xanthate

**ML0120**

**7.** Which of the oxide groups among the following cannot be reduced by carbon :- **[J-Mains-2012 (On line)]**

(1) $Fe_3O_4$, ZnO (2) PbO, $Fe_3O_4$ (3) $Cu_2O$, $SnO_2$ (4) CaO, $K_2O$

**ML0121**

**8.** In Goldschmidt alumino thermic process which of the following reducing agents is used : **[J-Mains-2013 (On line)]**

(1) Calcium (2) Coke (3) Sodium (4) Al-powder

**ML0122**

**9.** Calcination is the process in which :

(1) Ore is heated strongly below its melting point in the presence of excess of air and is used for the conversion of carbonates and hydrated oxide ores to their respective oxides.

(2) Ore is heated strongly below its melting point in the absence or limited supply of air and is used for conversion of sulphide ores to their respective oxides

(3) Ore is heated strongly below its melting point either in the limited supply or absence of air and is used to convert carbonates and hydrated oxide ores to their respective oxides

(4) Ore is heated strongly above its melting point in the limited supply of air to convert sulphide ores to their respective oxides.

**ML0123**

**10.** The metal that cannot be obtained by electrolysis of an aqueous solution of its salts is :

**[JEE-MAINS-2014]**

(1) Cu (2) Cr (3) Ag (4) Ca

**ML0124**

**11.** The form of iron obtained from blast furnace is : **[J-Mains-2014 (On line)]**

(1) Steel (2) Wrought Iron (3) Cast Iron (4) Pig iron

**ML0125**

**12.** In the context of the Hall-Heroult process for the extraction of Al, which of the following statements is false ? **[JEE-MAINS-2015]**

(1) $Al^{3+}$ is reduced at the cathode to form Al

(2) $Na_3AlF_6$ serves as the electrolyte

(3) CO and $CO_2$ are produced in this process

(4) $Al_2O_3$ is mixed with $CaF_2$ which lowers the melting point of the mixture and brings conductivity

**ML0126**

**13.** Galvanization is applying a coating of :- **[JEE-MAINS-2016]**

(1) Zn (2) Pb (3) Cr (4) Cu

**ML0127**

**14.** Which one of the following ores is best concentrated by froth floatation method ?

**[JEE-MAINS-2016]**

(1) Malachite (2) Magnetite (3) Siderite (4) Galena

**ML0128**

**15.** What will occur if a block of copper metal is dropped into a beaker containing a solution of 1M $ZnSO_4$ ? **[JEE-MAINS (Online) - 2016]**

(1) The copper metal will dissolve and zinc metal will be deposited

(2) No reaction will occur

(3) The copper metal will dissolve with evolution of oxygen gas

(4) The copper metal will dissolve with evolution of hydrogen gas

**ML0129**

**16.** In the leaching method, bauxite ore is digested with a concentrated solution of NaOH that produces 'X'. When $CO_2$ gas is passed through the aqueous solution of 'X', a hydrated compound 'Y' is precipitated. 'X' and 'Y' respectively are :- **[JEE MAIN ONLINE. 2018]**

(1) $Na[Al(OH)_4]$ and $Al_2O_3 \cdot x\ H_2O$

(2) $Al(OH)_3$ and $Al_2O_3 \cdot x\ H_2O$

(3) $Na[Al(OH)_4]$ and $Al_2(CO_3)_3 \cdot x\ H_2O$

(4) $Na\ AlO_2$ and $Al_2(CO_3)_3 \cdot x\ H_2O$

**ML0130**

**17.** When metal 'M' is treated with NaOH, a white gelatinous precipitate 'X' is obtained, which is soluble in excess of NaOH. Compound 'X' when heated strongly gives an oxide which is used in chromatography as an adsorbent. The metal 'M' is **[JEE MAIN OFFLINE. 2018]**

(1) Ca (2) Al (3) Fe (4) Zn

**ML0131**

# EXERCISE # JEE-ADVANCED

**1.** Carnallite does not contain
(A) K (B) Ca (C) Mg (D) Cl

**ML0132**

**2.** During initial treatment, preferential wetting of ore by oil and gangue by water takes place in
(A) Levigation (gravity separation) (B) Froth floatation
(C) Leaching (D) Bessemerisation

**ML0133**

**3.** Which of the following is true for calcination of a metal ore?
(A) It makes the ore more porous
(B) The ore is heated to a temperature when fusion just begins
(C) Hydrated salts lose their water of crystallisation
(D) Sulphur in sulphides is oxidised to $SO_2$
(E) Heating with carbon leads to better calcination

**ML0134**

**4.** In the commercial electrochemical process for aluminium extraction, the electrolyte used as : **[JEE-1999]**
(A) $Al(OH)_3$ in NaOH solution
(B) an aqueous solution of $Al_2(SO_4)_3$
(C) a molten mixture of $Al_2O_3$ and $Na_3AlF_6$
(D) a molten mixture of AlO(OH) and $Al(OH)_3$

**ML0135**

**5.** The chemical process in the production of steel from haematite ore involve: **[2000 Qualifying]**
(A) reduction (B) oxidation
(C) reduction followed by oxidation (D) oxidation followed by reduction

**ML0136**

**6.** Electrolytic reduction of alumina to aluminium by Hall-Heroult process is carried out:
(A) in the presence of NaCl **[2000 Qualifying]**
(B) in the presence of fluorite
(C) in the presence of cryolite which forms a melt with lower melting temperature
(D) in the presence of cryolite which forms a melt with higher melting temperature

**ML0137**

**7.** The chemical composition of "slag" formed during the smelting process in the extraction of copper is : **[2001 Qualifying]**
(A) $Cu_2O + FeS$ (B) $FeSiO_3$ (C) $CuFeS_2$ (D) $Cu_2S + FeO$

**ML0138**

**8.** Which of the following processes is used in extractive metallurgy of magnesium? **[2002 Qualifying]**
(A) Fused salt electrolysis (B) Self reduction
(C) Aqueous solution electrolysis (D) Thermite reduction

**ML0139**

**9.** In the process of extraction of gold, **[2003 Qualifying]**

$$\text{Roasted gold ore} + CN^- + H_2O \xrightarrow{O_2} [X] + OH^-$$

$$[X] + Zn \longrightarrow [Y] + Au$$

Identify the complexes [X] and [Y] :

(A) $X = [Au(CN)_2]^-$ , $Y = [Zn(CN)_4]^{2-}$ (B) $X = [Au(CN)_4]^{3-}$ , $Y = [Zn(CN)_4]^{2-}$

(C) $X = [Au(CN)_2]^-$ , $Y = [Zn(CN)_6]^{4-}$ (D) $X = [Au(CN)_4]^-$ , $Y = [Zn(CN)_4]^{2-}$

**ML0140**

**10.** The methods chiefly used for the extraction of lead and tin from their ores are respectively : **[JEE-2004]**

(A) self reduction and carbon reduction (B) self reduction and electrolytic reduction

(C) carbon reduction and self reduction (D) cyanide process and carbon reduction

**ML0141**

**11.** Which ore contains both iron and copper ? **JEE-2004]**

(A) Cuprite (B) Chalcocite (C) Chalcopyrite (D) Malachite

**ML0142**

**12.** Extraction for zinc from zinc blende is achieved by : **[JEE-2007]**

(A) electrolytic reduction

(B) roasting followed by reduction with carbon

(C) roasting followed by reduction with another metal

(D) roasting followed by self-reduction

**ML0143**

**13.** Native silver metal forms a water soluble complex with a dilute aqueous solution of NaCN in the presence of :-

(A) nitrogen (B) oxygen (C) carbon dioxide (D) argon **[JEE-2008]**

**ML0144**

**Paragraph for questions 14 to 16**

Copper is the most nobel of the first row transition metals and occurs in small deposits in several countries. Ores of copper include chalcanthite ($CuSO_4 . 5H_2O$), atacamite ($Cu_2Cl(OH)_3$), cuprite ($Cu_2O$), copper glance ($Cu_2S$) and malachite ($Cu_2(OH)_2CO_3$). However, 80% of the world copper production comes from the ore chalcopyrite ($CuFeS_2$). The extraction of copper from chalcopyrite involves partial roasting, removal of iron and self-reduction. **[JEE-2010]**

**14.** Partial roasting of chalcopyrite produces :-

(A) $Cu_2S$ and FeO (B) $Cu_2O$ and FeO (C) CuS and $Fe_2O_3$ (D) $Cu_2O$ and $Fe_2O_3$

**ML0145**

**15.** Iron is removed from chalcopyrite as :-

(A) FeO (B) FeS (C) $Fe_2O_3$ (D) $FeSiO_3$

**ML0145**

**16.** In self-reduction, the reducing species is :-
(A) S (B) $O^{2-}$ (C) $S^{2-}$ (D) $SO_2$

**ML0145**

**17.** Match the extraction processes listed in column I with metals listed in column II. **[JEE-2006]**

| **Column I** | **Column II** |
|---|---|
| (A) Self reduction | (P) Lead |
| (B) Carbon reduction | (Q) Silver |
| (C) Complex formation and displacement by metal | (R) Copper |
| (D) Decomposition of iodide | (S) Boron |

**ML0146**

**18.** Match the conversions in **Column I** with the type(s) of reaction(s) given in **Column II**. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

| **Column I** | **Column II** **[JEE-2008]** |
|---|---|
| (A) $PbS \rightarrow PbO$ | (P) Roasting |
| (B) $CaCO_3 \rightarrow CaO$ | (Q) Calcination |
| (C) $ZnS \rightarrow Zn$ | (R) Carbon reduction |
| (D) $Cu_2S \rightarrow Cu$ | (S) Self reduction |

**ML0147**

**19.** In extractive metallurgy of zinc partial fusion of ZnO with coke is called _____ and reduction of the ore to the molten metal is called _____ (smelting, calcining, roasting, sintering). **[JEE-1988]**

**ML0148**

**20.** Extraction of metal from the ore cassiterite involves **[JEE-2011]**
(A) carbon reduction of an oxide ore (B) self-reduction of a sulphide ore
(C) removal of copper impurity (D) removal of iron impurity

**ML0149**

**21.** Oxidation states of the metal in the minerals haematite and magnetite, respectively, are **[JEE-2011]**
(A) II, III in haematite and III in magnetite (B) II, III in haematite and II in magnetite
(C) II in haematite and II, III in magnetite (D) III in haematite and II, III in magnetite

**ML0150**

**22.** In the cyanide extraction process of silver from argentite ore, the oxidizing and reducing agents used are : **[JEE-2012]**
(A) $O_2$ and CO respectively. (B) $O_2$ and Zn dust respectively.
(C) $HNO_3$ and Zn dust respectively. (D) $HNO_3$ and CO respectively.

**ML0151**

**23.** Sulfide ores are common for the metals - **[JEE-2013]**
(A) Ag, Cu and Pb (B) Ag, Cu and Sn (C) Ag, Mg and Pb (D) Al, Cu and Pb

**ML0152**

**24.** The carbon-based reduction method is **NOT** used for the extraction of **[JEE-2013]**
(A) tin from $SnO_2$ (B) Iron from $Fe_2O_3$
(C) aluminium from $Al_2O_3$ (D) magnesium from $MgCO_3.CaCO_3$

**ML0153**

**25.** Upon heating with $Cu_2S$, the reagent(s) that give copper metal is/are **[JEE Adv. 2014]**
(A) $CuFeS_2$ (B) CuO (C) $Cu_2O$ (D) $CuSO_4$

**ML0154**

**26.** Copper is purified by electrolytic refining of blister copper. The correct statement(s) about this process is (are) **[JEE Adv. 2015]**

(A) Impure Cu strip is used as cathode

(B) Acidified aqueuous $CuSO_4$ is used as electrolyte

(C) Pure Cu deposits at cathode

(D) Impurities settle as anode-mud

**ML0155**

**27.** Match the anionic species given in Column-I that are present in the ore(s) given in Column-II **[JEE Adv. 2015]**

| **Column - I** | **Column - II** |
|---|---|
| (A) Carbonate | (P) Siderite |
| (B) Sulphide | (Q) Malachite |
| (C) Hydroxide | (R) Bauxite |
| (D) Oxide | (S) Calamine |
| | (T) Argentite |

**ML0156**

**28.** Extraction of copper from copper pyrite ($CuFeS_2$) involves **[JEE Adv. 2016]**

(A) crushing followed by concentration of the ore by froth-flotation

(B) removal of iron as slag

(C) self-reduction step to produce 'blister copper' following evolution of $SO_2$

(D) refining of 'blister copper' by carbon reduction

**ML0157**

**29.** Galena (an ore) is partially oxidized by passing air through it at high temperature. After some time, the passage of air is stopped, but the heating is continued in a closed furnance such that the contents undergo self-reduction. The weight (in kg) of Pb produced per kg of $O_2$ consumed is _____ . (Atomic weights in g $mol^{-1}$ : O = 16, S = 32, Pb = 207) **[JEE ADV. 2018]**

**ML0158**

**30.** Calamine, malachite, magnetite and cryolite, respectively are **[JEE ADV. 2019]**

(1) $ZnSO_4$, $CuCO_3$, $Fe_2O_3$ , $AlF_3$ (2) $ZnCO_3$, $CuCO_3.Cu(OH)_2$, $Fe_3O_4$, $Na_3AlF_6$

(3) $ZnSO_4$, $Cu(OH)_2$, $Fe_3O_4$, $Na_3AlF_6$ (4) $ZnCO_3$, $CuCO_3$, $Fe_2O_3$, $Na_3AlF_6$

**ML0159**

**31.** The cyanide process of gold extraction involves leaching out gold from its ore with $CN^-$ in the presence of **Q** in water to form **R**. Subsequently, **R** is treated with **T** to obtain Au and **Z**. Choose the correct option(s). **[JEE ADV. 2019]**

(1) **T** is Zn (2) **R** is $[Au(CN)_4]^-$ (3) **Z** is $[Zn(CN)_4]^{2-}$ (4) **Q** is $O_2$

**ML0160**

# ANSWER-KEY

## EXERCISE # O-I

| | | | | | |
|---|---|---|---|---|---|
| 1. (A) | 2. (C) | 3. (B) | 4. (B) | 5. (C) | 6. (A) |
| 7. (A) | 8. (B) | 9. (D) | 10. (B) | 11. (B) | 12. (A) |
| 13. (B) | 14. (B) | 15. (A) | 16. (D) | 17. (A) | 18. (A) |
| 19. (B) | 20. (C) | 21. (C) | 22. (C) | 23. (C) | 24. (B) |
| 25. (B) | 26. (D) | 27. (C) | 28. (B) | 29. (A) | 30. (D) |
| 31. (A) | 32. (B) | 33. (C) | 34. (B) | 35. (A) | 36. (C) |
| 37. (C) | 38. (D) | 39. (A) | 40. (B) | 41. (C) | 42. (B) |
| 43. (A) | 44. (A) | 45. (D) | 46. (C) | 47. (C) | 48. (C) |
| 49. (B) | 50. (B) | 51. (A) | 52. (C) | 53. (B) | 54. (D) |
| 55. (B) | 56. (A) | 57. (D) | 58. (D) | 59. (C) | 60. (D) |
| 61. (B) | 62. (B) | 63. (A) | 64. (A) | 65. (B) | 66. (C) |

## EXERCISE # O-II

| | | | | | |
|---|---|---|---|---|---|
| 1. (A,B,D) | 2. (A,B,C) | 3. (B,C) | 4. (A,B) | 5. (A,C,D) | 6. (A,B,C,D) |
| 7. (A, C) | 8. (A, C) | 9. (A, B) | 10. (A, B) | 11. (A,B) | 12. (B, C) |
| 13. (A,B) | 14. (B,C) | 15. (A,B,C, D) | 16. (A,B) | 17. (A,B, C) | 18. (B,C,D) |
| 19. (A,B) | 20. (A,B,C) | 21. (C,D) | 22. (A, D) | 23. (A,B) | 24. (A, D) |
| 25. (A,B,D) | 26. (B,D) | 27. (B,C) | 28. (C,D) | 29. (A,C) | 30. (B, C) |

## EXERCISE # S-1

| | | | | | |
|---|---|---|---|---|---|
| 1. (3) | 2. (3) | 3. (4) | 4. (4) | 5. (2) | 6. (4) |
| 7. (4) | 8. (4) | 9. (2) | | | |

## EXERCISE # S-2

| | | | | |
|---|---|---|---|---|
| 1. (B) | 2. (C) | 3. (A) | 4. (B) | 5. (D) |
| 6. (A) Q; (B) R; (C) S; (D)P | 7. (A) $\rightarrow$ P, (B) $\rightarrow$ R ; (C) $\rightarrow$ Q, R, S (D) $\rightarrow$ Q, S | | | |
| 8. (A) R ; (B) P; (C) Q | 9. (A) S ; (B) P; (C) Q; (D) R | | | |
| 10. (A) S ; (B) Q ; (C) R ; (D) P | 11. (A) | 12. (A) | 13. (A) | 14. (D) |

## EXERCISE # JEE-MAINS

| | | | | | |
|---|---|---|---|---|---|
| **1. (3)** | **2. (1)** | **3. (1)** | **4. (3)** | **5. (1)** | **6. (2)** |
| **7. (4)** | **8. (4)** | **9. (3)** | **10. (4)** | **11. (4)** | **12. (2)** |
| **13. (1)** | **14. (4)** | **15. (2)** | **16. (1)** | **17. (2)** | |

## EXERCISE # JEE-ADVANCED

| | | | | | |
|---|---|---|---|---|---|
| **1. (B)** | **2. (B)** | **3. (A,C)** | **4. (C)** | **5. (C)** | **6. (C)** |
| **7. (B)** | **8. (A)** | **9. (A)** | **10. (A)** | **11. (C)** | **12. (B)** |
| **13. (B)** | **14. (A)** | **15. (D)** | **16. (C)** | | |

**17. (A) – P, R ; (B) – P ; (C) – Q ; (D) – S** **18. (A) – P ; (B) – Q ; (C) – P, R ; (D) – P, S**

**19. Sintering , Smelting** **20. (A, D) or (A, C, D)** **21. (D)**

**22. (B)** **23. (A)** **24. (C, D)** **25. (B, C, D)** **26. (B, C, D)**

**27. (A) – P , Q , S ; (B) – T ; (C) – Q , R ; (D) – R** **28. (A, B, C)**

**29. Ans. (6.47)** **30. Ans.(2)** **31. Ans.(1,3,4)**

**Sol.** $PbS + O_2 \longrightarrow Pb + SO_2$

$\frac{1000}{32}$ mol $\frac{1000}{32} \times 207$ gm

mol of Pb = mol of $O_2$

$= \frac{1000}{32}$ mol

$\therefore$ mass of Pb = $\frac{1000}{32} \times 207$g

$= \frac{207}{32}$ kg $= 6.47$ kg