

INTRODUCTION

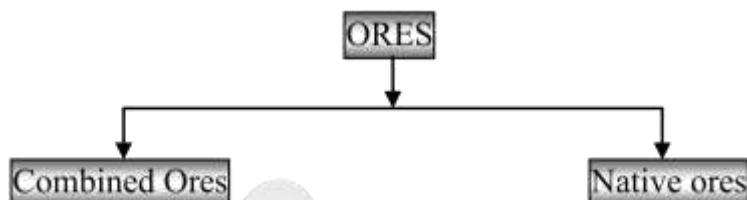
The compound of a metal found in nature is called a mineral.

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

An ore is usually contaminated with earthy or undesired materials 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.

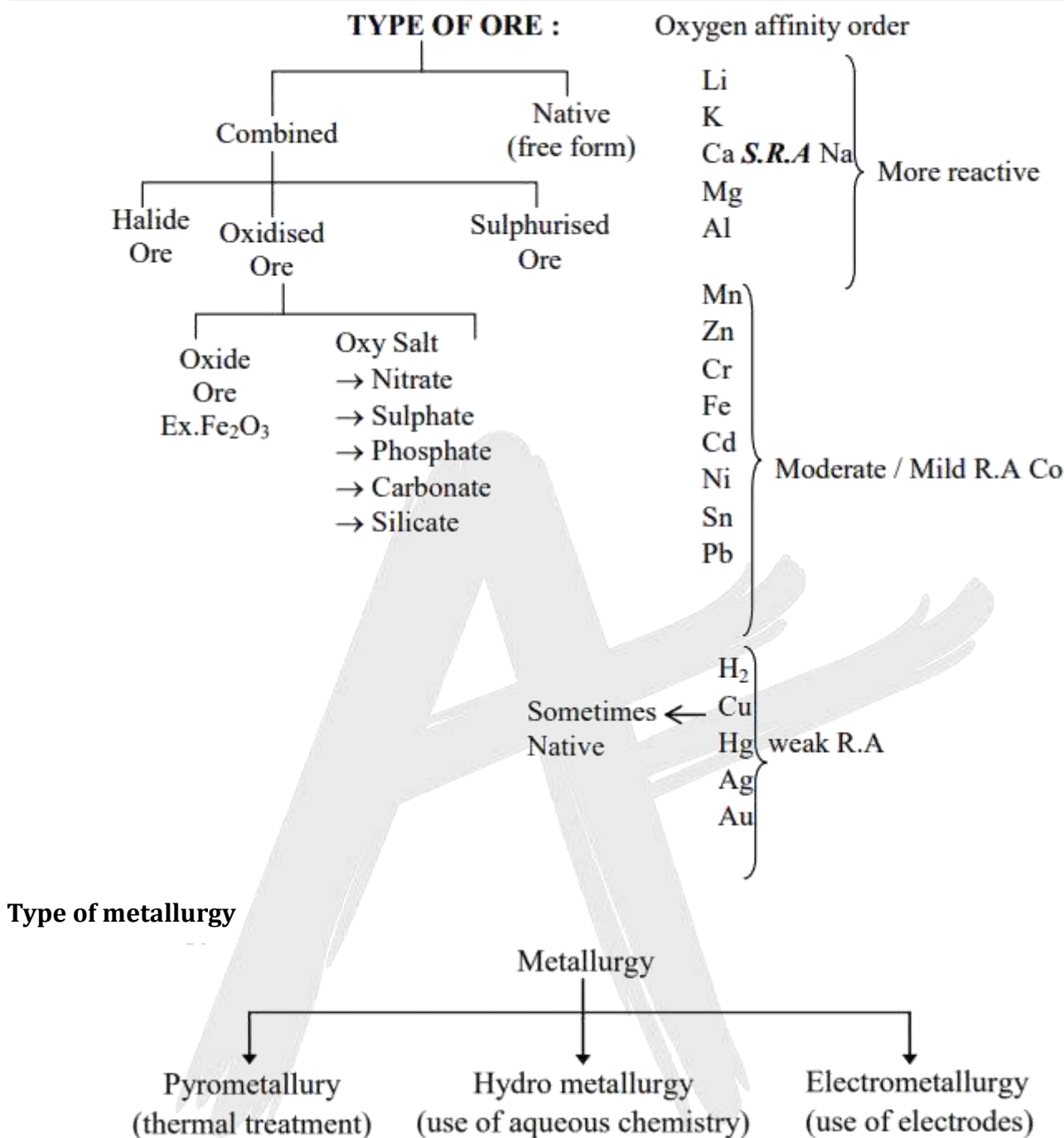
(ii) Sulphurised ore: These ores consist of sulphides of metals like iron, lead, zinc, mercury etc.

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

Extraction of pure metal from its ore is called metallurgy.

Mineral :- Naturally occurring substance in which metal exists in free form or in combined form is called mineral.

Ore :- Mineral from which metal can be conveniently & economically extracted is called ore.



(A) Electrometallurgy: When electrolysis involved in extraction of pure metal from its ore. Ex. S.block metal & Al.

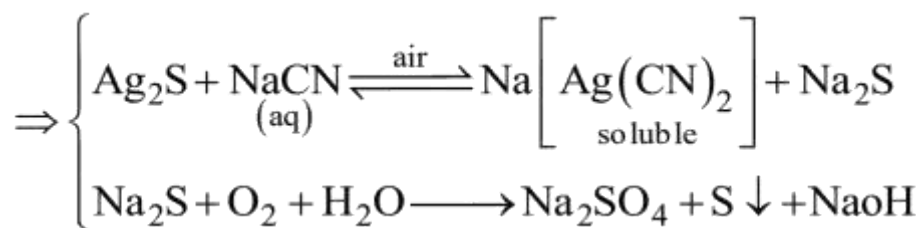
(B) Pyrometallurgy: When heating effect involved in extraction of pure metal, from its ore, then it is called pyrometallurgy. Ex – Mn, Zn, Cr, Fe, Sn, Pb, $\underset{\substack{\downarrow \\ \text{high grade}}}{\text{Cu}}$, Hg

(C) Hydrometallurgy: Ag, Au, Cu (low grade)

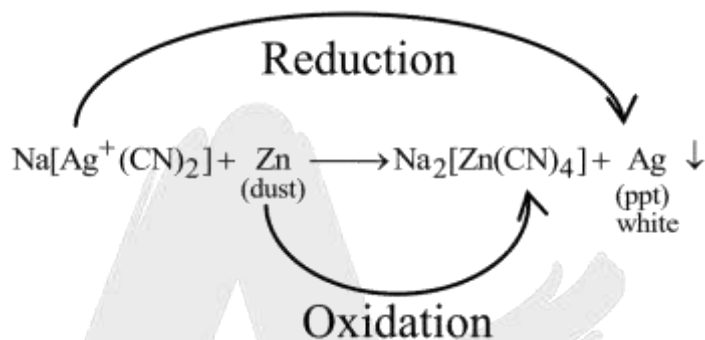
It involves dissolution of metallic ore in a suitable solvent in which metallic ore is soluble & impurities are insoluble. After filtration, metal can be precipitated by treating it with more electropositive

elements.

Leaching:



Hydro metallurgic Reduction :-

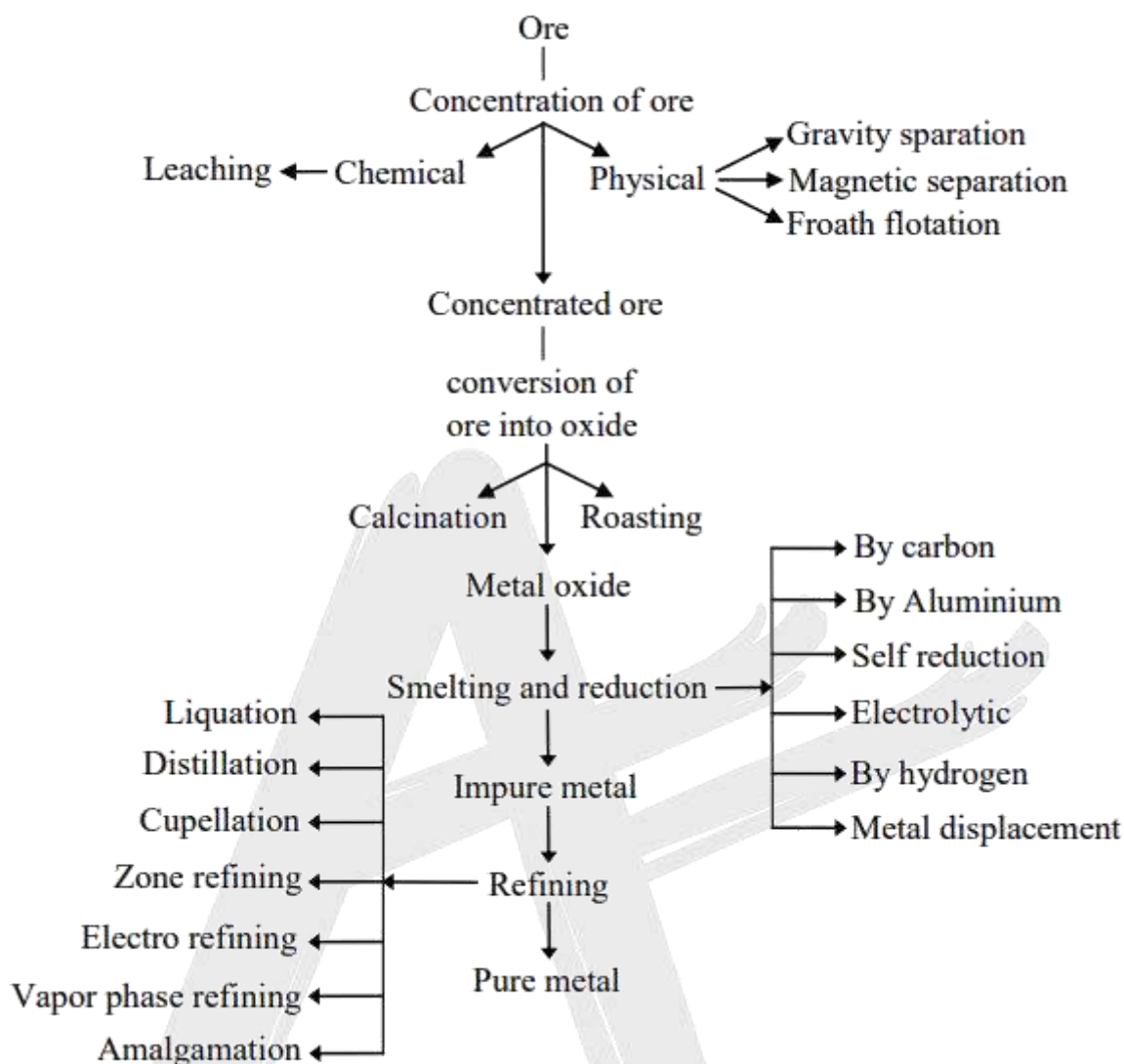


Zn being more electropositive reduces Ag^+ to Ag.

Extraction of metal depends on nature of metal & nature of impurities.

However, some common steps are used

STEPS INVOLVED IN METALLURGY :



Common steps involved in metallurgy:

1. **Crushing (Grinding)** (also known as pulverization)

Crushing and grinding (Pulverization)

Operation in which size reduction of large lumps to small pieces followed by finely ground material is done by the use of crushers and grinders.

Handpicking: To pick up selective pieces of ores.

Concentration (Dressing) of the ore

Operation in which the removal of impurities (gangue) from ore by the following methods.

2. **Levigation or gravity separation:**

(i) This method is based on the difference in densities of the ore gangue particles.

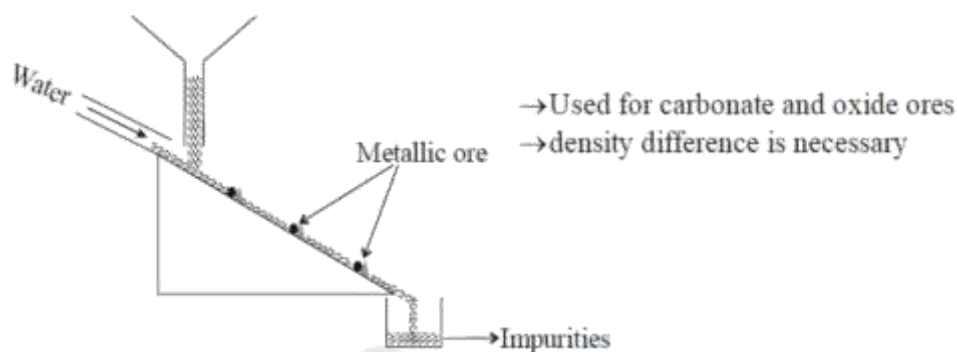
(ii) The powdered ore with gangue particles is introduced in the running stream of water.

(iii) Lighter impurity particles washed off with water and heavier ore particles settle down at

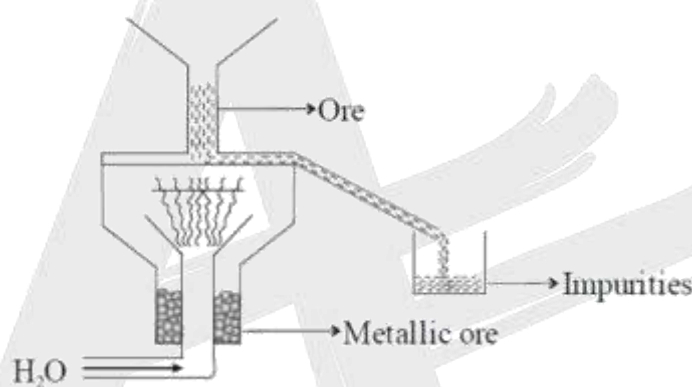
the bottom.

Eg. Generally oxides and carbonate ores are concentrated by this method.

(a) Wilfley Table :-



(b) Hydraulic Washing Method :-



3. Magnetic Separation :

Ore and gangue are separated, if only one of them is having magnetic property.

Eg. In metallurgy of Fe.

Ore → magnetic

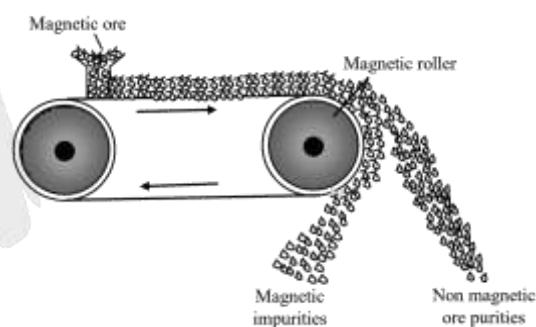
impurity → non magnetic

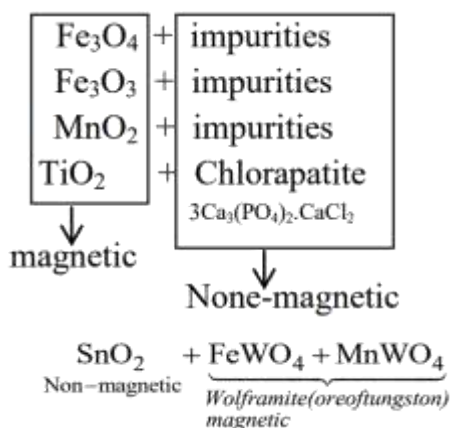
In metallurgy of Sn (tin stone)

Ore → non magnetic (SnO_2)

impurity → wolframite ($FeWO_4$)

Example:

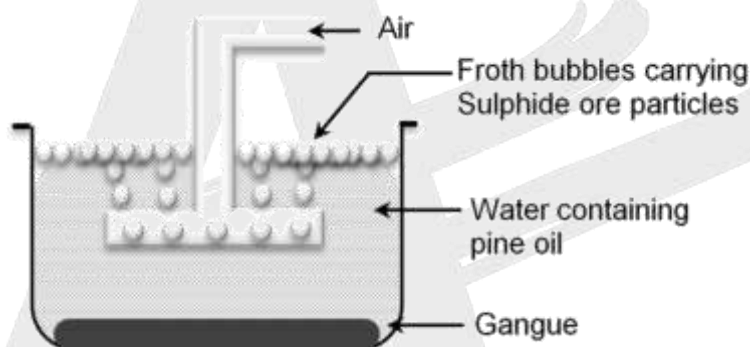




4. Froath floatation:

(i) It is employed for sulphide ores.

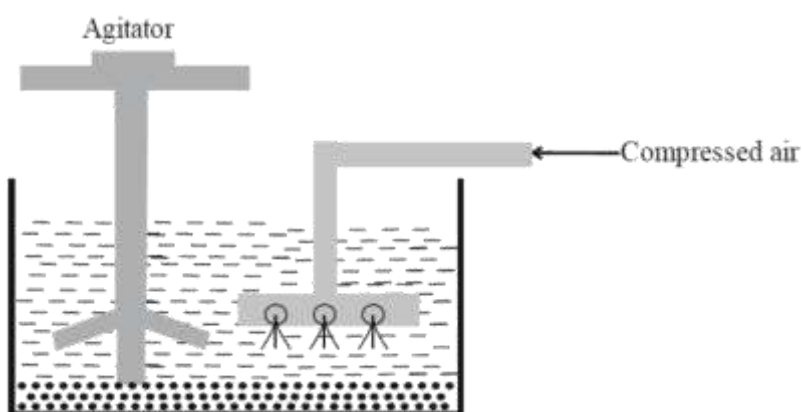
(ii) It is based on the different wetting characteristics of the ore and gangue particles with water and oil



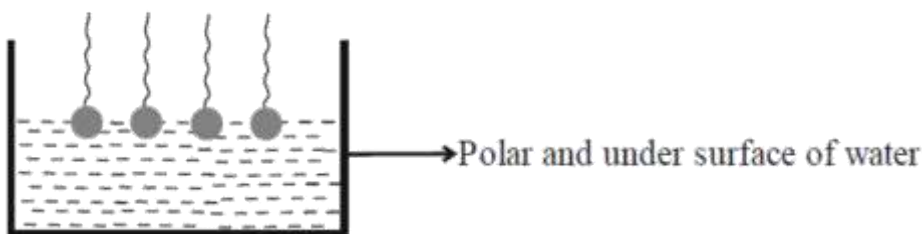
(iii) Usually ore particles are making as acrofillic and gangue particles as acrophobic by using different reagents.

(iv) Ore particles raised to the surface along with air bubbles and collected at the surface where as gangue particles are wetted and settled down at the bottom of the tank.

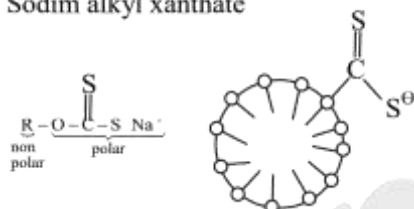
(v) Reagents used a froathing agents (pine oil), collectors (sodium ethyl xanthate and potassium ethyl xanthate), Activators (copper sulphate) and depressors (sodium cyanide, alkali).



(Water + Pine oil + Metallic ore + Sodium ethyl xanthate)



Sodium alkyl xanthate



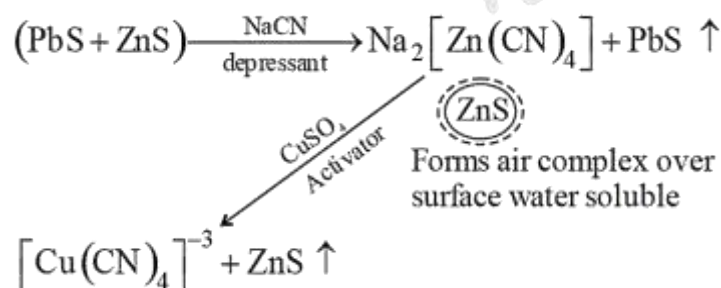
bubbles are formed where in xanthate molecules are attached to surface. Non - polar end inside it. The sulphide ores are adsorbed on the xanthate group

- Pine oil or Eucalyptus oil Frothing agent
- Sodium ethyl xanthate Collector
- The sulphide ores are deposited on surface by pine oil towards which they have preferential wetting property. Then, as air bubble bursts, the sodium ethyl xanthate comes down.
- Adsorption phenomena involved in this method



Surface phenomena due to weak forces.

- To maintain life time of air bubble (froth stabilizing) aniline or cresol is added
froth stabiliser
- Sometimes two or more metal sulphide are simultaneously present, then they are separated by using depressant & activator.



- By adjusting water-oil proportion, we can separate out PbS & ZnS as collection times are changed. (surface Tension)
- Activator increases activity of collector.

Collectors :

These compounds adsorb themselves on polar groups to grains of ores and thus derive them on the surface to pass on into the forth e.g. sodium ethyl xanthate and potassium ethyl xanthate.

Activators and depressants :

These compounds activate or depress the floating property of one of the components of the ore and thus help in the separation of different minerals present in the same ore. Copper sulphate is an example of activator, while sodium and potassium cyanides are the examples of depressants e.g. Galena (PbS) is usually associated with sphalerite (ZnS) and pyrites (FeS_2). Floatation is carried out in presence of potassium ethyl xanthate (collector) and sodium cyanide and alkali (depressants). The later compounds depress the flotation property of ZnS and FeS_2 particles and hence only PbS particles go into the forth when air is blown in. After the removal of galena, the process is repeated by adding copper sulphate (activator) which activates the floating character of ZnS particles and thus this time ZnS comes with the froath. The acidification of remaining slurry leads to the flotation of FeS_2 .

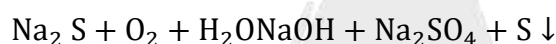
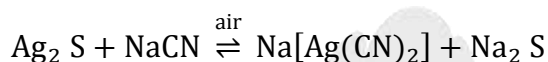
CHEMICAL CONCENTRATION

Leaching:

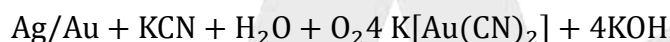
It involves dissolution of metallic ore in a suitable solvent in which metallic ore is soluble & impurities are insoluble.

- Chemical method of concentration.
- Selective dissolution of ore in strong reagents where as gangue particles are undissolved and gets separated. (Hydrometallurgy)
- Employed for concentrating ores of aluminium, silver, gold etc.

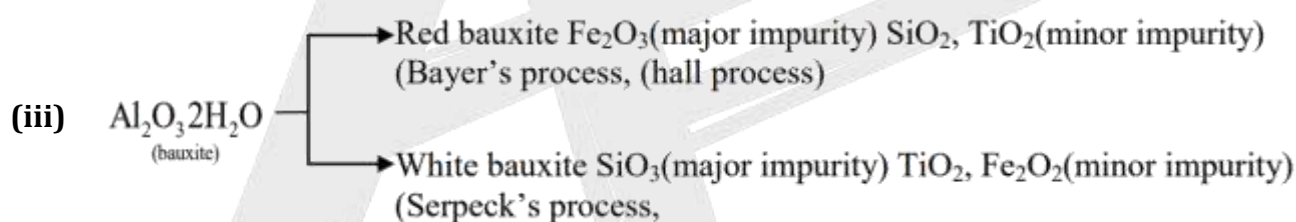
(i) **Mac. Arthur forest Process (Cyanide process)**



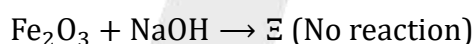
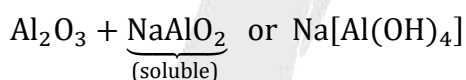
(ii) **Leaching of Ag from native ore**



(Native ore)



Bayer's process :



(Base) (Base)

(Insoluble)



Conversion of concentrated ore into oxide ore

Calcination:

Roasting:

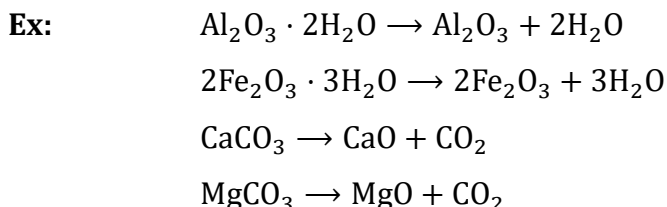
CALCINATION:

Process of heating of ore at high temperature but below its melting point in absence of air or limited supply of air.

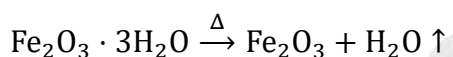
- (i) Ore is heated in absence of air to remove water or CO_2 from hydrated oxides or

carbonates respectively.

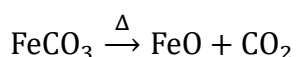
- (ii) Process temperature is below the melting points of treated ores.
- (iii) During calcinations moisture, volatile impurities are removed there by ore becomes porous.



Hydrate ore becomes anhydrous



Carbonate ore \rightarrow oxide ore

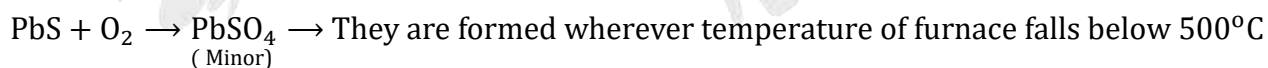
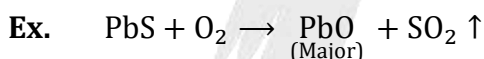


During calcination hydrated ore becomes anhydrous, organic matter is also removed because they are volatile. it will become porous so surface area increases & reduction becomes easier.

ROASTING:

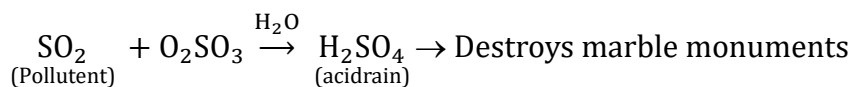
Process of heating of ore at high temperature below its melting point in presence of air (regular supply of air) is called roasting.

- (i) Ore is heated strongly with other substances, usually with oxygen.
- (ii) Employed for sulphide ores.
- (iii) Process temperature is below the melting points of treated ore.
- (iv) Chemical conversion of ore is takes place.
- (v) Some of the impurities removed as volatile substances.



\rightarrow They are thermally stable, at this temperature.

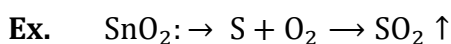
Note: SO_2 is a cause of serious pollution.

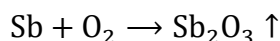
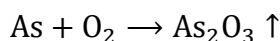


Roasting is a major cause of pollutant. Fe_2O_3 is preferred over FeS_2

$\text{SO}_2 \uparrow$ is released. & brittleness is increased due to presence of sulphur

If impurity is non-volatile, but its oxide is volatile, then roasting is required.



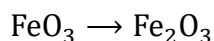
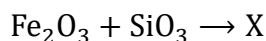
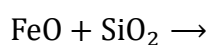
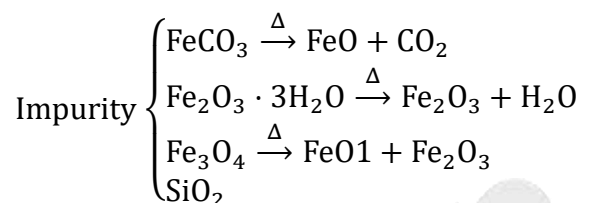


So, roasting is not done only for sulphide ores.

Ex: SnO_2

(ore)

Ex: (ii) Fe_2O_3 have impurities of FeCO_3 , $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, Fe_3O_4 & SiO_2



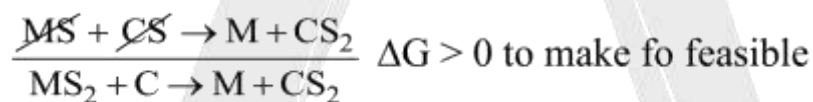
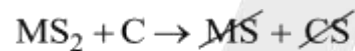
Oxygen is used to convert FeO to Fe_2O_3 which doesn't react with SiO_2 to form Slag.

So, roasting is also used to convert oxide from lower oxidation state to higher oxidation state.

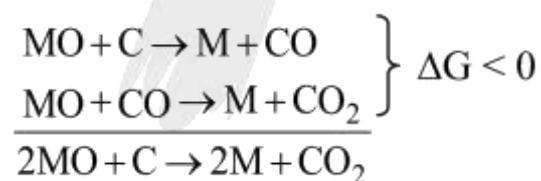
Roasting and calcination carried out in reverberatory furnace.

Roasting is an exothermic process as combustion occurs.

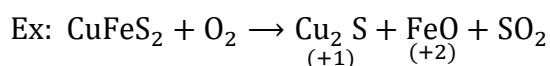
Q. Why roasting is required?



High temperature is required as $\Delta G = \Delta H - T\Delta S$



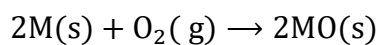
- Sometimes roasting maynot bring about complete oxidation



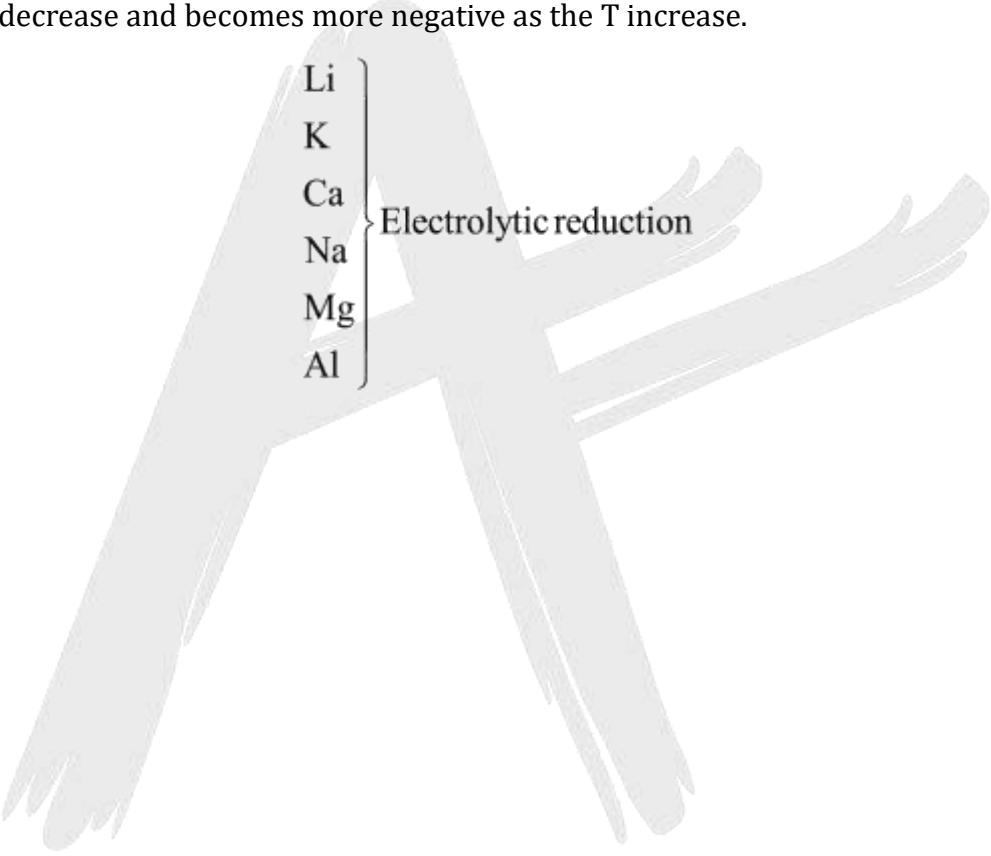
REDUCTION

Thermodynamic principles:

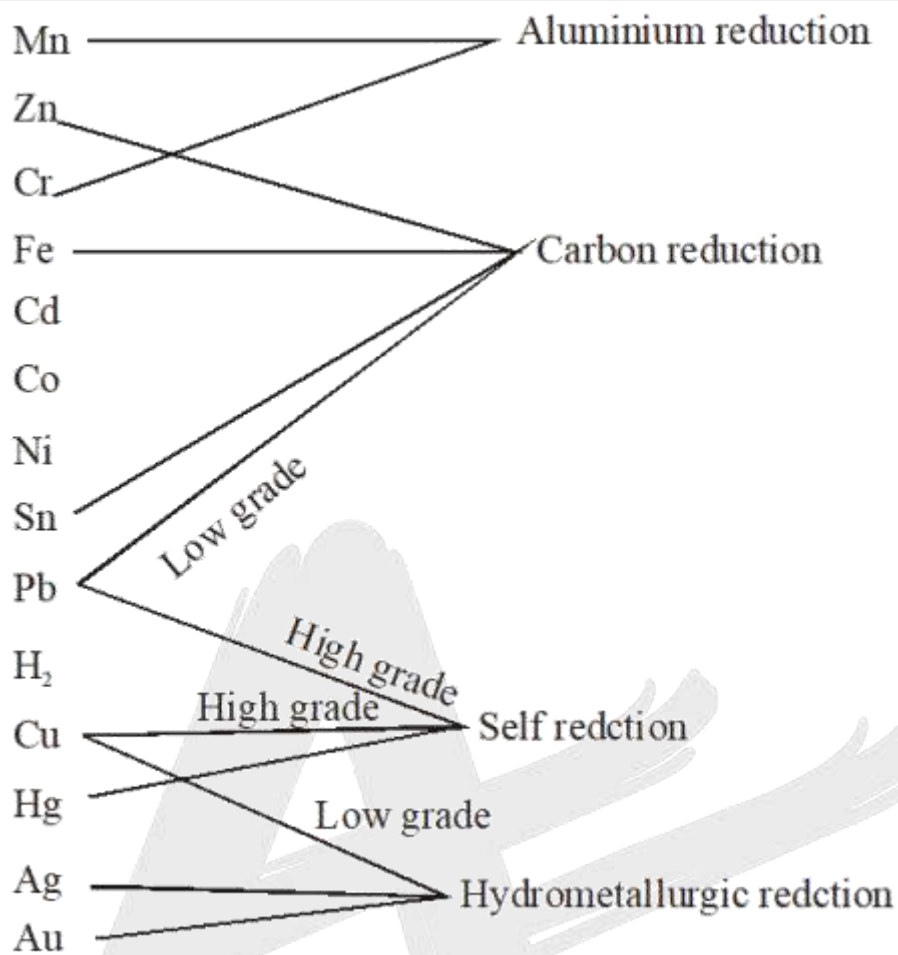
Consider a reaction such as formation of an oxide.



In this reaction, the random of the system decreases because gases have more random than solids. Hence ΔS for this reaction is negative. Thus, if temperature is increased than $T\Delta S$ becomes more negative. Since $T\Delta S$ is subtracted in equation, ΔG becomes less negative. On the other hand, if ΔS is positive, on increasing the temperature the value of ΔG decreases and becomes more negative. For example, in the reaction, $2C(s) + O_2(g) \rightarrow 2CO(g)$, ΔS is positive and ΔG decrease and becomes more negative as the T increase.



Li	} Electrolytic reduction
K	
Ca	
Na	
Mg	
Al	

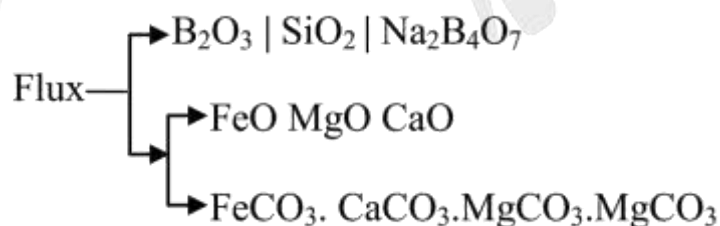


Carbon Reduction : → The oxides of less electropositive metals like Pb, Zn, Fe, Sn, Cu etc. are reduced by strongly heating with coal or coke.



Metal oxide + Coke power + flux metal + CO₂ + Slag

Flux : → Additional substance that are used for removal of unwanted impurities.



Slag: Stable molten form which is immiscible with metallic ore, it is lighter than metallic ore, it has low density and low melting point than metallic ore.

Lux-flood concept

O^{2-} donor = base

O^{2-} acceptor = acid

(Base)

(acid)



CaO

+

SiO₂

CaSiO₃

(Impurity)

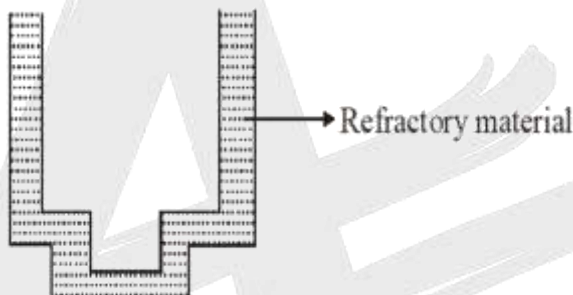
(flux)

(Slag)

$Ca^{+2} SiO_3^{2-}$

This concept is only applicable for high temperature metallurgic processes.

Refractory Material : → High melting point having Substance.

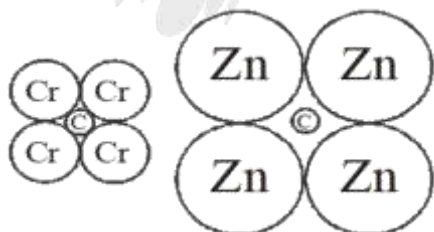


Q. Why in Mn&Cr ore, Al is used for reduction?

Mn&Cr have high affinity for oxygen. So it is not possible for C to reduce it at normal temperature. When it reduces the metal oxide at high temperature, metal carbide is formed which makes it impure. So aluminium is used for reduction.

Q. Why in zinc oxide, C is used ?

Sizes of voids of Cr, Mn are comparable with that of 'C' but size of voids of Zn is very large than that of 'C' so, it is not accommodated in the voids. So, C is used as it is cheap.

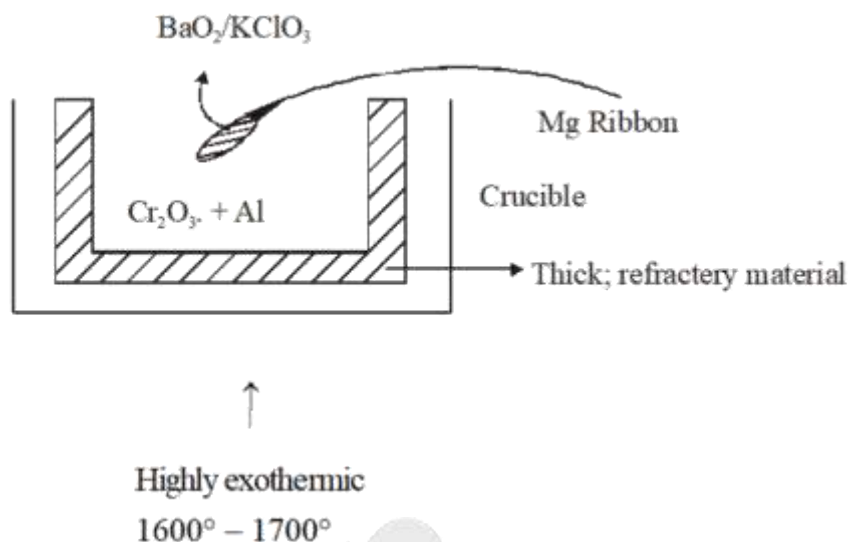


(B) Thermite Reduction:- (Goldschmidt aluminothermite reduction)

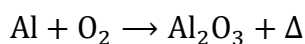
(i) Aluminium acts as reducing agent due to its high electropositive nature.

(ii) Oxides such as Cr₂O₃, Mn₃O₄ are reduced by this method

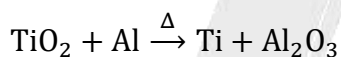
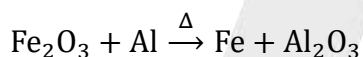
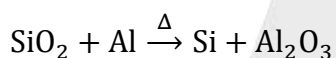
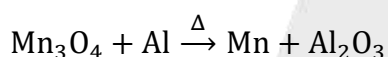
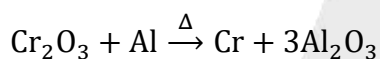
(iii) The process is also known as "Gold Schmidt thermite process".



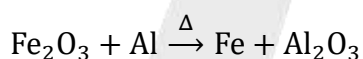
Thermite reaction:



$\text{BaO}_2/\text{KClO}_3$ mixture along with Mg ribbon is used to start the reaction, providing with activation energy

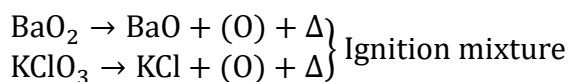


Note: Fe_2O_3 can not commercially used by thermite reduction.



This reaction widely used for joining of rail roads and known as thermite welding.

Starting: •



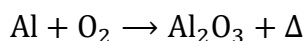
Thermite mixture :

Metal oxide : Aluminium

(Al)

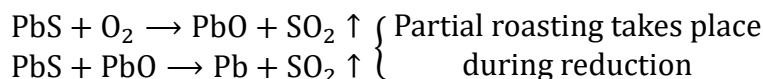
3 : 1

In flakland area, when a missile was being tested, it hit a ship made up of aluminium. Due to high starting enrgy, it reaction proceeded forward \& the whole ship drowned (thermite reaction was involved)



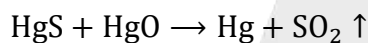
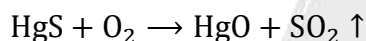
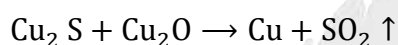
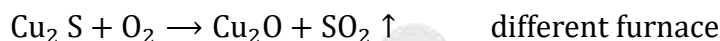
(C) Self Reduction:

- (i) Employed for metals of less active such as Hg, Cu and Pb
- (ii) Due to unstable nature in the oxide form at high temperature, no reducing agent is required for their reduction.

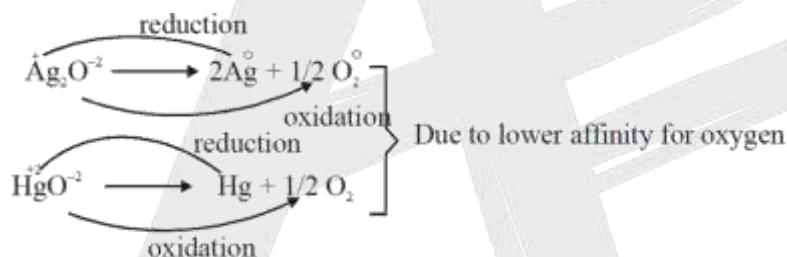


↓

(R. A) (S²⁻ is R. A.)



Thermal decomposition reaction:



Other method are following :

- (i) Reduction by carbon monoxide (employed for iron (iii) oxide)
- (ii) Reduction by water gas (employed for nickel oxide)
- (iii) Amalgamation method (employed for noble metals)

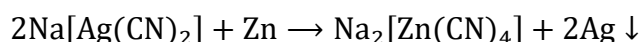
Hydrometallurgy (Reduction by precipitation)

- (i) Process in which more electropositive metal displace less electropositive metals from salt solution.
- (ii) First the concentrated ore is dissolved in strong reagent and remove insoluble precipitates.
- (iii) Now the metal is precipitated by addition of more electropositive metal.

Example: Silver sulphide dissolved in sodium cyanide which forms a soluble complex, then silver is precipitated by the addition of zinc powder.



Sodium, dicyanoargentate (A)



Note : This type of precipitation process is called cementation.

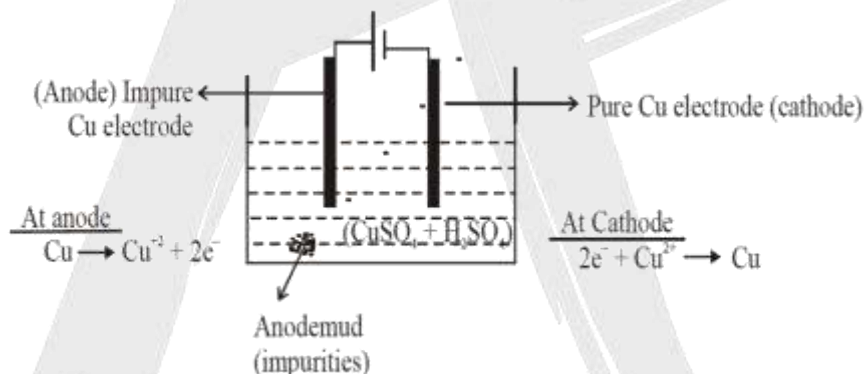


Refining or purification

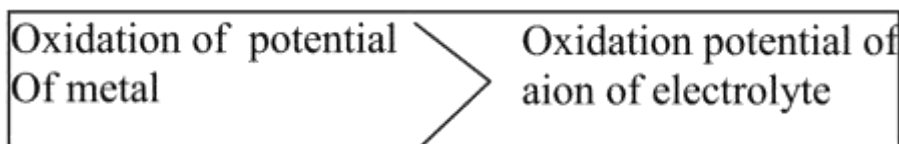
- (i) The metals after reduction process consists of number of impurities like Si, P, Slag, Oxides, other metals etc.
- (ii) Remove of all these impurities to get pure metal is called as refining.
- (iii) Methods of refining are as under.

Electro refining Method :

- (i) Employed for refining of highly electro positive metals like Al, Cu, Ag, Zn, Sn, Pb, Cr and Ni.
- (ii) Impure metal is made as anode, thin pure metal sheet is kept as cathode and the electrolysis comprising with soluble salt solution of the metal.
- (iii) On passing the electric current, pure metal from the anode dissolved and is deposited on the cathode.
- (iv) The soluble impurities goes into the solution (remains in the solution after the completion of refining) while the insoluble impurities settle down below the anode as "anode mud"



- Initially, Mn, Zn, when Copper rod comes in to solution. Then, no metal down the group comes into solution. But already, Cu^{2+} is present in solution, it goes into deposition of rod. & other ions which were more reactive were not deposition.

For choosing electrolyte:

Note: Impurities from blister copper deposit as anode mud which contain Sb. Se, Te, Ag, Au&Pt.

(Inorganic Chemistry)

METALLURGY

Recovery of these elements may meet the cost of refining.

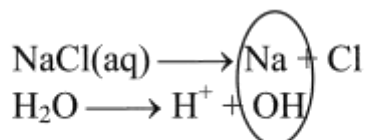
→ Zn may also be refined this way.

In molten form: $\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-$

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

At anode: $\text{Cl}^- \rightarrow 1/2\text{Cl}_2 + \text{e}^\ominus$

Electrolysis of aqueous NaCl:



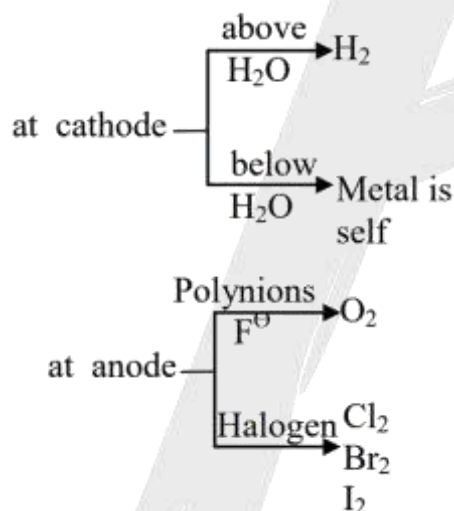
PH > 7 basic solution is formed

At cathode: $\text{H}^+ + \text{e}^- \rightarrow \text{H}_2$

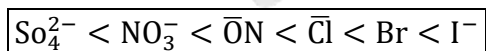
At anode : $\text{Cl}^\ominus \rightarrow 1/2\text{Cl}_2 + \text{e}^\ominus$

In presence of aqueous solution :

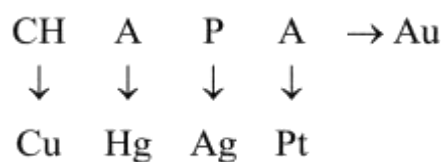
Important point



Deposition order of anion:



Key point



If CHAPA is present in aqueous solution and is CHAPA, Otherwise H_2

Polyatomic anion in aqueous solution → O_2

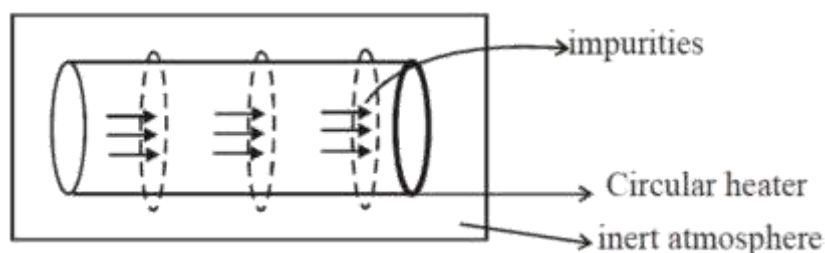
Otherwise anion.

discharge potential: - minimum required potential to deposition of the ion.

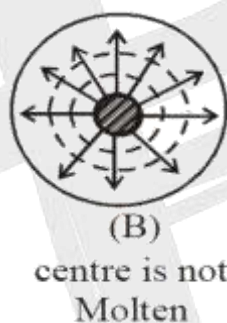
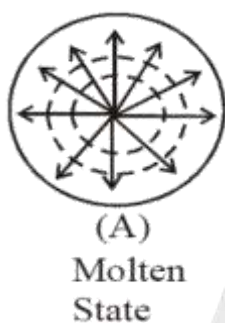
D.P. of cation:- Reduction potential

D.P. of anion:- Oxidation potential

Zone Refining Method :



- This is Based on property of impurities that they are more soluble in liquid phase, than in solid phase
- This method is used in purification of ultra pure metals such as silicon, Germanium, Gallium, Boron and Indium.
- The order of impurity is in ppm. It is based on fractional crystallisation method.



A is preferred as in B, impurities remain in the central region.

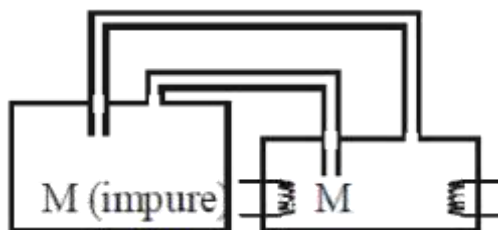
Method:

This method is based on the principle that the impurities are more soluble in the melt than in the solid state of the metal. A circular mobile heater is fixed at one end of a rod of the impure metal. The molten zone moves along with the heater which is moved forward. As the heater moves forwards the pure metal crystallises out of the melt and the impurities pass on to the adjacent molten zone. This process is repeated several times. At one end impurities get concentrated. This end is cut off. This method is very useful for producing semi-conductor and other metals of very high purity e.g germanium, silicon, boron, gallium, indium.

VAPOUR PHASE REFINING

In this method, the metal is converted into its volatile compound and collected elsewhere it is then decomposed to give pure metal, so the two requirements are:

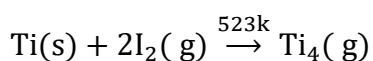
- ⇒ The metal should form a volatile compound with an available reagent.
- ⇒ The volatile compound should be easily decomposable so that the recovery is easy.



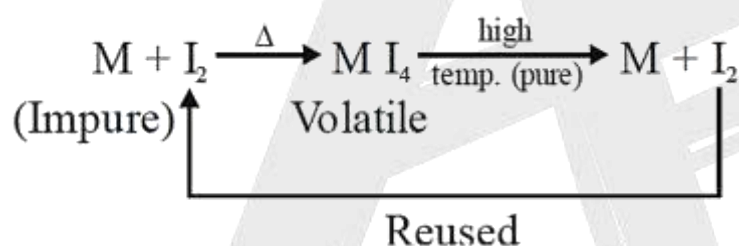
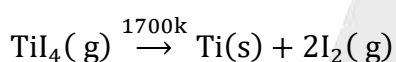
(i) Employed to get metal in very pure form of small quantities.

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

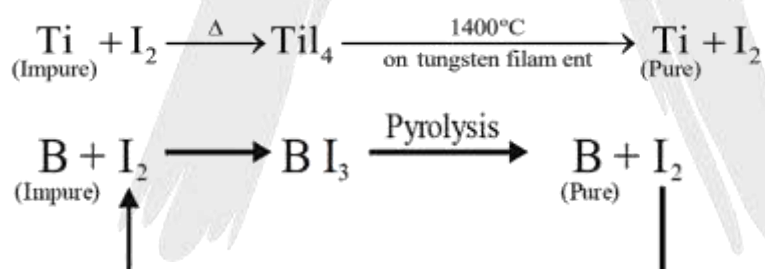
(iv) Employed for purification of metals like titanium and zirconium



Impure



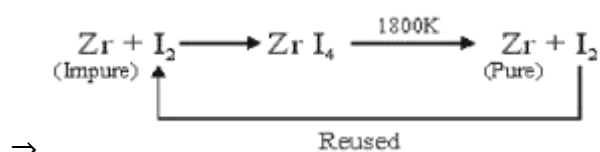
Ex. Ti, Zr, Hf, Th, B



Note:

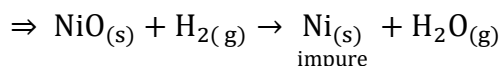
⇒ This method is very useful for removing all oxygen and nitrogen present in the form of impurity, in certain metals like Zr and Ti.

⇒ The pure metal is thus deposited on the filament.

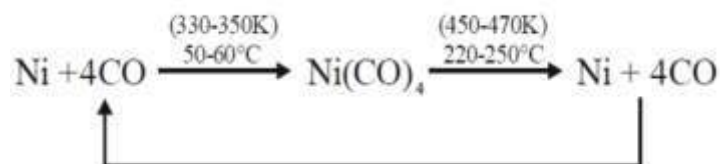


Monds Process:

Nickel oxide reacts with syn gas at 200°C to give nickel together with impurities including iron and cobalt.

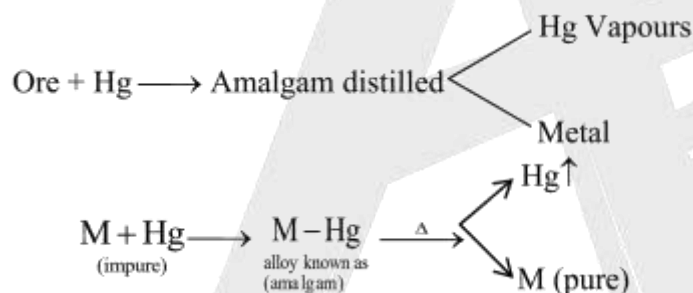


- Impure nickel has iron and cobalt as impurity.



Amanlgamation process:

Nobel metals ores like Ag, Au, Pt in finelay powdered state are mixed water to form slurry. The slurry is then flown over Cu or brass plates coated with hg arranged in slanting position. The metal particles forming amalgam with Hg are retained on these plates. The amalgam is scrapped off and then distilled in iron retorts where Hg distillates over leaving free metals. Hg vapours.

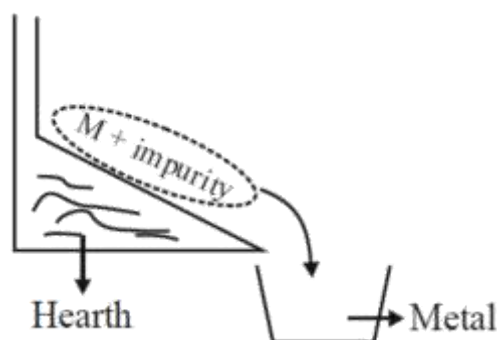


Ex. Ag/Au

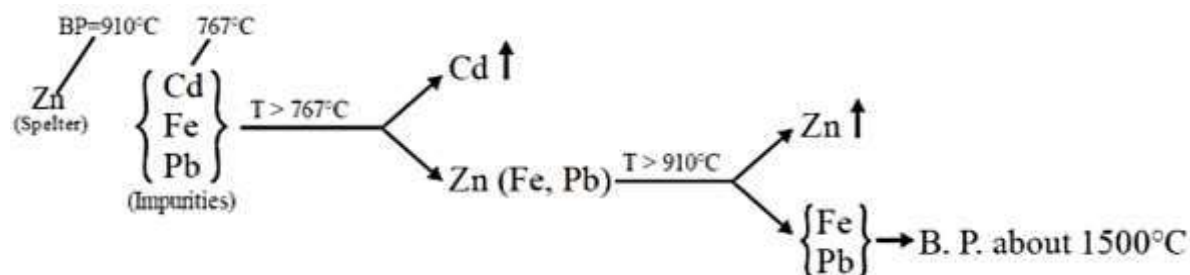
Hg can form alloys with many metals except, (Pt, Fe, W).

Liquation:

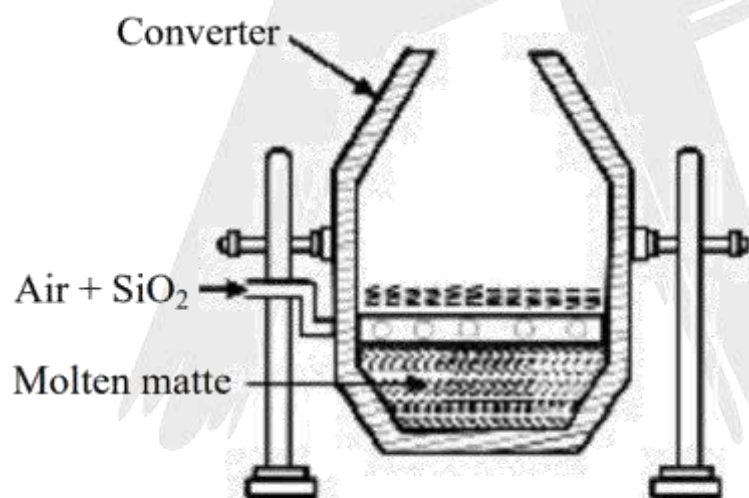
- This is based on the principle of difference in melting points of metal and impurity.
- Employed for purification of low melting point metals like Pb, Sn etc. Melting point of metal should be less than that of impurity. Pb, Sn, Bi are the metals for which method is used. It is used when impurity percentage is 10 to 15w



When metal and impurities have different boiling point.



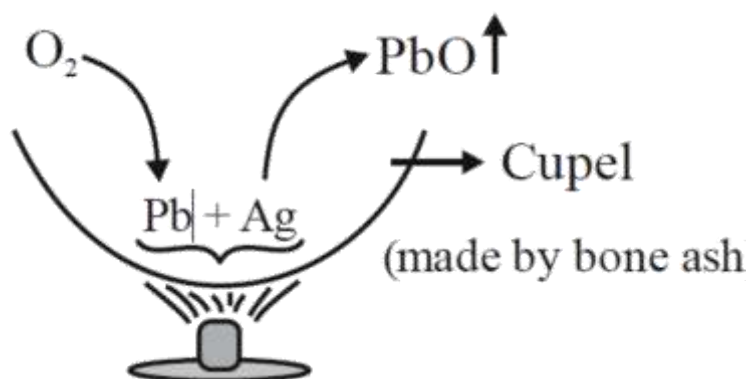
(iv) Various oxidation processes used for different metals bear different names, e.g., poling, puddling, bessemerisation and cupellation (for Ag).



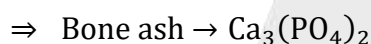
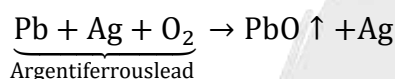
Bessemer convertor of copper

- (i) Cupellation
- (ii) Poling
- (iii) Bessemerisation

Cupellation:



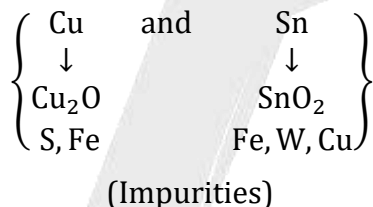
The process in which a impure sample of metal (say Pb in Ag) is fused in a bone ash crucible (Cupel) on the hearth of furnace in the blast of air. The impurity (Pb) present is oxidized and blown away with air. Some PbO is absorbed by Cupel.



Poling:

When metal have impurity of its on metal oxide.

Example:



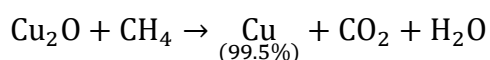
Hot blast air is sent to oxidise S , impurity to their volatile form.

In reverberatory furnace having impure copper a thick lining of SiO_2 is present with reacts with oxidised iron (FeO) to form slag ($FeSiO_3$).

After removal of slag:

Poles of green wood are stirred with molten copper. At high temperature, they release hydrocarbons such as methane (CH_4) which is reducing in nature, which reduces Cu_2O to Cu .

This copper is called tough pitch copper.



Poling of Sn

Molten tin taken in a big container and stirred with pole of green wood. Impurity of Fe , W , Cu come upto the surface and form their oxides. Their oxides form scum an surface of molten tin.

After removal of scum, poles of green wood is used which liberate hydrocarbon gases which

reduce SnO_2 to Sn.

Note : Upper surface can be covered with coke(Anthracite powder) to prevent reoxidation of metal.

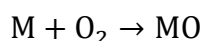
THERMODYNAMICS OF REDUCTION PROCESSES (ELLINGHAM DIAGRAM)

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.

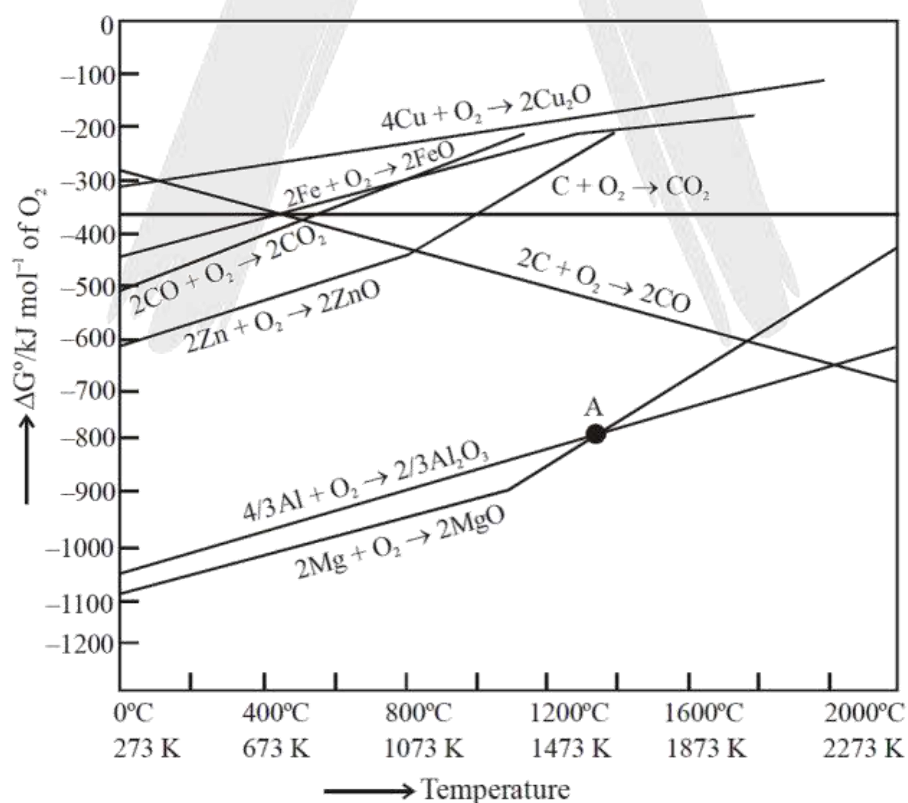
For a spontaneous reaction, the free energy ΔG must be negative.

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

ΔH is the enthalpy change during the reaction, T is the absolute temperature, and ΔS is the change in entropy during the reaction. Consider a reaction such as the formation of an oxide:



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 ΔS the entropy or randomness decreases, the hence ΔS 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 ΔG 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 for halides.

The Ellingham diagram for oxides shows several important features:

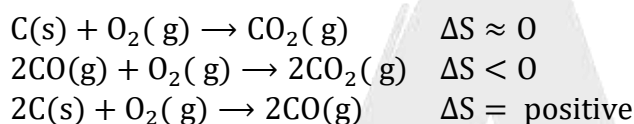
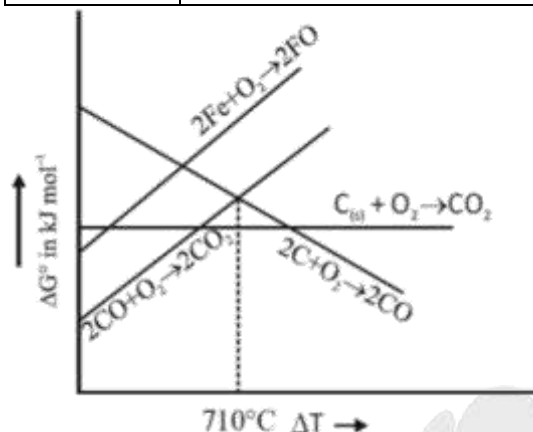
- (i) The graph for metal oxide all slope upwards, because the free energy change increases with an increase of temperature as discussed above.
- (ii) The free energy changes all follows a straight line unless the materials metal or vaporize.
- (iii) When the temperature is raised, a point will be reached 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

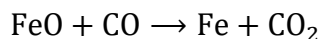
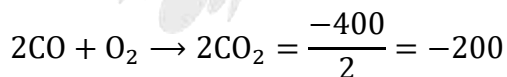
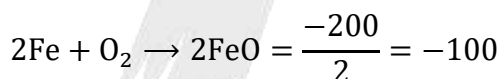
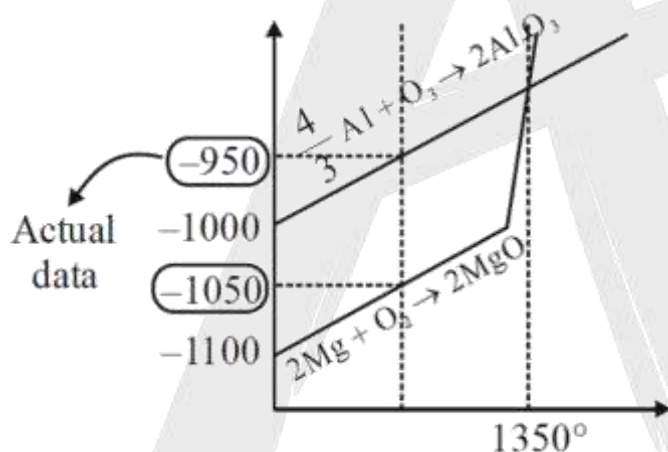
- (i) The graph simply indicates whether a reaction is possible or not i.e., the tendency of reduction with a reducing agent is indicated. This is so because it is based only on the thermodynamic concepts. It does not say about the kinetics of the reduction process (Cannot answer questions like how fast it could be ?).
- (ii) The interpretation of ΔG^\ominus is based on $K(\Delta G^\ominus = -RT\ln K)$. Thus it is presumed that the reactants of products are in equilibrium.

Aluminium	1. Bauxite, $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ 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 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 2. Copper glance, Cu_2S 3. Malachite, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ 4. Cuprite, Cu_2O	Roasting of sulphide partially and Reduction	It is self reduction in a specially designed converter. reduction takes place is also used in hydrometallurgy from low grade ores.

Zinc	1. Zinc blende or Sphalerite, ZnS 2. Zincite, ZnCO 3. Zincite, ZnO	Roasting followed by reduction with coke	The metal may be purified by fractional.
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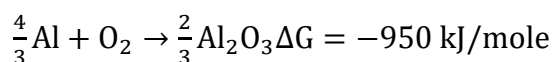


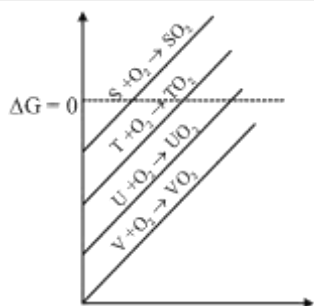
Ex. Below 710°C CO is better reducing agent than C for FeO explain why?



$$\Delta G = -200 + 100 = -100 < 0$$

Q. Below 1350°C can Mg reduce Al₂O₃ explain why?





Note:

Above 1350°C, Al reduces MgO.

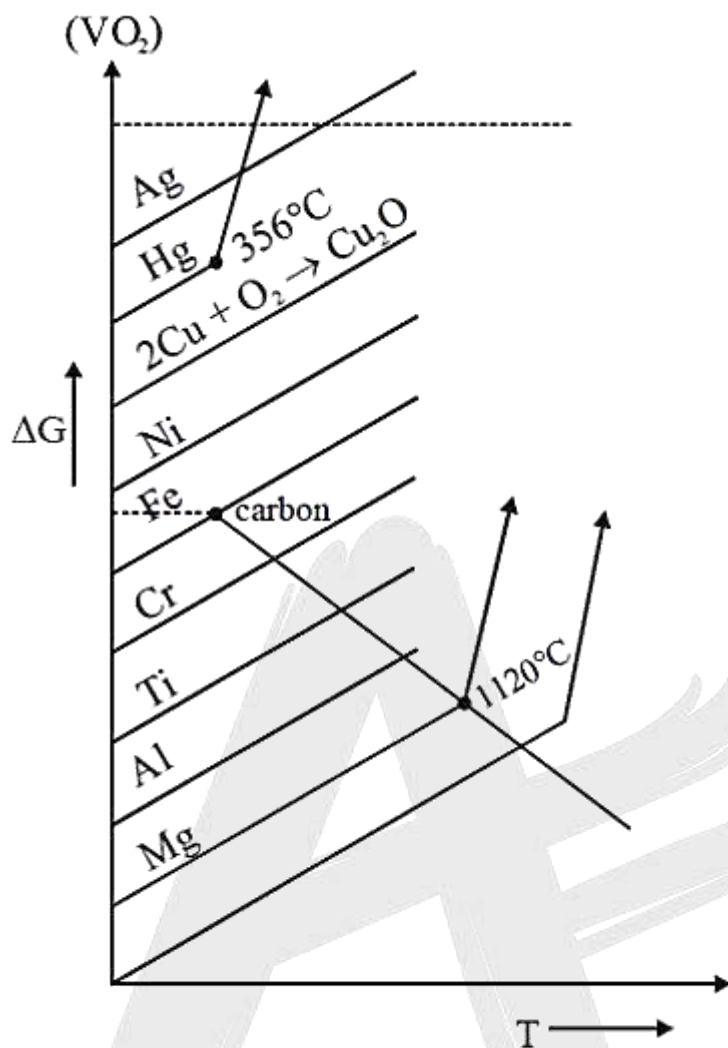
Q. The one which metal oxide will be easiest to decompose

Ans. SO_2 :

Q. Which of the following metal oxide will reduce by U at normal (not high) temperature?

Ans. SO_2 , TO_2

Q. Which of the following metal oxide will reduce by U metal only at high temperature?



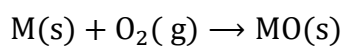
Ellingham diagram
(Metal to metal oxide only)

Ans. VO_2

Originally, the graph was given between,

(A) Metal to metal oxide (B) Metal to metal sulphide (C) Metal to metal halide

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

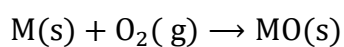


$$\Delta S < 0$$

$$T \uparrow \Delta G \downarrow$$

- All slopes are upwards in metal to metal oxide

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



$$\Delta S < 0$$

$$\text{So } \Delta G^\circ \uparrow T \uparrow$$

- Free energy changes, all follow straight line unless metal is melt or vaporised. Ex. Hg boils at 350°C and Mg boil at 1120°C .
- Oxides of native metals easily decomposed.
(when temperature increase $\Delta G = 0$, oxide decomposition starts and becomes spontaneous.)
- Carbon is a good reducing agent for oxides but it is a poor reducing agent for sulphide.
- At high temperature, carbon (C) can form carbide with some metals.
- Metals can reduce oxide of other metal which can lie above it in ellingham diagram.

Q. Why hydrogen is not widely used in metallurgy, even if it is a good reducing agent?

- It has positive slope of ΔG and T curve, lies above non metals
- For some metal hydride reaction, the ΔG remains constant independent of temperature.
- Even for those metals which lie above hydrogen form metal hydride which makes the metal impure.
- And, for those who do not metal hydride lie, below hydrogen, when we increase temperature, the H_2 gives explosive reaction with O_2 .

Q. Why FeO 's reduction is not done at room temperature?

- Even if ΔG is negative, the reaction will be kinetically slow and every reaction needs an activation energy to proceed.

Q. Reduction proceeds in which state in Metallurgy?

- At molten state.

Do yourself - 1

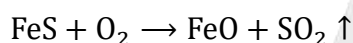
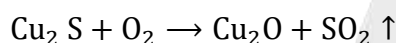
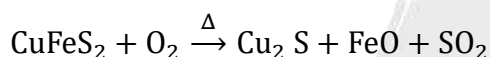
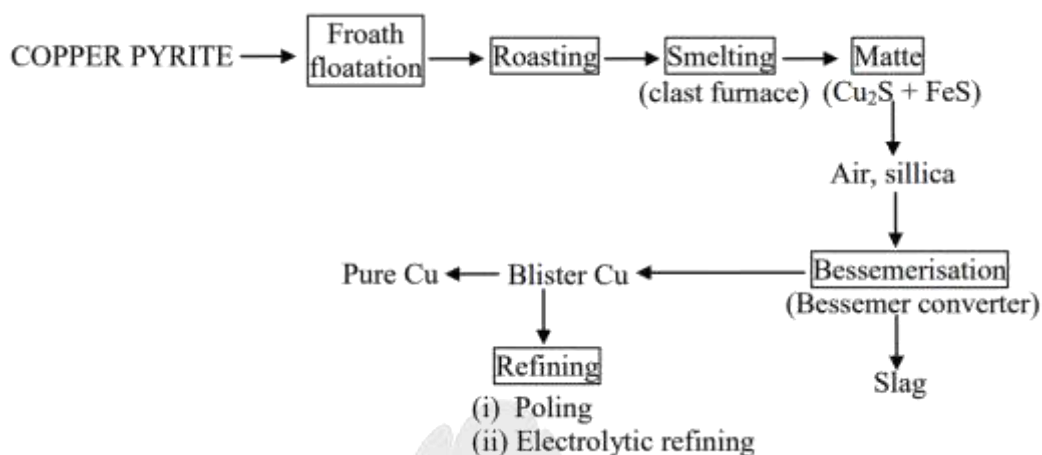
- Magnetic separation process may be used for the concentration of
(A) chalcopryrite (B) buaxite (C) haematite (D) calamine
- The process of removing lighter gangue particles by washing in a current of water is called
(A) levigation (B) liquation (C) leaching (D) cupellation
- Froth floatation process is based on
(A) specific gravity of the particles (B) magnetic properties of the particles
(C) electrical properties of the particles (D) wetting properties of the particles
- An ore of tin containing FeCr_2O_4 is concentrated by
(A) magnetic separation (B) froth floatation
(C) leaching method (D) gravity separation
- In roasting
(A) moisture is removed (B) non-metals as their volatile oxide are removed
(C) ore becomes porous (D) all of the above
- Roasting is carried out in case of
(A) galena (B) iron pyrites (C) copper glance (D) all of these
- Slag is a product of
(A) flux and coke (B) coke and metal oxide
(C) flux and impurities (D) metal and flux
- Annealing of steel is the process of heating steel
(A) to a bright red hot and then cooling it slowly
(B) to a bright red hot and then cooling it suddenly
(C) to a temperature much below redness and cooling it slowly
(D) none of the above
- In Ellingham diagram, the slope of the curve of the formation metal oxide
(A) is mostly +ve (B) is mostly -ve
(C) depends on the type of metal (D) depends on the formula of metal oxide
- Ellingham diagram represents a graph of
(A) ΔG vs T (B) Cu_2O (C) MgO (D) ZnO

Extraction of copper:

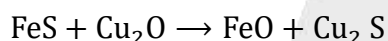
(From CuFeS_2):**(a) Ores :** Copper pyrites CuFeS_2 ; Cuprite or ruby copper Cu_2O ; Copper glance Cu_2S ; Malachite

$\text{Cu}(\text{OH})_2 \cdot \text{CuCO}_3$; Azurite $\text{Cu}(\text{OH})_2 \cdot 2\text{CuCO}_3$.

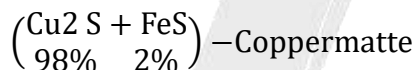
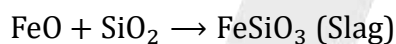
(b) Process :



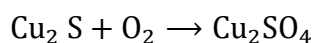
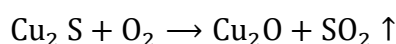
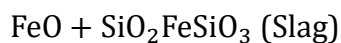
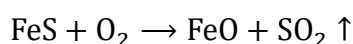
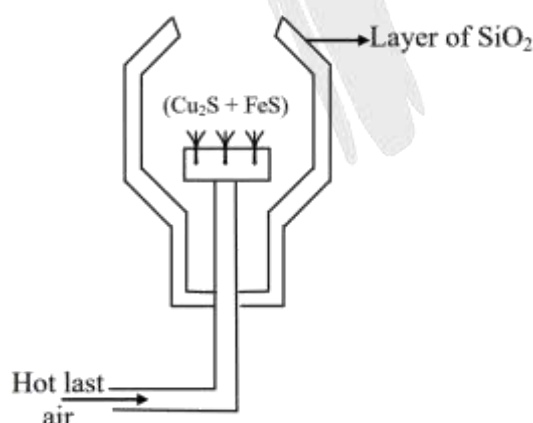
Iron has higher oxygen affinity so it will extract oxygen from Cu_2O .



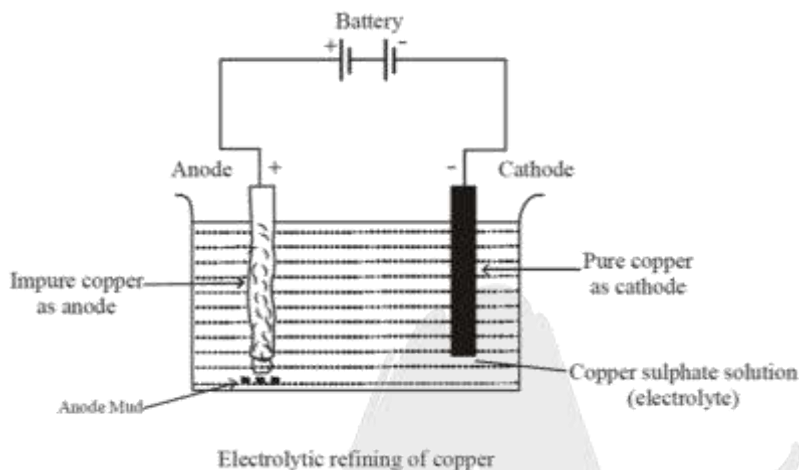
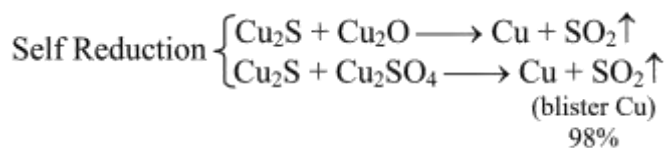
Smelting Roasted Ore ($\text{Cu}_2\text{S} + \text{FeO} + \text{FeS} + \text{little Cu}_2\text{O}$) roasted ore introduced in blast furnace with coke powder with SiO_2 .



Coppermatte further introduced in bassemer converter



Air Cut Off

**Uses:**

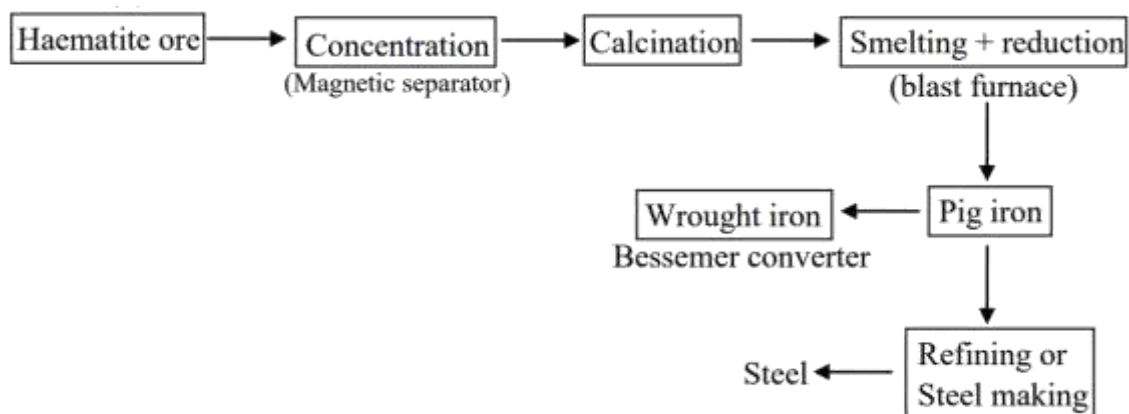
Copper is the second most useful metal (the first being Iron) because of its stability in air and water and excellent conductivity.

- (i) Copper is used for making wires used in electrical industry and for water and steam pipes.
- (ii) For electroplating.
- (iii) As a coinage alloy (with nickel) and in ornaments and jewellery.
- (iv) 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), copper coins (Cu + Zn + Sn) etc.

Extraction of Fe**(From Fe₂O₃)**

(a) Ores : Haematite –Fe₂O₃ Limonite –2Fe₂O₃ · 3H₂O; Siderite FeCO₃ : Magnetite Fe₃O₄, Pyrite - FeS₂.

(b) Process :



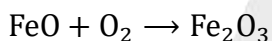
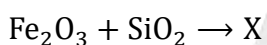
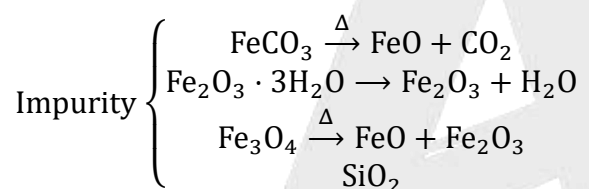
STEPS INVOLVE IN EXTRACTION OF IRON:

(A) Crushing

(B) Concentration (gravity separation followed by magnetic separation)

(C) Roasting/Calcination (if no impurities)

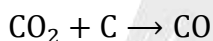
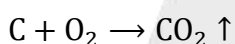
Fe_2O_3 have impurities of FeCO_3 , $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, Fe_3O_4 and SiO_2



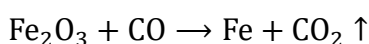
Carbon reduction: \Rightarrow

Reducing agent (principal) $\rightarrow \text{CO}$

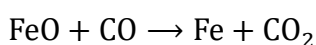
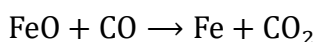
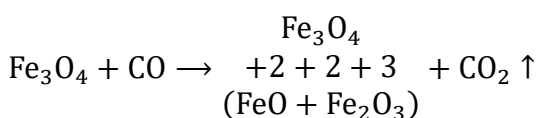
Combustion zone :



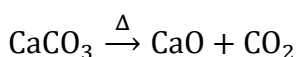
Reduction zone :

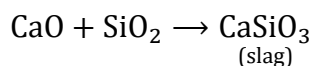
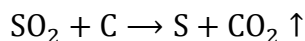
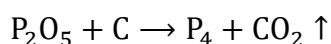
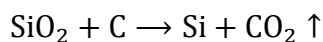
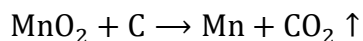


Stepwise reduction :



Slag zone:



**Fusion zone:**

Below (710 – 800°C), CO is better reducing agent.

Above, it C is better reducing agent.

- Iron obtained from reduction zone is spongy iron.
- Slag is collected over molten iron.
- Only place where downwards reaction takes place is blast furnace.
- Iron obtained from blast furnace is 'Pig iron' due to high amount of impurity.
- Small amount of (partial) roasting also takes place in blast furnace.
- Layer of slag prevents reoxidation of pig iron with hot blast air.
- CO is principal reducing agent.

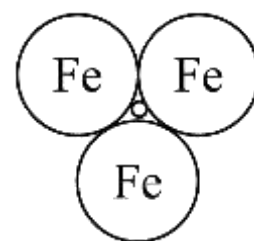
Impurities in impure iron

Mn, Si, S, P, C

The iron obtained from blast furnace contain about 4% carbon and many impurities in smaller amount (e.g. S P si and Mn) this is known as pig iron and cast into variety of shapes. Cast iron is different from pig iron and is made by melting pig iron with scrap iron and coke using hot air blast. It has slightly lower carbon content (about 3%) and is extremely hard and brittle.

Type of cast iron

Cast iron { grey cast iron → having impurity of graphite
white cast iron → having impurity of cementite

**3 types of iron: impurities**

Cast iron = 2 to 5% (extremely hard and brittle)

Steel = 0.5 to 2%

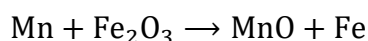
Wrought iron = < 0.5%

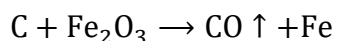
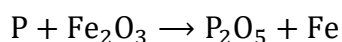
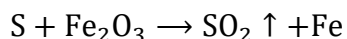
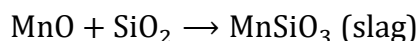
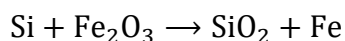
Wrought iron, soft iron purest form of iron, malleable iron, commercial iron

Puddling process:

Puddling/Reverberatory furnace is used having inner lining of haematite.

Fe_2O_3 acts as a oxidising agent.





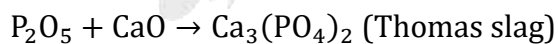
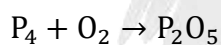
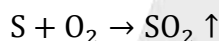
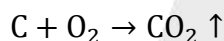
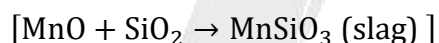
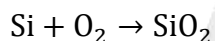
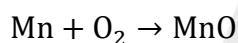
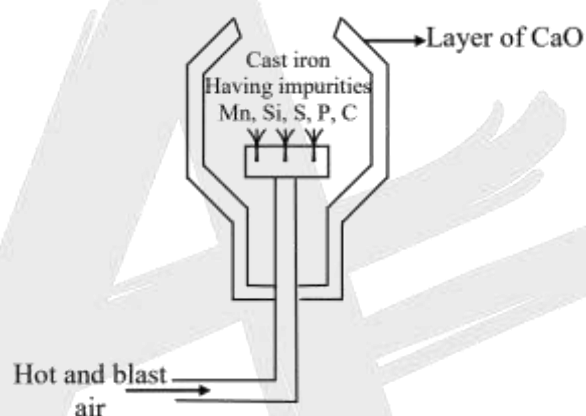
Steel Manufacturing

(A) Bessemerisation (Thomas process)

(B) Open hearth process (Siemens-martin process)

(C) L.D process (Basic oxygen process) (Lin-Donawitz process)

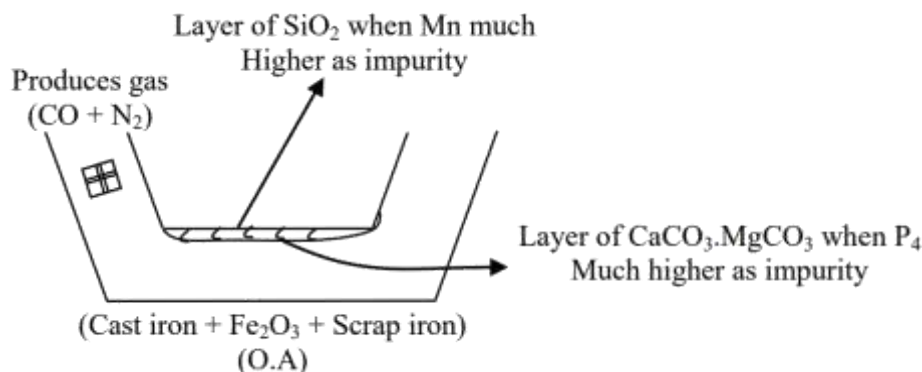
(A) Bessemerisation: (Thomas Process)



Drawback

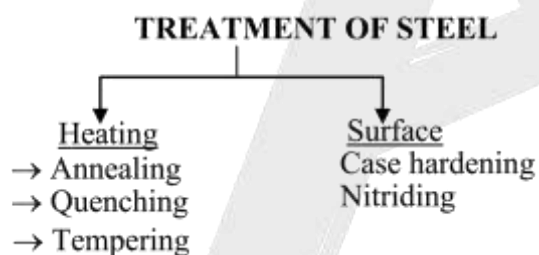
- 10-15% iron is oxidised which causes huge loss.
- Some iron reacts with nitrogen present in air, to form iron nitride which makes it impure.

Open-hearth Process



- In this process, 5% iron also oxidised.
L.D Process: Now a day, steel is manufactured by this process. In this process, pure O_2 is used instead of air. Heating effect is produced by electricity.
- In this process, 0.5% iron is also oxidised.
- Haematite acts as oxidising agent.

Wrought iron $\xrightarrow[\text{alloy}(\text{Si}, \text{C}, \text{Mn})]{\text{spiegelisen}}$ steel



Annealing : Process of heating of steel upto bright redness, then cooling it slowly. From this steel becomes soft and elastic.

Quenching : Process of heating of steel upto bright redness, then cooling it suddenly. From this steel becomes hard and brittle.

Tempering : Process of heating of quenched steel below redness, then cooling it slowly. From this, brittleness disappears and hardness remains same.

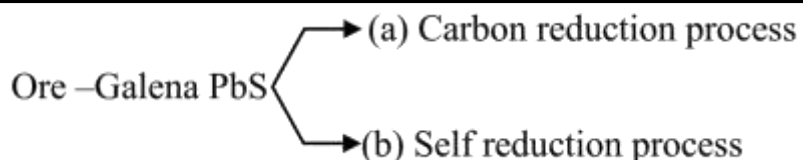
Case-hardening : Process of producing hard-coating of iron carbide by heating with charchol.

Nitriding: Process of producing hard coating of iron-nitiride by heating with ammonia.

Extraction of lead

PbS

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

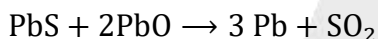
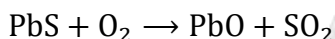
**(a) Carbon reduction process (When impurity content is high)**

- (i) Crushing & Grinding
- (ii) Concentration by Froth floatation method
- (iii) Roasting process with Lime stone (CaCO_3)
- (iv) Smelting (Carbon reduction method with coke + Fe_2O_3)

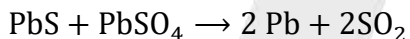
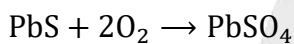
(b) Self reduction process :- (When the impurity content is less)

- (i) Crushing & Grinding
- (ii) Concentration by Froth floatation method
- (iii) Self reduction process

Reaction involved in self reduction:-



Parallel reaction

**(c) Refining process :**

- (a) Poling
- (b) Bett's electrorefining

Anode \rightarrow Impure Pb

Cathode \rightarrow Pure Pb

Electrolyte $\rightarrow \text{Pb}[\text{SiF}_6] + \text{H}_2\text{SiF}_6 + \text{Gelatin}$ (to adjust viscosity)

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

Note : Copper obtained has blistered appearance due to the evolution of SO_2 and so it is called blister copper.

Occurrence of lead:

Lead does not occur in the free state, The important ores of lead are:

- (i) Galene(PbS) (ii) Anglesite (PbSO_4) and (iii) Cerussite (PbCO_3).

(A) Crushing

(B) Concentration of ore:- - Froth flotation

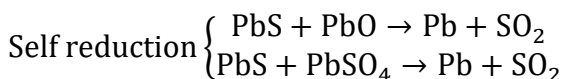
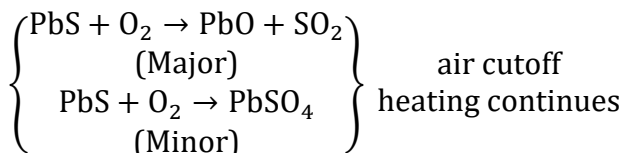
(Inorganic Chemistry)**METALLURGY**

(C) Roasting \rightarrow high grade ore \rightarrow ore rich in Pb content than impurity.

\rightarrow Low grade ore \rightarrow ore poor relative in Pb than impurity.

For high grade ore lead :

Partial roasting/reverberatory furnace.



\Rightarrow Does self reduction & partial roasting take place in same furnace?

Yes

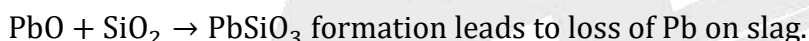
\Rightarrow Do they happen at different temperature?

Yes

Lime is also added :



as

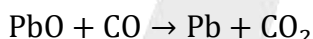
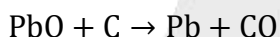


\Rightarrow Low grade ore :

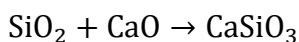
Roasting:

In reverberatory furnace: $\text{PbS} + \text{O}_2 \rightarrow \text{PbO}$

Carbon reduction : (Blast) furnace.



Lime also added : $\text{CaO} + \text{PbSiO}_3 \rightarrow \text{CaSiO}_3 + \text{PbO}$

Function of lime:

(i) Prevents formation of PbSiO_3 and PbSO_4

(ii) Absorbs SO_2 , forms CaSO_4 , making it porous.

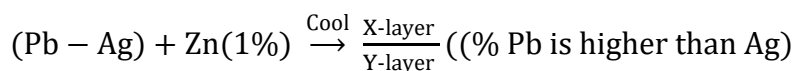
Pb obtained from self reduction or carbon reduction contains many impurities.

S, As, Sb, Fe, Cu, Zn, Bi, Sn/Ag, (Au very less)

Due to presence of these basic impurities, Pb becomes hard and brittle. For removal of these basic impurities, hot blast air passed into molten lead, Impurity of S, As, Sb are removed due to formation of their volatile oxide. Rest other oxides form scum on the surface of molten lead.

After removal of this scum, lead becomes soft. So, this is called softening process. Major impurity in Pb is Ag and it is called argentiferous lead and commercial lead.

Park's/Pattinson process :

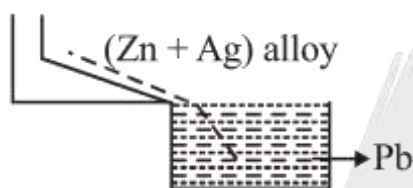


X layer = Solid [Zn – Ag] alloy .

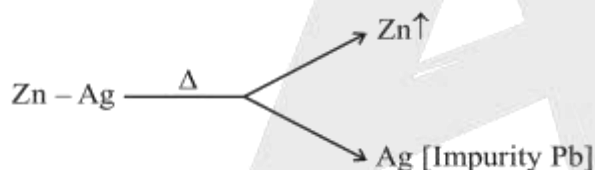
Y layer = Molten Lead [Further purified by bett's electrolysis]

Note: Park's process is applicable when percentage of Pb is higher than Ag it is also called desilverisation method.

Liquation:

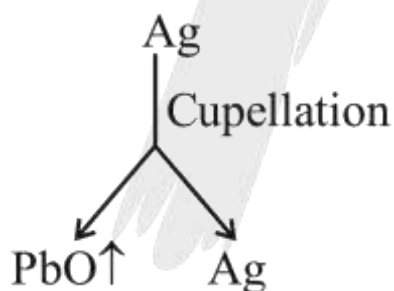


Distillation:

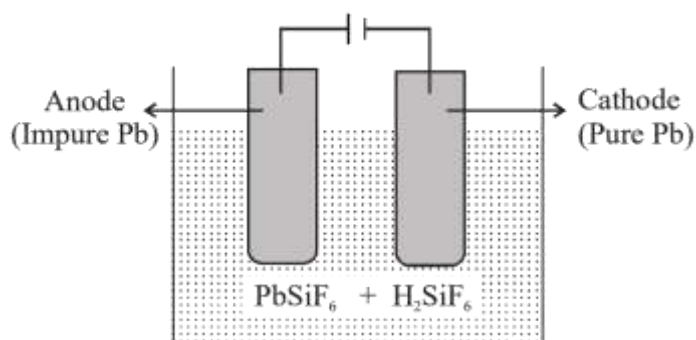


Cupellation:

It is applicable when percentage of Ag is higher than Pb



Bett's electrolysis :



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

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

→ Small amount of gelatin is also added in this process, to adjust density of electrolyte.

So, lead obtained on cathode becomes smooth and uniform.

Properties of lead :

Lead is a bluish grey lustrous metal but when exposed to air, it acquires dull appearance due to the forming of a thin layer of $\text{Pb}(\text{OH})_2$ and PbCO_3 on its surface. It dissolves in hot concentrated alkali evolving H_2 .

$\text{Pb} + 2\text{NaOH} \rightarrow \text{H}_2 + \text{Na}_2\text{PbO}_2$ (Sod. plumbite)

Other reactions with acids, S, Cl_2 , are similar to those of Sn

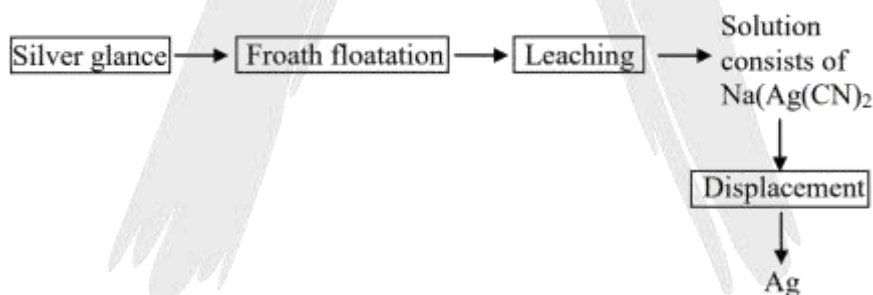
Lead forms two series of compounds i.e. Pb (II) Pb (IV) compounds but Pb (II) compounds are more stable than Pb (IV) compounds. Pb (II) compounds are essentially ionic while Pb(IV) compounds are covalent in nature.

Lead used for making cable coverings, bullet shots, lead accumulators, tetraethyl lead (antiknocking agent) and a number of pigments such as red lead (Pb_3O_4); white lead [$2\text{Pb}(\text{OH})_2 \cdot \text{PbCO}_3$]. Chrome yellow (PbCrO_4) and chrome red ($\text{PbO} \cdot \text{PbCrO}_4$).

Extraction of Silver

(a) Ores : Silver glance or argentite Ag_2S , Ruby silver $\text{Ag}_2\text{S}_2\text{Sb}_2\text{S}_3$, Horn silver AgCl .

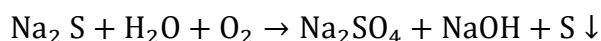
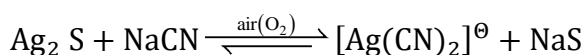
(b) Process : Cyanidation or Mac-Arthur-Forrest cynide process



1. Silver : Mac Arthur Forest(Cyanide-Process)

(A) Crushing

(B) Conc. (leaching)

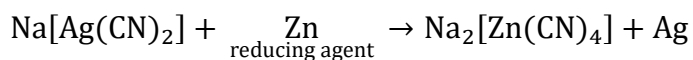
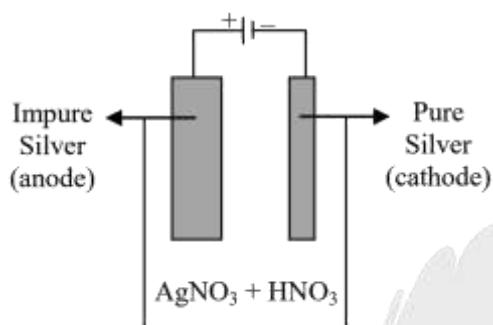


The precipitated silver is separated and purified by fusion with borax or KNO_3 to get pure silver.

Electrolytic refining : Anode : Impure Ag

(Inorganic Chemistry)**METALLURGY**

cathode : Pure Ag

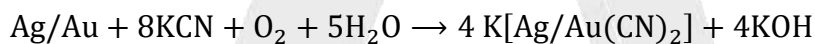
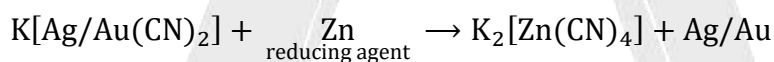
Electrolyte : AgNO_3 (aq.) + HNO_3 .**Hydrometallurgic reduction:****Purification:-**At anode: $\text{Ag} \rightarrow \text{Ag}^+ + \text{e}^-$ At cathode : $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$

→ Amalgamation also used as a purification

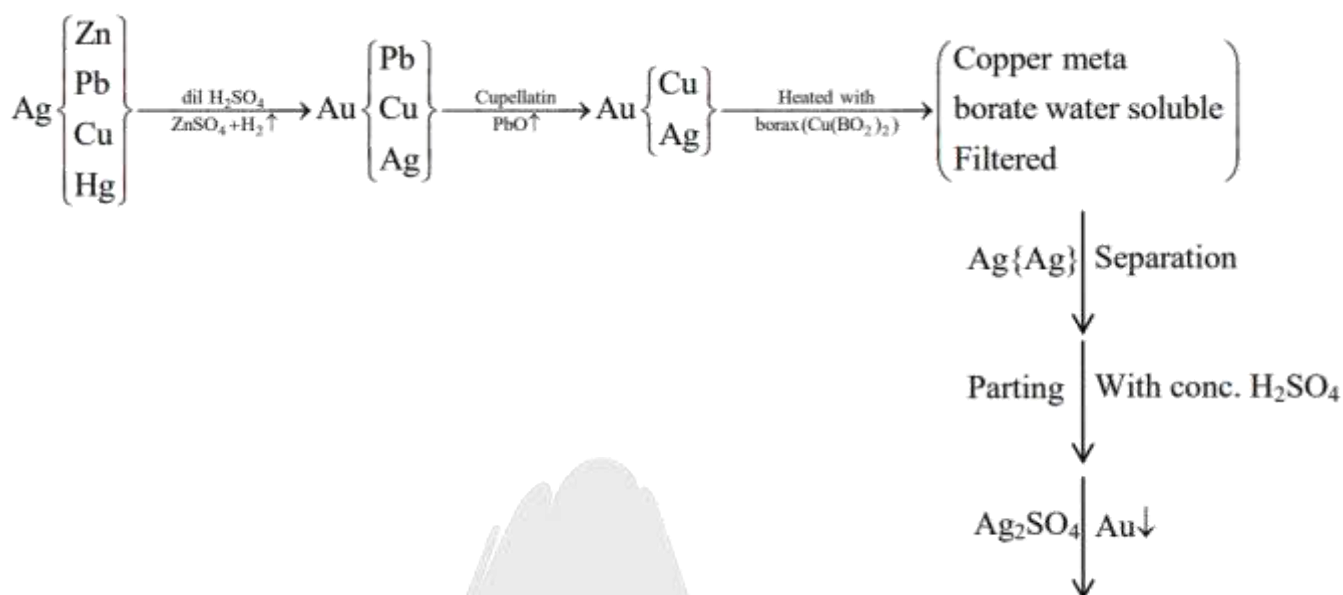
(ii) From Native ore: Mac Arthur Forest-Cyanide process.

(A) Crushing

(B) Conc. → leaching

**Hydrometallurgic reduction:****Purification**

(i) Electro refining (ii) Amalgamation Another method of Purification of Gold:

**Uses:**

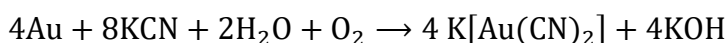
- (i) It is used in silver plating.
- (ii) Silver foils are used in medicine.
- (iii) Silver amalgam is used for dental filling.
- (iv) Compounds of silver are used in silvering of mirrors ($\text{AgNO}_3 + \text{HCHO} + \text{RedPb}$), in photography, as laboratory reagents etc.
- (v) Silver is easily 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 of Gold :**

Gold is mainly found in native state either as vein good, placer gold or alluvial good. It is also present to a small extent in the combined state as sulphide, telluride and arsenosulphide. Some important ores of gold are :

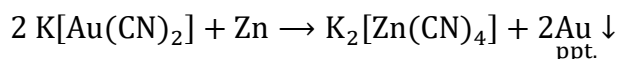
- (i) Calaverite, AuTe_2
- (ii) Sylvanite, AuAgTe_2 and
- (iii) Bismuth aurite, BiAu_2

(i) Mac-Arthur-Forest Cyanide process : The powdered gold ore, after concentration by Forth- floatation process, is roasted to remove easily oxidisable impurities of tellurium, arsenic and sulphur. The roasted ore is then treated with a dilute solution of KCN in presence of atmospheric oxygen when gold dissolves due to the formation of an aurocyanide complex.

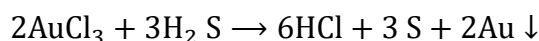
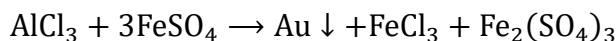


Soluble

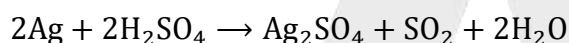
The metal is then extracted by adding zinc dust.



- (ii) **Plattner's chlorine process** : The roasted ore is moistened with water and placed in wooden vats with false perforated bottoms. It is saturated with current of chlorine, gold chloride thus formed is leached with water and the solution is treated with a reducing agent such as FeSO_4 or H_2S to precipitate gold.



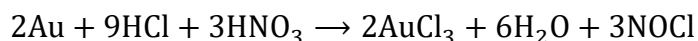
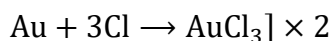
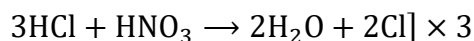
The impure gold thus obtained contains impurities of Ag and Cu. The removal of Ag and Cu from gold is called parting. This is done by heating impure gold with conc. H_2SO_4 (or HNO_3) when Ag and Cu dissolve leaving behind Au.

**Properties of gold:**

Gold is a yellow, soft and Ag are called noble metals since they are not attacked by atmospheric oxygen. However, Ag gets tarnished when exposed to air containing traces of H_2S . Gold is malleable, ductile and a good conductor of heat and electricity. Pure gold is soft. It is alloyed with Ag or Cu for making jewellery. Purity of gold is expressed in terms of carats. Pure gold is 24 carats. Gold '14 carats' means that it is an alloy of gold which contains 14 parts by weight of pure gold and 10 parts of copper per 24 parts by weight of the alloy. Thus the percentage of gold in " 14n carats: of gold is $= \frac{100}{24} \times 14 = 58.3\%$

Most of the jewellery is made from 22 carat gold (91.66% pure gold). Gold is quite inert. It does not react with oxygen, water and acids but dissolves in aqua regia (3 parts concentrated

$\text{HCl} + 1$ part concentrated HNO_3)



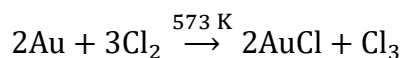
Auric chloride nitrosyl chloride

Oxidation states of gold:

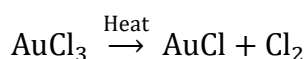
The principal oxidation states of gold are +1 and +3 though +1 state is more stable than +3.

Compound of gold :

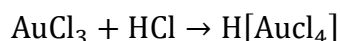
- (i) Auric chloride AuCl_3 . It is prepared by passing dry Cl_2 over finely divided gold powder at 573 K.



It is a red coloured crystalline solid soluble in water and decomposes on heating to give gold (i) chloride and Cl_2 .

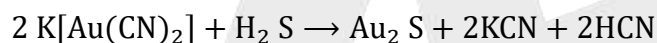


It dissolved in conc. HCl forming chloroauric acid



Chloroauric acid is used in photography for toning silver prints and as an antidote for snake poisoning.

- (ii) Aurous sulphide, Au_2S . It is prepared when H_2S is passed through and acidified solution of potassium aurocyanide, $\text{K}[\text{Au}(\text{CN})_2]$



It is dark brown solid, not attacked by dilute mineral acids and hence is probably the most stable gold (A) compound.

Do yourself - 2

1. During the process of electrolytic refining of copper, some metals present as impurity settle as anode mud. These are
(A) Fe and Ni (B) Ag and Au (C) Sn and Ag (D) Pb and Zn
2. In blast furnace, the hearth is lined with
(A) dolomite refractories (B) alumina refractories
(C) chromite refractories (D) carbon refractories
3. Purpose of coke in the blast furnace is
(A) fuel (B) alloying element
(C) reducing agent (D) (A) and (C)
4. Copper and tin are refined by
(A) liquation (B) cupellation (C) bessemerization (D) poling
5. Blister copper is
(A) impure copper
(B) obtained in self-reduction process during bessemerisation
(C) both (A) and (B) are correct
(D) none of these
6. Self-reduction of Cu_2S to Cu can be carried out in.
(A) Bessemer convertor (B) blast furnace
(C) both (A) and (B) (D) none of these
7. In smelting, the most suitable furnace is
(A) Reverberatory furnace (B) Blast furnace
(C) Open hearth furnace (D) Muffle furnace
8. Which of the following has lowest carbon content?
(A) Cast iron (B) Chrome steel
(C) Stainless steel (D) Wrought iron
9. Magnesium is extracted from ore carnallite by
(A) the self-reduction process
(B) the carbon-reduction process
(C) the electrolytic process
(D) treating the ore with aqueous NaCN and then reducing the mixture
10. $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ is the formula of
(A) chalcopryrite (B) malachite (C) siderite (D) azurite

(Inorganic Chemistry)

METALLURGY

Extraction of Aluminium :

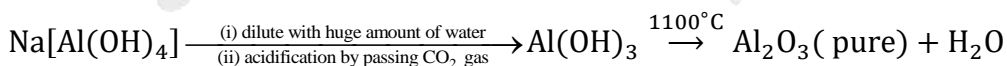
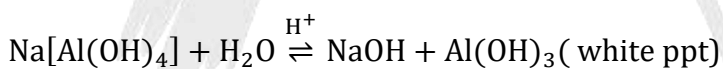
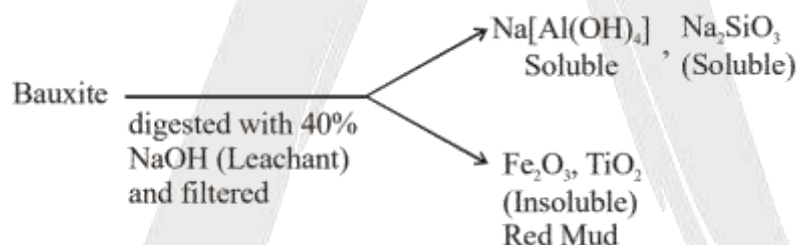
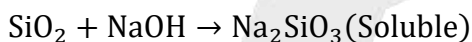
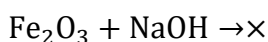
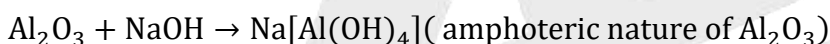
Ores :

- (i) Oxides : bauxite ($\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$) (chif); Diaspore ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$) Corundum (Al_2O_3)
- (ii) Silicates : Felspar (KAlSi_3O_8) Mica ($\text{K}_2\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) Kaolinite ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$)
- iii) Fluorides : Cryolite (Na_3AlF_6)
- (iv) Crushing
- (v) Concentration – Leaching

Bauxite –

- (i) Red bauxite (Bayer's/Hall process) having impurity of Fe_2O_3 (Major), SiO_2 (Minor), TiO_2 (Minor)
- (ii) White bauxite (Serpeck's process) having impurity of SiO_2 (Major), TiO_2 (Minor), Fe_2O_3 (Minor)

Bayer's process:

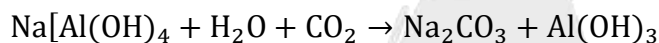
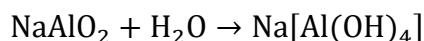
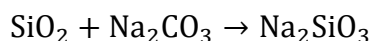
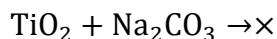
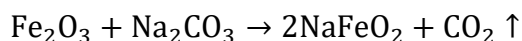
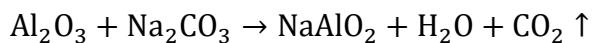
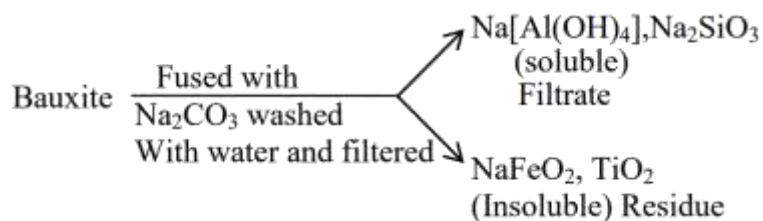


- This process purifies alumina and is used for leaching of aluminium.
- Al_2O_3 Also known as corundum
- $$\text{Na}[\text{Al}(\text{OH})_4] = \text{NaAlO}_2 + \text{H}_2\text{O}$$

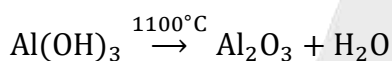
(Sodium
aluminate)

(Sodium
meta aluminate)
- Na_2SiO_3 remains on solution.
- Strong acids are not used for this process, as it can react with $\text{Al}(\text{OH})_3$
- Large amount of water reduces conc. of NaOH , So that less amount of CO_2 can react with NaOH .

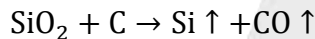
Hall process:



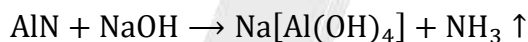
(Out side source)



Serpeck's process



(Vaporises at this temperature)



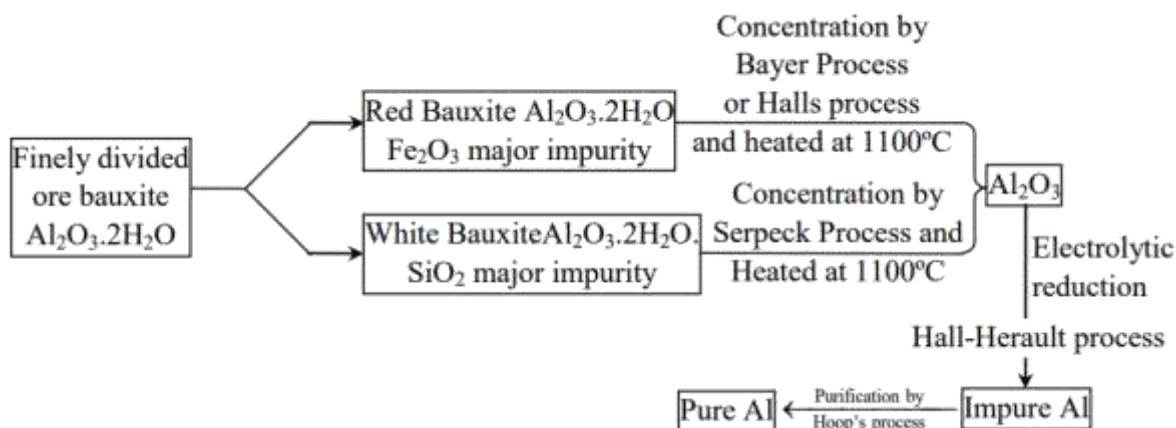
(aqueous)



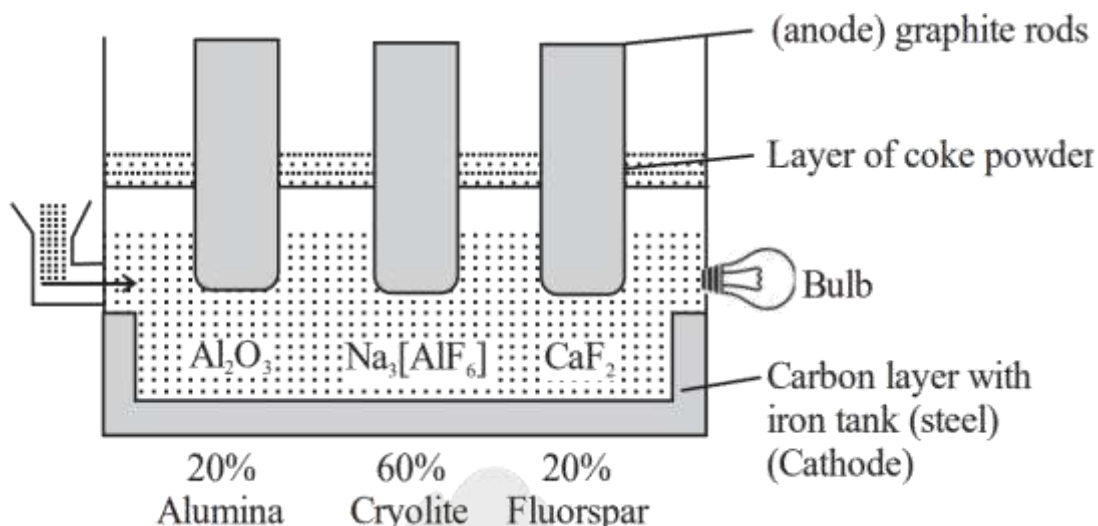
For Al: Nitride formation tendency > Carbide formation tendency

Ore - Bauxite $\text{AlO}_x(\text{OH})_{3-2x}$ (where $0 < x < 1$)

Flow chart of Al from $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ (Bauxite)



Hall Heroult process (Electrolytic Reduction)

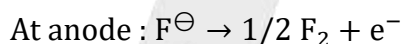
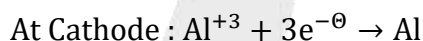
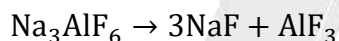


Difficulty of electrolysis of Al_2O_3 :

- Melting point of Al_2O_3 is very high
- It is a bad conductor
 - Cryolite and fluorospar is added.
 - Melting point decreases
 - Conductivity increases

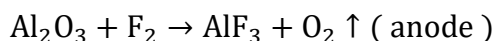
When bulb become dimmer, we know electrolyte mixture is being reduced.

Reaction :



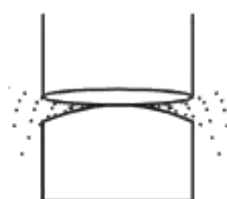
↑

(more reactive further react with Al_2O_3)



Corrode due to oxygen formed at anode : $\text{C} + \text{O}_2 \rightarrow \text{CO}$ and $\text{CO} + \text{O}_2 \rightarrow \text{CO}_2$ (graphite rod)

Use of layer of coke powder :



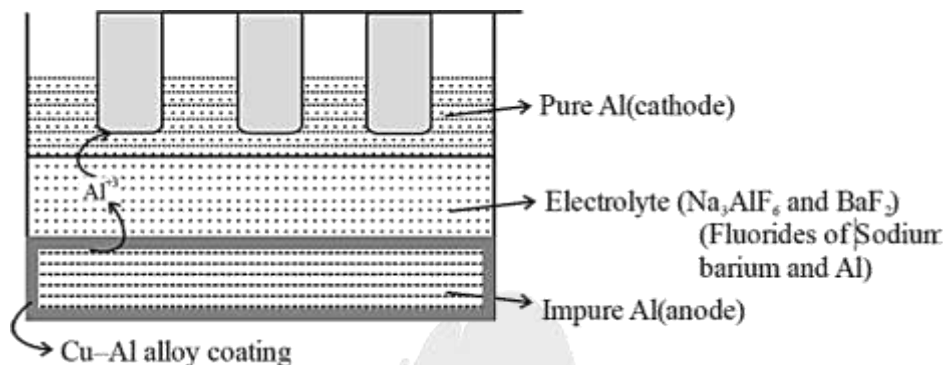
Corrosion of anode

- Prevents loss of heat

(Inorganic Chemistry)

METALLURGY

- Prevents corrosion of anode
- AlF_3 from Al_2O_3 increases conductivity graphite anode is not inert.

Purification :**Hoop's process :**

- BaF_2 is used instead of CaF_2 , to maintain differences in density.
- These layers are immiscible in each other.
- Graphite rod do not act as electrodes. They are used for conductivity.
- 99.98% pure Al is obtained.

Uses

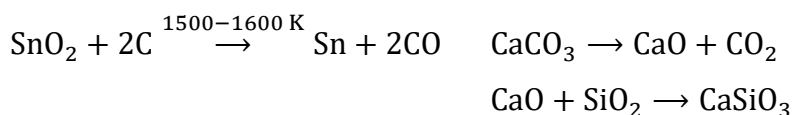
- Aluminium foils are used as wrappers for chocolates.
- The fine dust of the metal is used in paints and lacquers.
- Aluminium, being highly reactive, is also used in the extraction of chromium and manganese from their oxides.
- Wires of aluminium are used as electricity conductors.
- Alloys containing aluminium, being light, are very useful.

Extraction of Tin**Occurrence of tin:**

Tin does not occur in nature in the native state. Its chief ore is cassiterite or tin stone (SnO_2).

Extraction of tin from tin stone:

The ore is crushed, washed and concentrated magnetically to remove magnetic impurities of tungstate of iron (wolframite, FeWO_4) and manganese. The concentrated ore is roasted to remove sulphur and arsenic as their oxides. The roasted ore is then subjected to smelting i.e. ore is mixed with anthracite (coke) in the ratio 1: 4 and little limestone (flux) and heated in a reverberatory furnace.



The molten metal is tapped out from the bottom of the furnace and cast into blocks. The tin thus obtained is called block tin and contains impurities of Fe, Pb and Cu etc. The crude metal is finally refined by either liquation, poling or electro-refining.

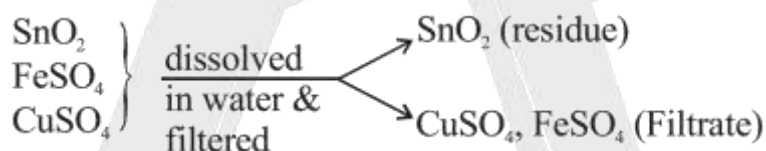
In electro refining, impure metal is made the anode while a sheet of pure metal acts as the cathode. The electrolyte consists of stannous sulphate SnSO_4 containing little H_2SO_4 and hydrofluosilicic acid (H_2SiF_6). On passing current, tin dissolves from the anode and passes into the electrolyte while an equivalent amount of tin from the electrolyte gets deposited on the cathode.

$\text{SnO}_2 \rightarrow$ Cassiterite:

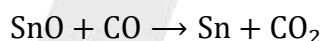
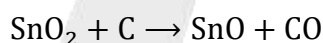
1. Crushing
2. Concentration \rightarrow gravity separation followed by magnetic separation
3. Roasting:

$$\begin{aligned} \text{S} + \text{O}_2 &\rightarrow \text{SO}_2 \uparrow \\ \text{As} + \text{O}_2 &\rightarrow \text{As}_2\text{O}_3 \uparrow \\ \text{Sb} + \text{O}_2 &\rightarrow \text{Sb}_2\text{O}_3 \uparrow \\ \text{CuS} + \text{O}_2 &\rightarrow \text{CuSO}_4 \\ \text{FeS} + \text{O}_2 &\rightarrow \text{FeSO}_4 \end{aligned}$$

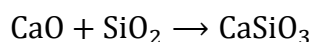
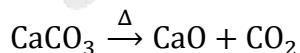
Leaching : It is not chemical leaching



Carbon reduction (smelting)



If SiO_2 is present, CaCO_3 is added as flux



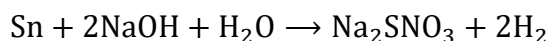
Purification:

(A) Poling

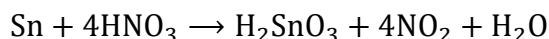
(B) Electrorefining

Properties of tin :

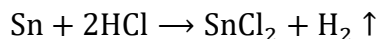
It is a soft white metal, malleable and ductile and can be rolled into sheets and foils. When heated in air, it forms SnO_2 , with S it forms SnS_2 and with Cl_2 it gives SnCl_4 . It dissolves in hot concentrated alkalis evolving H_2 gas



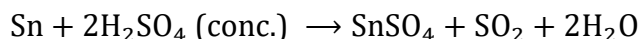
and reacts with HNO_3 to give metastannic acid (H_2SnO_3)



With dil. HCl or H_2SO_4 tin reacts liberating H_2 gas



With hot conc. H_2SO_4 tin reacts to give SO_2 gas



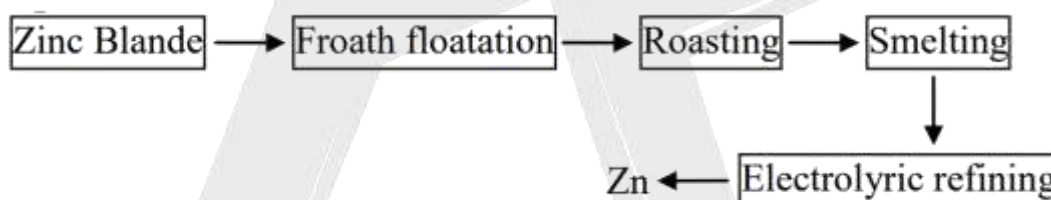
Tin is widely used for plating iron and brass vessels to resist corrosion. Tin foils are also used for wrapping cigarettes and making food containers.

Extraction of Zn(ZnS)

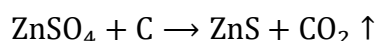
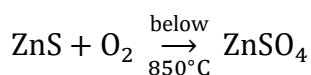
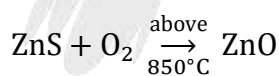
Occurrence : Zinc is usually found in the combined state although traces of the metal in the native state have been reported from Melbourne (Australia). Its chief ores are :

1. Zinc blende, ZnS .
2. Calamine or Sphalerite, ZnCO_3
3. Zincite, ZnO

1. Extraction process : In involves the following steps:



1. Crushing
2. Conc. (Froth flotation)
3. Roasting :

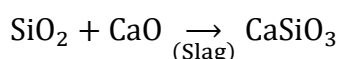
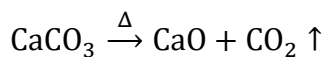


To avoid loss by producing ZnSO_4 , we roast ZnS by using at above 850°C . If ZnSO_4 is formed, it is again reduced to ZnS .

Carbon reduction/smelting : $\text{ZnO} + \text{C} \rightarrow \text{Zn} + \text{CO}$

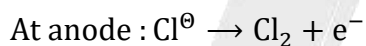
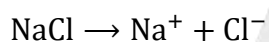
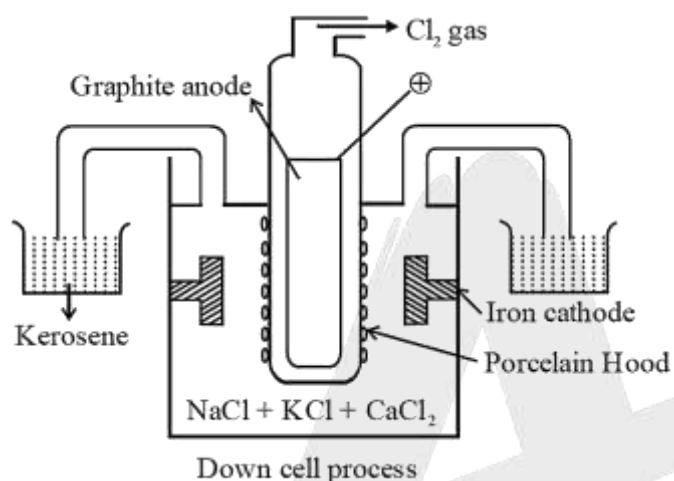
$\rightarrow \text{ZnO} + \text{C} \rightleftharpoons \text{Zn} + \text{CO}_2$ (To bring the reaction forward and increase yield excess coke powder is added)



**Purification :**

(A) Distillation

(B) Electrorefining

Extraction of Sodium (Na). (Down Cell)

Porcelain Hood : Separates anode and cathode :

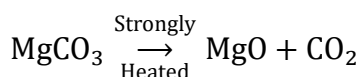
Floating sodium is taken in kerosene.

KCl and CaCl_2 are added to lower melting point**Extraction of Magnesium :****(i) From Carnallite :**

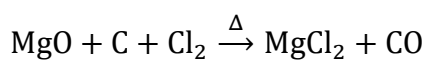
The ore is dehydrated in a current of hydrogen chloride and the mixture of fused chlorides is electrolysed.

(ii) From Magnesite :

The concentrated ore is calcined at higher temperature



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

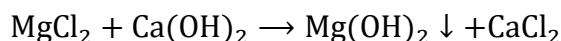


The magnesium chloride is fused and then electrolysed.

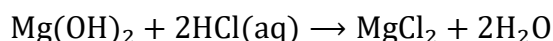
**Extraction of Magnesium : (Sea-Dow's process)****(iii) From Sea water (Dow's process) :**

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

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

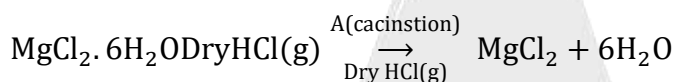


(b) Preparation of hexahydrated magnesium chloride



The solution on concentration and crystallisation gives the crystals of $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$

(c) Preparation of anhydrous magnesium chloride



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



(d) Electrolysis of fused anhydrous MgCl_2

(i) Electrolyte : Molten $\text{MgCl}_2 + \text{NaCl} + \text{CaCl}_2$

(ii) Anode : Graphite electrode

(iii) Cathode : Iron cell

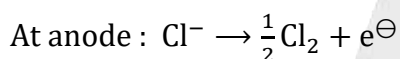
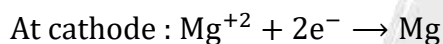
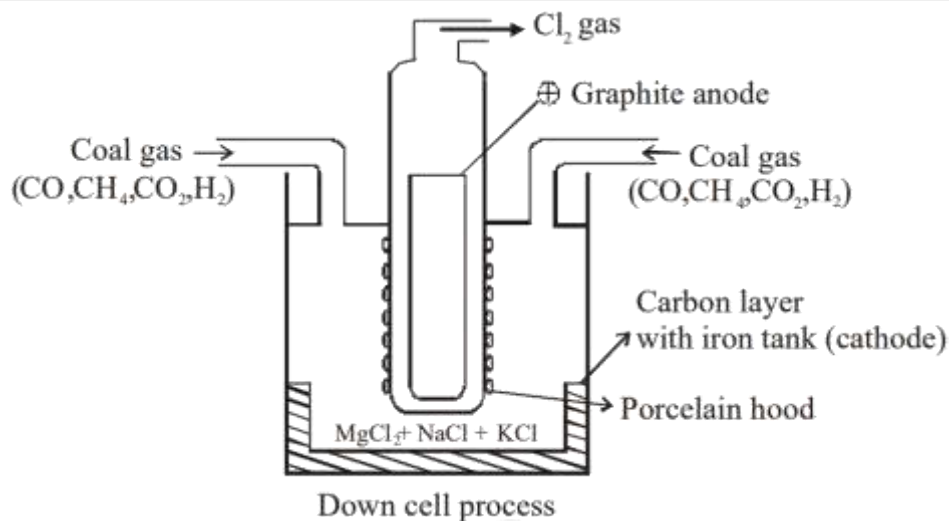
Reaction occurs :

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



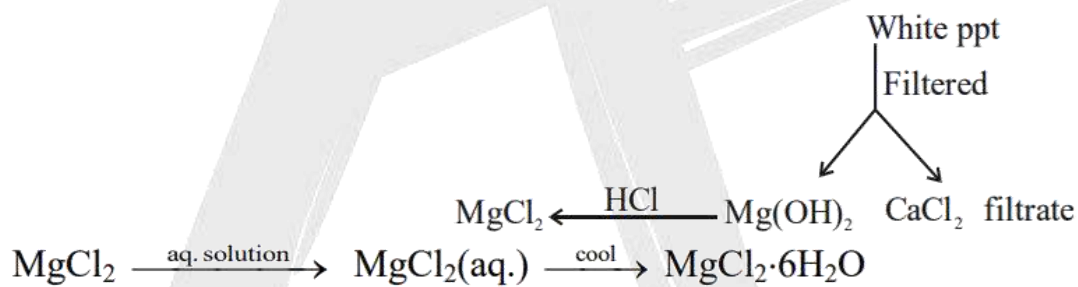
At cathode : $\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg(99\% pure)}$;

At anode : $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$

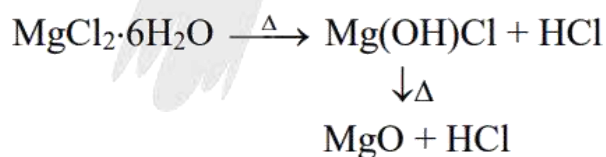


To avoid reaction with O_2 , coal gas is passed.

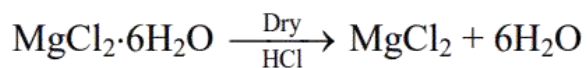
Seperation of MgCl_2 (anhydrous) from sea water:

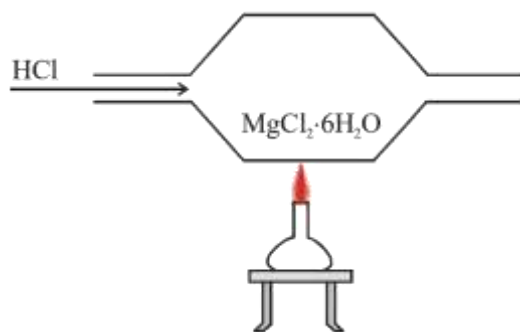


Hydrolysis of $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ on heating.



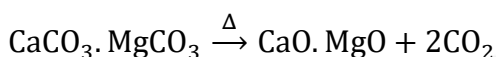
So dry HCl is passed along with heating



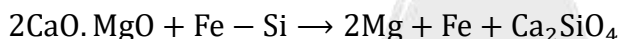


From Dolomite: In the Pidgeon Process Mg is Produced.

The concentrated ore is calcined at higher temperature

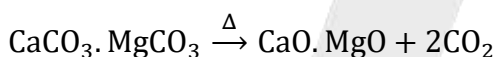


It is then reduced by ferrosilicon at 1273 K under reduced pressure.

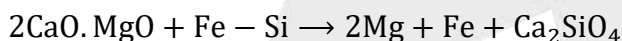


In the Pidgeon Process Mg is Produced.

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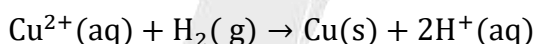


It is then reduced by ferrosilicon at 1273 K under reduced pressure.

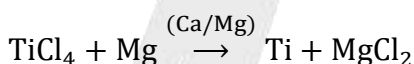


Hydrometallurgy of low grade ore of Copper :

Copper is extracted by hydrometallurgy from low grade ores. It is leached out using acid or bacteria. The solution containing Cu^{2+} is treated with scrap iron or H_2



Kroll Process (Ti) (extraction of Ti)



Mossian process (extraction of F_2)

KHF_2 is used as electrolyte

Nitrates are explosive

Verdigris : $\text{Cu}(\text{CH}_3\text{COO})_2 \cdot \text{Cu}(\text{OH})_2$
(basic copper acetate)

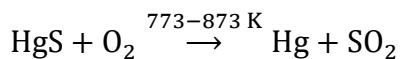
In pickle air, (bronze copper absorbs
water and reacts with acetic acid)

$\text{Cr} \rightarrow$ Aqueous solution can be used for acid electrolysis (variable oxidation state)

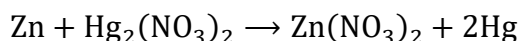
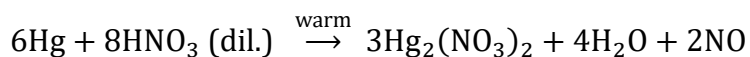
Extraction of Mercury :

Occurrence and extraction of mercury :

Cinnabar (HgS) is the only important ore of Hg. It is concentrated by froth floatation method and mercury is extracted from this ore by heating it in air at 773-873 K (auto reduction)



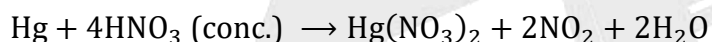
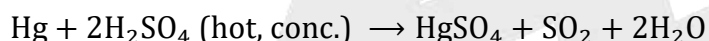
The mercury vapours thus obtained are condensed to give liquid metal. Hg thus obtained contains impurities of Zn, Sn and Pb. These are removed by treating the impure metal with dil. HNO_3 . Mercurous nitrate, $\text{Hg}_2(\text{NO}_3)_2$ thus formed reacts with metals present as impurities forming their nitrates which pass into solution leaving behind pure mercury. However, it is best purified by distillation under reduced pressure.



Similar reaction is given by Pb and Sn.

Properties of mercury :

Mercury is less reactive than Zn. It is liquid at room temperature and has low thermal and electrical conductivity. Mercury forms dimeric mercury(II) ion, Hg_2^{+2} in which the two Hg atoms are bonded by a covalent bond. It is slowly oxidized to HgO at about its boiling point. Hg does not react with dil. HCl or dil. H_2SO_4 but reacts with hot concentrated H_2SO_4 to form HgSO_4 . It, however, reacts with both warm dil. and conc. HNO_3 evolving NO and NO_2 respectively.



Do yourself - 3

1. Which is an alloy of aluminium ?
(A) Magnalium (B) Duralumin (C) Brass (D) Both (A) and (B)
2. Which one of the following metals has the largest abundance in the earth's crust?
(A) Magnesium (B) Calcium (C) Aluminium (D) Sodium
3. Which of the following metals may be present in the anode mud during electrorefining of copper?
I. Gold
II. Iron
III. Silver
IV. Magnesium
(A) I and II (B) II and IV (C) I and III (D) III and IV
4. Aluminium metal is purified by
(A) Hooper's process (B) Hall-Heroult process
(C) Serpeck's process (D) Baeyer's process
5. Silver can be separated from lead by
(A) fractional crystallization (B) liquation
(C) cupellation (D) addition of zinc (Parke's method)
6. Which of the following metals cannot be extracted by the carbon reduction process?
(A) Zn (B) Fe (C) Al (D) Sn
7. Which of the following is not the ore of aluminium?
(A) Bauxite (B) Corundum (C) Langbeinite (D) Kaolinite
8. In the electrolytic refining of zinc
(A) the impure metal is at of zinc
(B) graphite is at the anode
(C) the metal iron gets reduced at the anode
(D) acidified zinc sulphate is the electrolyte
9. Purification of aluminium is called
(A) Baeyer's process (B) Bosh process (C) Hoopes process (D) Castner's process
10. In sulphation roasting of ZnS products are
(A) $\text{ZnO} + \text{ZnSO}_4 + \text{SO}_2$ (B) $\text{ZnO} + \text{SO}_2$
(C) ZnCl_2 (D) $\text{Zn} + \text{SO}_2$

EXERCISE # I

ONLY ONE OPTION IS CORRECT

ORES

1. Which of the following does not contain Mg :
(A) magnetite (B) magnesite (C) asbestos (D) carnallite
2. Which of the following is not an ore:
(A) malachite (B) calamine (C) stellite (D) cerussite
3. Carnallite does not contain
(A) K (B) Ca (C) Mg (D) Cl
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
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
6. "Fool's gold" is
(A) iron pyrites (B) horn silver (C) copper pyrites (D) bronze
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.

CONCENTRATION METHODS

8. $\text{Ag}_2\text{S} + \text{NaCN} + \text{Zn} \rightarrow \text{Ag}$
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

(Inorganic Chemistry)

METALLURGY

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
10. Chemical leaching is useful in the concentration of:
(A) copper pyrites (B) bauxite (C) galena (D) cassiterite
11. In froth-floatation process, pine oil functions as
(A) activator (B) frother (C) collector (D) agitator
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
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
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
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
16. The beneficiation of the sulphide ores is usually done by
(A) Electrolysis (B) Smelting process
(C) Metal displacement method (D) Froth flotation method
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
18. Froth floatation process for concentration of ores is an illustration of the practical application of:
(A) Adsorption (B) Absorption (C) Coagulation (D) Sedimentation

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.
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.

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
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

REDUCTION PROCESS

23. In the aluminothermite process, Al acts as
(A) An oxidising agent
(B) A flux
(C) A reducing agent
(D) A solder

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.
25. Formation of metallic copper from the sulphide ore in the commercial thermo-metallurgical process essentially involves which one of the following reaction:
(A) $\text{Cu}_2\text{S} + \frac{3}{2}\text{O}_2 \rightarrow \text{Cu}_2\text{O} + \text{SO}_2$; $\text{CuO} + \text{C} \rightarrow \text{Cu} + \text{CO}$
(B) $\text{Cu}_2\text{S} + \frac{3}{2}\text{O}_2 \rightarrow \text{Cu}_2\text{O} + \text{SO}_2$; $2\text{Cu}_2\text{O} + \text{Cu}_2\text{S} \rightarrow 6\text{Cu} + \text{SO}_2$
(C) $\text{Cu}_2\text{S} + 2\text{O}_2 \rightarrow \text{CuSO}_4$; $\text{CuSO}_4 + \text{Cu}_2\text{S} \rightarrow 3\text{Cu} + 2\text{SO}_2$
(D) $\text{Cu}_2\text{S} + \frac{3}{2}\text{O}_2 \rightarrow \text{Cu}_2\text{O} + \text{SO}_2$; $\text{Cu}_2\text{O} + \text{CO} \rightarrow 2\text{Cu} + \text{CO}_2$
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
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

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) Aluminothermite process (B) Electrolysis process
(C) Van-Arkel's process (D) Cupellation

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.

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.

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

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

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



T_1 and T_2 are:

(A) $100^\circ C, 50^\circ C$

(B) $50^\circ C, 100^\circ C$

(C) $50^\circ C, 230^\circ C$

(D) $230^\circ C, 50^\circ C$

(Inorganic Chemistry)

METALLURGY

34. Zone refining is based on the principle of
(A) fractional distillation (B) fractional crystallisation
(C) partition coefficient (D) chromatographic separation
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
36. Which process of purification is represented by the following equation :
$$\text{Ti (Impure)} + 2\text{I}_2 \xrightarrow{250^\circ\text{C}} \text{TiI}_4 \xrightarrow{1400^\circ\text{C}} \text{Ti (Pure)} + 2\text{I}_2$$

(A) Cupellation (B) Poling
(C) Van-Arkel Process (D) Zone refining
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
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
39. Assertion : Titanium is purified by Van-Arkel method.
Reason : Ti reacts with I₂ to form volatile TiI₄ 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.

40. Assertion : Nickel is purified 'by the thermal decomposition of nickel tetracarbonyl.
Reason : Nickel is a transitional 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.
41. Refining of silver is done by:
(A) liquation (B) poling (C) cupellation (D) van Arkel method
42. Mercury is purified by:
(A) Passing through dilute HNO_3 (B) Distillation
(C) Distribution (D) Vapour phase refining
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.
44. When an impurity in a metal has greater affinity for oxygen and is more easily oxidises than the metal itself. Then, the metal is refined by
(A) cupellation (B) zone-refining (C) distillation (D) electrolytic process

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 $\text{Na}[\text{Ag}(\text{CN})_2]$ aq.
46. Blister Cu is about:
(A) 60%Cu (B) 90%Cu (C) 98%Cu (D) 100%Cu

(Inorganic Chemistry)

METALLURGY

47. Iron obtained from blast furnace is:
(A) wrought iron (B) cast iron (C) pig iron (D) steel
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
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
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
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
52. In the commercial electrochemical process for aluminium extraction the electrolyte used is
(A) $\text{Al}(\text{OH})_3$ in NaOH solution
(B) an aqueous solution of $\text{Al}_2(\text{SO}_4)_3$
(C) a molten mixture of Al_2O_3 , Na_3AlF_6 & CaF_2
(D) a molten mixture of Al_2O_3 and $\text{Al}(\text{OH})_3$
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
54. A piece of steel is heated until redness and then plugged 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
55. Modern method of steel manufacturing is
(A) open hearth process (B) L.D. Process
(C) Bessemerisation (D) Cupellation

(Inorganic Chemistry)

METALLURGY

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 fluorspar (B) cryolite and alum
(C) alum and fluorspar (D) fluorspar and bauxite
57. For extraction of sodium from NaCl, the electrolytic mixture $\text{NaCl} + \text{KCl} + \text{CaCl}_2$ 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.
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
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
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

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
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

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
64. Assertion: Generally in smelting, roasted/calcinated 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.
65. Assertion : Magnesite 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.
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.

EXERCISE # II

ONE OR MORE THAN ONE OPTION MAYBE CORRECT

1. Which of the following is(are) sulphide ores?
(A) Argentite (B) Galena (C) Anglesite (D) Copper glance
2. Which of the following is(are) regarded as iron ores?
(A) Haematite (B) Magnetite (C) Limonite (D) Copper pyrites

CONCENTRATION

3. Which of the following ores is(are) concentrated by froth floatation?
(A) haematite (B) galena (C) copper pyrite (D) azurite
4. Which of the following ores is (are) concentrated industrially by froth floatation?
(A) Copper pyrites (B) Galena (C) Dolomite (D) Carnallite
5. Leaching is used for the concentration of:
(A) Red bauxite (B) Haematite (C) Gold ore (D) Silver ore

CALCINATION/ROASTING

6. Calcinations 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
7. Which of the following reaction(s) occur during calcination?
(A) $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ (B) $4\text{FeS}_2 + 11\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + 8\text{SO}_2$
(C) $2\text{Al}(\text{OH})_3 \rightarrow \text{Al}_2\text{O}_3 + 3\text{H}_2\text{O}$ (D) $\text{CuS} + \text{CuSO}_4 \rightarrow 2\text{Cu} + 2\text{SO}_2$
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.
9. Roasting can be performed in
(A) blast furnace (B) reverberatory furnace
(C) electric furnace (D) None of these

REDUCTION

10. Carbon reduction method is employed for commercial extraction of metal from amongst these:
(A) haematite (B) cassiterite (C) iron pyrite (D) corundum
11. Auto reduction process is used in extraction of
(A) Cu (B) Hg (C) Al (D) Fe
12. Which of the following reduction reactions are actually employed in commercial extraction of metals?
(A) $\text{Fe}_2\text{O}_3 + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 2\text{Fe}$
(B) $\text{Cr}_2\text{O}_3 + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 2\text{Cr}$
(C) $2\text{Na}[\text{Au}(\text{CN})_2] + \text{Zn} \rightarrow \text{Na}_2[\text{Zn}(\text{CN})_4] + 2\text{Au}$
(D) $\text{Cu}_2\text{S} + \text{Pb} \rightarrow \text{Cu} + \text{PbS} \downarrow$

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
14. Poling is employed in refining of
(A) iron (B) copper (C) tin (D) lead
15. Zone refining is used for purification of
(A) Ge (B) Si (C) Ga (D) Se
16. Metal(s) which does/do not form amalgam is/are
(A) Fe (B) Pt (C) Zn (D) Au
17. Metals which can be commercially extracted by smelting process
(A) Pb (B) Fe (C) Zn (D) Mg

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 .
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, Pd 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
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
21. Common impurities present in Bauxite are
- (A) CuO
 - (B) ZnO
 - (C) Fe_2O_3
 - (D) SiO_2
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.
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) Serpek's process
 - (D) Dow's process
24. The chief reaction(s) occurring in blast furnace during extraction of iron from haematite is(are)
- (A) $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
 - (B) $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeSiO}_3$
 - (C) $\text{Fe}_2\text{O}_3 + \text{C} \rightarrow 2\text{Fe} + 3\text{CO}$
 - (D) $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$
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

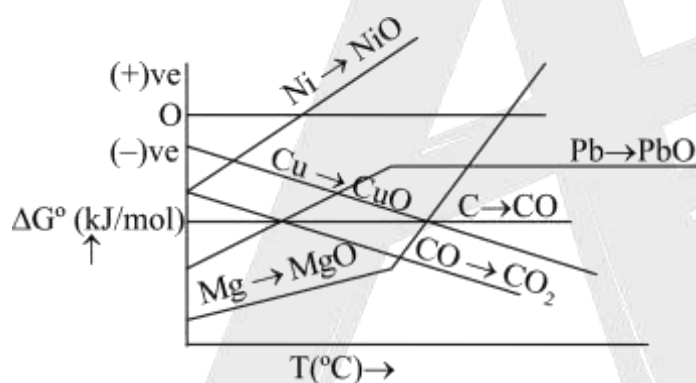
26. During extraction of copper, it is obtained in the form of molten matte. Which of the following is not true?
- (A) matte is further treated in Bessemer's converter
(B) molten matte is electrolysed
(C) It is treated with a blast of air and sand
(D) It is dissolved in CuSiF_6 and crystallised.
27. 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.
28. Which of the following reaction does not occur in blast furnace during extraction of iron :
- (A) $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$ (B) $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
(C) $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeSiO}_3$ (D) $\text{FeO} \rightarrow \text{Fe} + \frac{1}{2}\text{O}_2$

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 converter
30. The correct statements are :
- (A) generally the calcination and roasting is done in blast furnace
(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

EXERCISE - III

- Find the number of ore which are concentrated by magnetic separation method.
Haemetite, Cassiterite, Copper Glance, Chromite, Cinnabar
- Find the number of metals which are commercially extracted by carbon reduction method
Pb, Fe, Zn, Mg, Al, Na, Au, Ag
- 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
- Find the number of curves which are wrongly presented in the Elingham diagram.



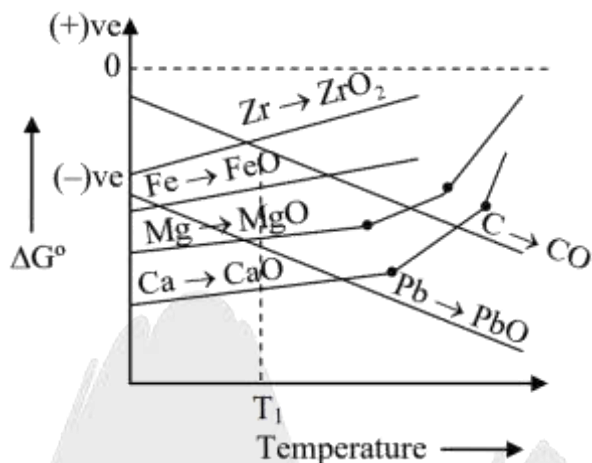
- How many of the following minerals containing Mg.
Magnetite, Carnallite, Epsom salt, Siderite
- Find out the number of minerals given below contain iron as Fe(II).
Haematite, Magnetite, Limonite, Siderite, Chromite, Wolframite.
- Amongst the following ores, the total number of oxide ores are Siderite, Magnetite, Haematite, Malachite, Zincite, Cuprite
- Amongst the following, total number of sulphide ores are Calamine, Sphalartie, Copper pyrites, Copper glance, Iron pyrites, bauxite
- How many of the following ores of silver?
Horn silver, Cerussite, Chalcoppyrite, Galena, Anglesite, Argentite

EXERCISE - IV

COMPREHENSION AND MATCH

THE COLUMN ELLINGHAM DIAGRAM

Paragraph for 1 to 3

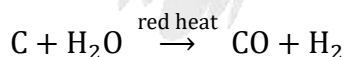


- Which of the above curve is wrongly presented -
 (A) $C \rightarrow CO_2$ (B) $Pb \rightarrow PbO$ (C) $Zr \rightarrow ZrO_2$ (D) $Mg \rightarrow MgO$
- Which of the above metal oxide is having minimum thermal decomposition temperature?
 (A) CaO (B) FeO (C) ZrO_2 (D) MgO
- Which of the followings metal's oxide can be reduced by Fe as reducing agent at temperature (T_1).
 (A) Zr (B) Ca (C) Mg (D) None of these

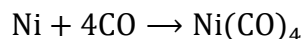
PURIFICATION METHOD

Paragraph for 4 to 5

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



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



- How many moles of $Ni(CO)_4$ could be obtained from the CO produced by the reaction of 75.0 g of carbon? Assume 100% reaction and 100% recovery in both steps.
 (A) 6.25 (B) 1.563 (C) 3.125 (D) 25.0

(Inorganic Chemistry)

METALLURGY

5. Formation of volatile $\text{Ni}(\text{CO})_4$ and its subsequent heating give pure Ni. process is called -
 (A) Hall (B) Dow (C) Serpeck (D) Mond

MISCELLANEOUS

Match Column

6. Match Column-I with Column-II

Column-I (Metals)

- (A) Iron & copper
 (B) Zirconium & Titanium
 (C) Lead & Tin
 (D) Copper & Tin

Column-II (Method used for refining)

- (P) Poling
 (Q) Bessemerisation
 (R) Van-Arkel
 (S) Liquation

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

Column-X

- (A) Zinc from ZnCO_3
 (B) Lead from PbS
 (C) Cu from CuFeS_2
 (D) Tin from cassiterite

Column-Y

- (P) Calcination
 (Q) Removal of iron
 (R) Froth floatation process
 (S) Poling

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

Column (I) (process)

- (A) Downs cell
 (B) Dow's sea water process
 (C) Hall-Heroult

Column (II) (electrolyte)

- (P) fused MgCl_2
 (Q) fused $(\text{Al}_2\text{O}_3 + \text{Na}_3\text{AlF}_6 + \text{CaF}_2)$
 (R) fused $(40\%\text{NaCl} + 60\%\text{CaCl}_2)$
 (S) $(\text{AlN} + \text{C} + \text{N}_2)$

9. Match column - I with column - II

Column - I (Property)

- (A) Explosive
 (B) Self-reduction
 (C) Ferrimagnetic material
 (D) Verdigris

Column - II (Element/compound)

- (P) Cu
 (Q) Fe_3O_4
 (R) $\text{Cu}(\text{CH}_3\text{COO})_2 \cdot \text{Cu}(\text{OH})_2$
 (S) $\text{Pb}(\text{NO}_3)_2$

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

Column - I

- (A) Cyanide process
(B) Floatation process
(C) Electrolytic reduction
(D) Zone refining

Column - II

- (P) Ultrapure Ge
(Q) Dressing of HgS
(R) Extraction of Al
(S) Extraction of Au

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

Column I

- (A) Blistered Cu
(B) Blast furnace
(C) Reverberatory furnace
(D) Hall-Heroult process

Column II

- (P) Aluminium
(Q) $2\text{Cu}_2\text{O} + \text{Cu}_2\text{S} \rightarrow 6\text{Cu} + \text{SO}_2$
(R) Iron
(S) $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeSiO}_3$
(T) $2\text{Cu}_2\text{S} + 3\text{O}_2 \rightarrow 2\text{Cu}_2\text{O} + 2\text{SO}_2$

- (A) P → (B) ; Q → (C) ; R → (D) ; S → (A) (B) P → (A) ; Q → (B) ; R → (C) ; S → (5)
(C) P → (5) ; Q → (D) ; R → (C) ; S → (B) (D) P → (D) ; Q → (5) ; R → (C) ; S → (B)

EXERCISE - V (JEE-Mains)

- Aluminium is extracted by the electrolysis of :- [AIEEE-2002]
 (A) Bauxite
 (B) Alumina
 (C) Alumina mixed with molten cryolite
 (D) Molten cryolite
- Pyrolusite is a/an :- [AIEEE-2002]
 (A) Oxide ore (B) Sulphide ore (C) Carbide ore (D) Not an ore
- Which one of the following ores is best concentrated by froth-flotation method : [AIEEE-2004]
 (A) Galena (B) Cassiterite (C) Magnetite (D) Malachite
- 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]
 (A) Metal sulphides are thermodynamically more stable than CS_2
 (B) CO_2 is thermodynamically more stable than CS_2
 (C) Metal sulphides are less stable than the corresponding oxides
 (D) CO_2 is more volatile than CS_2
- Which method of purification is represented by the following equation : [AIEEE-2012]

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

 (A) Van Arkel (B) Zone refining (C) Cupellation (D) Poling
- The substance used as froth stabilisers in froth-floatation process is : [J-Mains-2012 (On line)]
 (A) Copper sulphate (B) Aniline
 (C) Sodium cyanide (D) Potassium ethyl xanthate
- Which of the oxide groups among the following cannot be reduced by carbon :- [J-Mains-2012 (On line)]
 (A) Fe_3O_4 , ZnO (B) PbO , Fe_3O_4 (C) Cu_2O , SnO_2 (D) CaO , K_2O
- In Goldschmidt aluminothermic process which of the following reducing agents is used : [J-Mains-2013 (On line)]
 (A) Calcium (B) Coke (C) Sodium (D) Al-powder
- Calcination is the process in which :
 (A) 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.
 (B) 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

(C) 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

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

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

[JEE-MAINS-2014]

(A) Cu (B) Cr (C) Ag (D) Ca

11. The form of iron obtained from blast furnace is :

[J-Mains-2014 (On line)]

(A) Steel (B) Wrought Iron (C) Cast Iron (D) Pig iron

12. In the context of the Hall-Heroult process for the extraction of Al, which of the following statements is false?

[JEE-MAINS-2015]

(A) Al^{3+} is reduced at the cathode to form Al
(B) Na_3AlF_6 serves as the electrolyte
(C) CO and CO_2 are produced in this process
(D) Al_2O_3 is mixed with CaF_2 which lowers the melting point of the mixture and brings conductivity

13. Galvanization is applying a coating of :-

[JEE-MAINS-2016]

(A) Zn (B) Pb (C) Cr (D) Cu

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

[JEE-MAINS-2016]

(A) Malachite (B) Magnetite (C) Siderite (D) Galena

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]

(A) The copper metal will dissolve and zinc metal will be deposited
(B) No reaction will occur
(C) The copper metal will dissolve with evolution of oxygen gas
(D) The copper metal will dissolve with evolution of hydrogen gas

16. In the extraction of copper from its sulphide ore, metal is finally obtained by the oxidation of cuprous sulphide with :

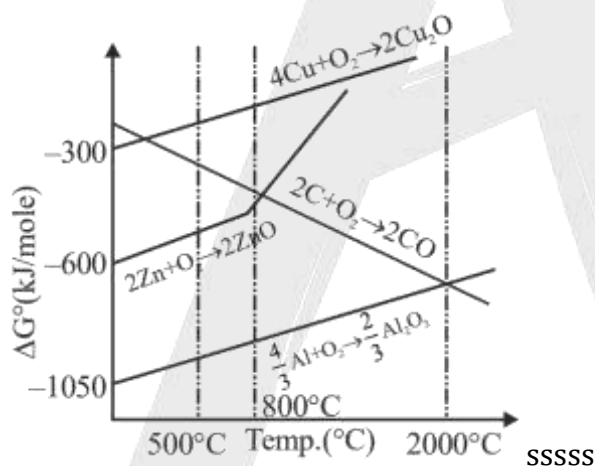
[JEE-MAINS(Online)-2018]

(A) Fe_2O_3 (B) Cu_2O (C) SO_2 (D) CO

(Inorganic Chemistry)

METALLURGY

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-MAINS-2018]**
 (A) Fe (B) Zn (C) Ca (D) Al
18. In the leaching method, bauxite ore is digested with a concentrated solution of NaOH that produces 'X'. When CO₂ gas is passed through the aqueous solution of 'X', a hydrated compound 'Y' is precipitated. 'X' and 'Y' respectively are : **[JEE-MAINS(Online)-2018]**
 (A) NaAlO₂ and Al₂(CO₃)₃ · xH₂O
 (B) Al(OH)₃ and Al₂O₃ · xH₂O
 (C) Na[Al(OH)₄] and Al₂O₃ · xH₂O
 (D) Na[Al(OH)₄] and Al₂(CO₃)₃ · xH₂O
19. The ore that contains both iron and copper is : **[JEE-MAINS-2019]**
 (A) malachite (B) dolomite (C) azurite (D) copper pyrites
20. The correct statement regarding the given Ellingham diagram is:



- (A) At 800°C, Cu can be used for the extraction of Zn from ZnO
 (B) At 1400°C, Al can be used for the extraction of Zn from ZnO
 (C) At 500°C, coke can be used for the extraction of Zn from ZnO
 (D) Coke cannot be used for the extraction of Cu from Cu₂O
21. Hall-Heroult's process is given by : **[JEE-MAINS-2019]**
 (A) Cr₂O₃ + 2Al → Al₂O₃ + 2Cr
 (B) Cu²⁺(aq) + H₂(g) → Cu(s) + 2H⁺(aq)
 (C) 2Al₂O₃ + 3C → 4Al + 3CO₂
 (D) ZnO + C $\xrightarrow{\text{Coke, 1673 K}}$ Zn + CO

(Inorganic Chemistry)

METALLURGY

22. Match the ores (Column A) with the metals (column B) : [JEE-MAINS-2019]

Column-A

Column-B

(I) Siderite

(a) Zinc

(II) Kaolinite

(b) Copper

(III) Malachite

(c) Iron

(IV) Calamine

(d) Aluminium

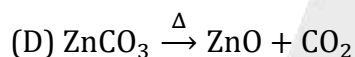
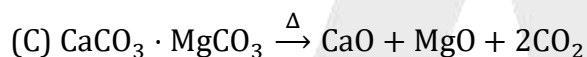
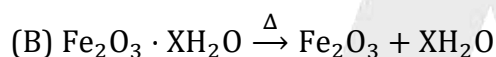
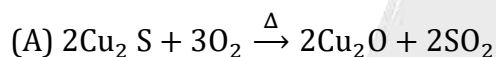
(A) (I)-(c); (II)-(d); (III)-(b); (IV)-(a)

(B) (I)-(c); (II)-(d); (III)-(a); (IV)-(b)

(C) (I)-(a); (II)-(b); (III)-(c); (IV)-(d)

(D) (I)-(b); (II)-(c); (III)-(d); (IV)-(a)

23. The reaction that does not define calcination is :- [JEE-MAINS-2019]



24. In the Hall-Heroult process, aluminum is formed at the cathode. The cathode is made out of : [JEE-MAINS-2019]

(A) Copper

(B) Platinum

(C) Pure aluminum

(D) Carbon

25. The pair that does NOT require calcination is: [JEE-MAINS-2019]

(A) ZnO and $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ (B) ZnCO_3 and CaO

(C) ZnO and MgO

(D) Fe_2O_3 and $\text{CaCO}_3 \cdot \text{MgCO}_3$

26. Purest form of commercial iron is: [JEE-MAINS-2020]

(A) Wrought iron

(B) Cast iron

(C) Pig iron

(D) Iron scrap + pig iron

27. Among statements (a) - (d), the correct ones are [JEE-MAINS-2020]

(a) lime stone is decomposed to CaO during the extraction of iron from its oxides.

(b) In the extraction of silver, silver is extracted as an anionic complex.

(c) Nickel is purified by Mond's process.

(d) Zr and Ti are purified by Van Arkel method.

(A) (a), (c) and (d) only

(B) (c) and (d) only

(C) (b), (c) and (d) only

(D) (a), (b), (c) and (d)

28. An Ellingham diagram provides information about [JEE-MAINS-2020]

(A) the temperature dependence of the standard Gibbs energies of formation of some metal oxides

(B) the pressure dependence of the standard electrode potentials of reduction reactions involved in the extraction of metals

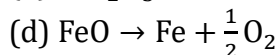
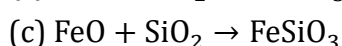
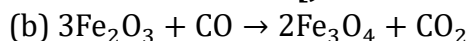
(Inorganic Chemistry)

METALLURGY

- (C) the conditions of pH and potential under which a species is thermodynamically stable
(D) the kinetics of the reduction process

29. The element that can be refined by distillation is [JEE-MAINS-2020]
(A) gallium (B) nickel (C) zinc (D) tin

30. Among the reactions (a) – (d), the reaction (s) that does/do not occur in the blast furnace during the extraction of iron is/are [JEE-MAINS-2020]



- (A) a&b (B) a, b&c (C) c&d (D) a, b, c, d

31. In the electrolytic refining of blister copper, the total number of main impurities, from the following, removed as anode mud is Pb, Sb, Se, Te, Ru, Ag, Au and Pt [JEE-MAINS-2021]

32. Given below are two statements : one is labelled as Assertion (a) and the other is labelled as Reason (r). [JEE-MAINS-2021]

Assertion (a) : Aluminum is extracted from bauxite by the electrolysis of molten mixture of Al_2O_3 with cryolite.

Reason (r) : The oxidation state of Al in cryolite is +3.

In the light of the above statements, choose the most appropriate answer from the options given below :

- (A) (a) is true but (r) is false.
(B) (a) is false but (r) is true.
(C) Both (a) and (r) are correct and (r) is the correct explanation of (a).
(D) Both (a) and (r) are correct but (r) is not the correct explanation of (a).

33. Match List - I with List - II : [JEE-MAINS-2021]

List-I

(Name of ore/mineral)

(a) Calamine

(b) Malachite

(c) Siderite

(d) Sphalerite

List-II

(Chemical formula)

(i) ZnS

(ii) FeCO_3

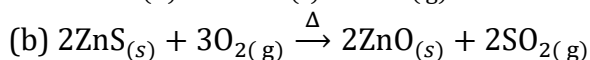
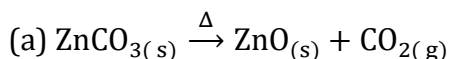
(iii) ZnCO_3

(iv) $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$

Choose the most appropriate answer from the options given below :

- (A) (a)-(iii), (b)-(iv), (c)-(ii), (d)-(i) (B) (a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)
(C) (a)-(iv), (b)-(iii), (c)-(i), (d)-(ii) (D) (a)-(iii), (b)-(ii), (c)-(iv), (d)-(i)

34. Consider two chemical reactions (A) and (B) that take place during metallurgical process:



The correct option of names given to them respectively is :

[JEE-MAINS-2021]

- (A) (a) is calcination and (b) is roasting
(B) Both (a) and (b) are producing same product so both are roasting
(C) Both (a) and (b) are producing same product so both are calcination
(D) (a) is roasting and (b) is calcination

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35. The addition of silica during the extraction of copper from its sulphide ore :-

[JEE-MAINS-2021]

- (A) converts copper sulphide into copper silicate
 (B) converts iron oxide into iron silicate
 (C) reduces copper sulphide into metallic copper
 (D) reduces the melting point of the reaction mixture

36. Which of the following reduction reaction CANNOT be carried out with coke?

[JEE-MAINS-2021]

- (A) $\text{Al}_2\text{O}_3 \rightarrow \text{Al}$ (B) $\text{ZnO} \rightarrow \text{Zn}$ (C) $\text{Fe}_2\text{O}_3 \rightarrow \text{Fe}$ (D) $\text{Cu}_2\text{O} \rightarrow \text{Cu}$

37. How many of these minerals are sulphide based?

[JEE-MAINS-2022]

- (a) Baryte, (b) Galena, (c) Zinc blende and (d) Copper pyrites.

38. Leaching of gold with dilute aqueous solution of NaCN in presence of oxygen gives complex [A], which on reaction with zinc forms the elemental gold and another complex [B]. [A] and [B], respectively are :-

[JEE-MAINS-2022]

- (A) $[\text{Au}(\text{CN})_4]^-$ and $[\text{Zn}(\text{CN})_2(\text{OH})_2]^{2-}$
 (B) $[\text{Au}(\text{CN})_2]^-$ and $[\text{Zn}(\text{OH})_4]^{2-}$
 (C) $[\text{Au}(\text{CN})_2]^-$ and $[\text{Zn}(\text{CN})_4]^{2-}$
 (D) $[\text{Au}(\text{CN})_4]^{2-}$ and $[\text{Zn}(\text{CN})_6]^{4-}$

39. In isolation of which one of the following metals from their ores, the use of cyanide salt is not commonly involved?

[JEE-MAINS-2022]

- (A) Zinc (B) Gold (C) Silver (D) Copper

40. Given below are two statements.

[JEE-MAINS-2022]

Statement I : Pig iron is obtained by heating cast iron with scrap iron.

Statement II: Pig iron has a relatively lower carbon content than that of cast iron. In the light of the above statements, choose the correct answer from the options given below.

- (A) Both Statement I and Statement II are correct.
 (B) Both Statement I and Statement II are not correct.
 (C) Statement I is correct but Statement II is not correct
 (D) Statement I is not correct but Statement II is correct.

41. Which of the following methods are not used to refine any metal?

[JEE-MAINS-2022]

- (a) Liquation (b) Calcination (c) Electrolysis
 (d) Leaching (e) Distillation

Choose the correct answer from the options given below:

- (A) b and d only (B) a, b, d and e only
 (C) b, d and e only (D) a, c and e only

42. In liquation process used for tin (Sn), the metal:

[JEE-MAINS-2022]

- (A) is reacted with acid

(Inorganic Chemistry)

METALLURGY

- (B) is dissolved in water
(C) is brought to molten form which is made to flow on a slope
(D) is fused with NaOH.

43. Which one of the following reactions does not occur during extraction of copper?

[JEE-MAINS-2023]

- (A) $2\text{Cu}_2\text{S} + 3\text{O}_2 \rightarrow 2\text{Cu}_2\text{O} + 2\text{SO}_2$
(B) $2\text{FeS} + 3\text{O}_2 \rightarrow 2\text{FeO} + 2\text{SO}_2$
(C) $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$
(D) $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeSiO}_3$

44. The reaction representing the Mond process for metal refining is

[JEE-MAINS-2023]

- (A) $\text{Ni} + 4\text{CO} \xrightarrow{\Delta} \text{Ni}(\text{CO})_4$
(B) $2\text{K}[\text{Au}(\text{CN})_2] + \text{Zn} \xrightarrow{\Delta} \text{K}_2[\text{Zn}(\text{CN})_4] + 2\text{Au}$
(C) $\text{Zr} + 2\text{I}_2 \xrightarrow{\Delta} \text{ZrI}_4$
(D) $\text{ZnO} + \text{C} \xrightarrow{\Delta} \text{Zn} + \text{CO}$

45. The methods not involved in concentration of ore are

[JEE-MAINS-2023]

- (a) Liqumtion (b) Leaching (c) Electrolysis
(d) Hydraulic washing (e) Froth floatation

Choose the correct answer from the options given below :

- (A) b, d and c only (B) c, d and e only
(C) a and c only (D) b, d and e only

46. Which one of the following statements is incorrect?

[JEE-MAINS-2023]

- (A) Boron and Indium can be purified by zone refining method.
(B) Van- Arkel method is used to purify tungsten.
(C) Cast iron is obtained by melting pig iron with scrap iron and coke using hot air blast.
(D) The malleable iron is prepared from cast iron by oxidising impurities in a reverberatory furnace.

47. Among following compounds, the number of those present in copper matte is

[JEE-MAINS-2023]

- (A) CuCO_3 (B) Cu_2S (C) Cu_2O (D) FeO

EXERCISE - VI (JEE-ADVANCED)

1. Carnallite does not contain
(A) K (B) Ca (C) Mg (D) Cl
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
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
4. In the commercial electrochemical process for aluminium extraction, the electrolyte used as :
[JEE-1999]
(A) $\text{Al}(\text{OH})_3$ in NaOH solution
(B) an aqueous solution of $\text{Al}_2(\text{SO}_4)_3$
(C) a molten mixture of Al_2O_3 and Na_3AlF_6
(D) a molten mixture of $\text{AlO}(\text{OH})$ and $\text{Al}(\text{OH})_3$
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
6. Electrolytic reduction of alumina to aluminium by Hall-Heroult process is carried out:
[2000 Qualifying]
(A) in the presence of NaCl
(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
7. The chemical composition of "slag" formed during the smelting process in the extraction of copper is :
[2001 Qualifying]
(A) $\text{Cu}_2\text{O} + \text{FeS}$ (B) FeSiO_3 (C) CuFeS_2 (D) $\text{Cu}_2\text{S} + \text{FeO}$

(Inorganic Chemistry)

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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
9. In the process of extraction of gold, Roasted gold ore $+ \text{CN}^- + \text{H}_2\text{O} \xrightarrow{\text{O}_2} [\text{X}] + \text{OH}^-$
 $[\text{X}] + \text{Zn} \rightarrow [\text{Y}] + \text{Au}$ Identify the complexes [X] and [Y]: [2003 Qualifying]
- (A) $\text{X} = [\text{Au}(\text{CN})_2]$, $\text{Y} = [\text{Zn}(\text{CN})_4]^{2-}$ (B) $\text{X} = [\text{Au}(\text{CN})_4]^{3-}$, $\text{Y} = [\text{Zn}(\text{CN})_4]^{2-}$
 (C) $\text{X} = [\text{Au}(\text{CN})_2]$, $\text{Y} = [\text{Zn}(\text{CN})_6]^{4-}$ (D) $\text{X} = [\text{Au}(\text{CN})_4]^-$, $\text{Y} = [\text{Zn}(\text{CN})_4]^{2-}$
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
11. Which ore contains both iron and copper? [JEE-2004]
- (A) Cuprite (B) Chalcocite (C) Chalcopyrite (D) Malachite
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
13. Native silver metal forms a water soluble complex with a dilute aqueous solution of NaCN in the presence of :- [JEE-2008]
- (A) nitrogen (B) oxygen (C) carbon dioxide (D) argon

Paragraph for questions 14 to 16

Copper is the most noble of the first row transition metals and occurs in small deposits in several countries. Ores of copper include chalcantite ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), atacamite ($\text{Cu}_2\text{Cl}(\text{OH})_3$), cuprite (Cu_2O), copper glance (Cu_2S) and malachite ($\text{Cu}_2(\text{OH})_2\text{CO}_3$). 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

(Inorganic Chemistry)

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15. Iron is removed from chalcopyrite as :-

- (A) FeO (B) FeS (C) Fe₂O₃ (D) FeSiO₃

16. In self-reduction, the reducing species is :-

- (A) S (B) O²⁻ (C) S²⁻ (D) SO₂

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

Column I

- (A) Self reduction
(B) Carbon reduction
(C) Complex formation and displacement by metal
(D) Decomposition of iodide

Column II

- (P) Lead
(Q) Silver
(R) Copper
(S) Boron

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.

[JEE-2008]

Column I

- (A) PbS → PbO
(B) CaCO₃ → CaO
(C) ZnS → Zn
(D) Cu₂S → Cu

Column II

- (P) Roasting
(Q) Calcination
(R) Carbon reduction
(S) Self reduction

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]

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

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

22. In the cyanide extraction process of silver from argentite ore, the oxidizing and reducing agents used are :

[JEE-2012]

- (A) O₂ and CO respectively.
(B) O₂ and Zn dust respectively.

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METALLURGY

- (C) HNO_3 and Zn dust respectively.
 (D) HNO_3 and CO respectively.
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
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 $\text{MgCO}_3 \cdot \text{CaCO}_3$
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
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 aqueous CuSO_4 is used as electrolyte
 (C) Pure Cu deposits at cathode
 (D) Impurities settle as anode-mud
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 |
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
29. Calamine, malachite, magnetite and cryolite, respectively, are [JEE Adv. 2019]
 (A) ZnCO_3 , CuCO_3 , Fe_2O_3 , Na_3AlF_6 (B) ZnCO_3 , $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$, Fe_3O_4 , Na_3AlF_6
 (C) ZnSO_4 , CuCO_3 , Fe_2O_3 , AlF_3 (D) ZnSO_4 , $\text{Cu}(\text{OH})_2$, Fe_3O_4 , Na_3AlF_6

30. 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]
- (A) Z is $[\text{Zn}(\text{CN})_4]^{2-}$ (B) R is $[\text{Au}(\text{CN})_4]^-$
(C) T is Zn (D) Q is O_2
31. Which among the following statement(s) is(are) true for the extraction of aluminium from bauxite? [JEE Adv. 2020]
- (A) Hydrated Al_2O_3 precipitates, when CO_2 is bubbled through a solution of sodium aluminate.
(B) Addition of Na_3AlF_6 lowers the melting point of alumina.
(C) CO_2 is evolved at the anode during electrolysis.
(D) The cathode is a steel vessel with a lining of carbon.
32. The electrochemical extraction of aluminium from bauxite ore involves [JEE Adv. 2022]
- (A) the reaction of Al_2O_3 with coke (C) at a temperature $> 2500^\circ\text{C}$.
(B) the neutralization of aluminate solution by passing CO_2 gas to precipitate hydrated alumina ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$).
(C) the dissolution of Al_2O_3 in hot aqueous NaOH.
(D) the electrolysis of Al_2O_3 mixed with Na_3AlF_6 to give Al and CO_2 .
33. The correct option(s) related to the extraction of iron from its ore in the blast furnace operating in the temperature range $900 - 1500\text{ K}$ is(are) [JEE Adv. 2022]
- (A) Limestone is used to remove silicate impurity.
(B) Pig iron obtained from blast furnace contains about 4% carbon.
(C) Coke (c) converts CO_2 to CO.
(D) Exhaust gases consist of NO_2 and CO.
34. The correct statement(s) related to processes involved in the extraction of metals is(are) [JEE Adv. 2023]
- (A) Roasting of Malachite produces Cuprite
(B) Calcination of Calamine produces Zincite
(C) Copper pyrites is heated with silica in a reverberatory furnace to remove iron
(D) Impure silver is treated with aqueous KCN in the presence of oxygen followed by reduction with zinc metal

ANSWER KEY

Do yourself - 1

- | | | | | | | |
|--------|--------|---------|--------|--------|--------|--------|
| 1. (C) | 2. (A) | 3. (D) | 4. (A) | 5. (D) | 6. (D) | 7. (C) |
| 8. (A) | 9. (A) | 10. (C) | | | | |

Do yourself - 2

- | | | | | | | |
|--------|--------|---------|--------|--------|--------|--------|
| 1. (B) | 2. (D) | 3. (D) | 4. (D) | 5. (C) | 6. (A) | 7. (B) |
| 8. (D) | 9. (C) | 10. (D) | | | | |

Do yourself - 3

- | | | | | | | |
|--------|--------|---------|--------|--------|--------|--------|
| 1. (D) | 2. (C) | 3. (C) | 4. (A) | 5. (D) | 6. (C) | 7. (C) |
| 8. (D) | 9. (C) | 10. (A) | | | | |

EXERCISE - 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 - II

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

EXERCISE - III

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

EXERCISE - IV

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) \rightarrow R; (B) \rightarrow P; (C) \rightarrow Q
9. (A) \rightarrow S; (B) \rightarrow P; (C) \rightarrow Q; (D) \rightarrow R
10. (A) \rightarrow S; (B) \rightarrow Q; (C) \rightarrow R; (D) \rightarrow P
11. (A)

EXERCISE - V (JEE-MAINS)

1. (C) 2. (A) 3. (A) 4. (C) 5. (A) 6. (B) 7. (D)
8. (D) 9. (C) 10. (D) 11. (D) 12. (B) 13. (A) 14. (D)
15. (B) 16. (B) 17. (D) 18. (C) 19. (D) 20. (C) 21. (C)
22. (A) 23. (A) 24. (D) 25. (C) 26. (A) 27. (D) 28. (A)
29. (C) 30. (C) 31. (6) 32. (D) 33. (A) 34. (A) 35. (B)
36. (A) 37. (3) 38. (C) 39. (D) 40. (B) 41. (A) 42. (C)
43. (C) 44. (A) 45. (C) 46. (B) 47. (C)

EXERCISE - VI (ADVANCED)

1. (B) 2. (B) 3. (AC) 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, 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. (ABC) 29. (B) 30. (ACD) 31. (A, B, C, D) 32. (B, C, D)
33. (A, B, C) 34. (B, C, D)

SOLUTION

EXERCISE - I

1. Magnetite = Fe_2O_3 is an ore of iron
2. Stellite is an alloy of Co&Cr
3. Carnallite: $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$
4. Argentite = Ag_2S is an sulphide ore
5. Siderite: FeCO_3 , Magnetite Fe_2O_3
Pyrolusite: MnO_2 , Fools gold: FeS_2
9. Smelting occurs during carbon reduction
10. Saperation/Cocentration of bausite is done via leaching
13. In cyanide process during extraction of Ag. Zn is used as an reducing agent

$$[\text{Ag}(\text{CN})_2]^- + \text{Zn} \rightarrow [\text{Zn}(\text{CN})_4]^{-2} + \text{Ag} \downarrow$$
14. In froth floatation process impurity gets wet by water & ore(suphide) gets wet by oil.
15. FeCr_2O_4 is magnetic in nature
20. Wolframite is magnetic in Nature.
21. Calcination - Heating of ore below its melting point in absence of air.
22. Roasting is carried out for sulphite ores below its melting point in presence of excess of air.
24. In aluminothermite reduction Al is used as reducing agent. Al has lower M.P. than Fe, Cr & mn.
27. Cinnabar (sulphide ore) is reduced by self reduction method.
29. Electrolysis of aqueous solutions of alkali metal chloride yields H_2 gas in place of alkali metal.
30. MgCl_2 (aq.) releases MgO which become difficult to be reduced.
31. Bessemerisation is carried out for Fe&Cu.
32. Mond's process :

$$\text{Ni} + \text{CO} \xrightarrow{50^\circ\text{C}} \text{Ni}(\text{CO})_4 \xrightarrow{230^\circ\text{C}} \text{Ni} + \text{CO}$$
34. Zoen refining is based on principle of fractional crystallization is used for Si & Ge, B, Ga etc.
39. Van Arkel method :

$$\text{Ti} + \text{I}_2 \xrightarrow{\Delta} \text{TiI}_4 \xrightarrow{1673\text{ K}} \text{Ti} \downarrow + \text{I}_2$$
42. Mercury has very low B.P. hence distillation is used.
43. Cupellation is used when impurity in a metal has greater affinity for oxygen and is more easily oxides than the metal itself.
45. Ag can not be recovered by boiling $\text{Na}[\text{Ag}(\text{CN})_2]$ solution.
48. Al is not reduced by thermite reduction.
50. In extraction of copper SiO_2 is added to remove Fe_2O_3 by forming slag. FeSiO_3 .

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53. Polling is used to refine copper. Green wood logs are used to reduce impurity of Cu_2O is reduced to Copper by hydrocarbons present in green wood logs.
59. Self reduction of Copper :
- $$\text{Cu}_2\text{S} + \text{O}_2 \rightarrow \text{Cu}_2\text{O}$$
- $$\text{Cu}_2\text{S} + \text{O}_2 \rightarrow \text{CuSO}_4$$
- $$\text{Cu}_2\text{S} + \text{Cu}_2\text{O} \rightarrow \text{Cu} + \text{SO}_2$$
- $$\text{Cu}_2\text{S} + \text{CuSO}_4 \rightarrow \text{Cu} + \text{SO}_2$$

EXERCISE - II

- Argentite - Ag_2S
Galena - PbS_3
Anglisite - PbSO_4
Copper glance - Cu_2S
- Haematite - Fe_2O_3
Magnetite - Fe_3O_4
Limonite - $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$
Copper pyrites - CuFeS_2
- Froth floatation is carried out for sulphide ores.
- Calcination used for carbonate & hydroxide ores.
- Generally carbon reduction is user for oxide ore like. Fe_2O_3 & SnO_2 & ZnO
- Thermite reductions is used for chromium :
$$\text{Cr}_2\text{O}_3 + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 2\text{Cr}$$

Mac arther forest cyanide process is used for extraction of au & Ag.
$$2\text{Na}[\text{Au}(\text{CN})_2] + \text{Zn} \rightarrow \text{Na}_2[\text{Zn}(\text{CN})_4] + 2\text{Au}$$
- In electrolysis method (Down's process) CaCl_2 is added to improve conductivity.
- Poling is used for refining when metal has impurity of its own oxide.
- Hg do not form alloy with Fe, Pt & Tc.
- Re bauxite is purified by Baeyer's process & white bauxite is purified by Hall's process & serpeck's process.
- Red bauxite contains impurity of Fe_2O_3 & SiO_2 .
- Baeyer's Process:
$$\text{Al}_2\text{O}_3 + \text{NaOH} \rightarrow \text{NaAlO}_2$$

$$\text{Fe}_2\text{O}_3 + \text{NaOH} \rightarrow$$

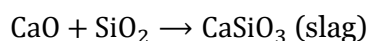
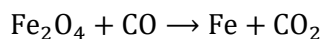
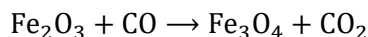
Hall's Process:
$$\text{Al}_2\text{O}_3 + \text{Na}_2\text{CO}_3 \rightarrow \text{NaAlO}_2$$

$$\text{SiO}_2 + \text{Na}_2\text{CO}_3 \rightarrow$$

(Inorganic Chemistry)

METALLURGY

24. Reduction of Iron by carbon reduction method:



27. $\text{CaF}_2 + \text{Na}_3\text{AlF}_6$ are added during electrolytic reduction of Aluminium to lower to M.P. & to increase the conductivity.

EXERCISE - III

2. Carbon reduction is used for Zn, Sn, Fe & Pb (low grade ore).
3. Correct matches are :
 - (i) Van arkel method - Zirconium
 - (ii) Distillation method - Zn
 - (iii) Poling - Cu
 - (iv) amalgamation - Au
4. Elingham diagram for Pb, Cu, C and CO are given incorrect.
5. Magnetite - Fe_2O_3
 Carnallite - $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$
 Epsom salt - $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
 Siderite - FeCO_3
9. Horn silver - AgCl
 Argentite - Ag_2S

EXERCISE - IV

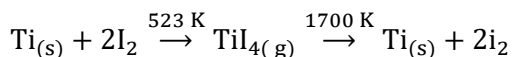
1. Negative value of ΔG is increasing is $\text{Pb} \rightarrow \text{PbO}$ which is not possible.
2. $\text{Zr} \rightarrow \text{ZrO}_2$ line is touching $\Delta G = 0$ line at the lowest temperature among all the given curves.
3. ZrO_2 can be reduced by Fe.
7. (i) Calcination is used for carbonates & hydroxides.
 (ii) Froth floatation is used for sulphide ores.
 (iii) Poling is used for Cu & Sn.
8. Down's cell - extraction of Na
 Dow's sea water process - extraction Mg
 Hall heroult process - extraction of Al

EXERCISE - V (JEE-MAINS)

1. Molten cryolite + CaF_2 is added in electrolysis while extracting the Al from Al_2O_3
2. Pyrolusite - MnO_2
5. Van Arkel method :

(Inorganic Chemistry)

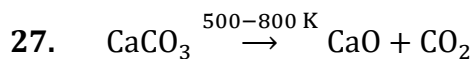
METALLURGY



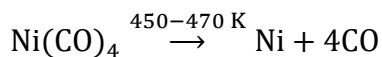
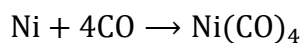
7. Electrolytic reduction is used for s-block metals.
10. In extraction of s-block metals molten solution of metal ore should be taken. If aqueous solution is taken in Electrolysis of metal ore then H_2 gas is obtained.
13. Galvanization (coating of Zn) is used to prevent metal (generally Fe) from rusting.
16. Self reduction is used for extraction of Cu from Cu_2S .
17. $\text{Al}_{(m)} + \text{NaOH} \rightarrow \text{NaAlO}_2$
(white gelatinous ppt.)
- $$\text{NaAlO}_2 \xrightarrow{\Delta} \text{Al}_2\text{O}_3$$
- $\text{NaAlO}_2(\text{X})$ is soluble in excess of NaOH .
18. Baeyer's Process :
- $$\text{Al}_2\text{O}_3 + \text{conc. NaOH} \rightarrow \text{Na} \left[\begin{matrix} \text{Al}(\text{OH})_4 \\ (\text{x}) \end{matrix} \right]$$
- $$\text{Na}[\text{Al}(\text{OH})_4]_{(\text{aq.})} \xrightarrow{\text{CO}_2} \text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O} + \text{Na}_2\text{CO}_3$$
- (y)
19. dolomite :- $\text{CaCO}_3 \cdot \text{MgCO}_3$
Azurite :- $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$
Malachite :- $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$
Copper Pyrite :- CuFeS_2
20. $\text{Al} \rightarrow \text{Al}_2\text{O}_3$ have higher ΔG negative value than $\text{Zn} \rightarrow \text{ZnO}$ at 1400°C , hence Al can reduce ZnO at 1400°C
21. Hall-Heroult's process is used to reduce Al_2O_3 in the metallurgy of Al.
It is given by reaction $-2\text{Al}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Al} + 3\text{CO}_2$
22. Siderite :- FeCO_3
Kaolinite :- $[\text{Al}_2(\text{OH})_4\text{Si}_2\text{O}_5]$
Malachite :- $\text{CuCO}_3\text{Cu}(\text{OH})_2$
Calamine :- ZnCO_3
23. Calcination is the process in which ore is heated in the absence of air below the fusion temperature.
"It is mainly used for hydrated oxide, carbonates and hydroxide"
24. Cathode is made up from carbon in the Hall-Heroult process.
25. \rightarrow Calcination is thermal treatment process in the absence or limited supply of air oxygen to res.
 \rightarrow Calcination is required for the carbonate ore, hydroxide ore & hydrated ore.
 \rightarrow ZnO and MgO do not required Calcination.
26. Purest form is wrought iron.

(Inorganic Chemistry)

METALLURGY



In extraction of silver, silver is extracted as an anionic complex $[\text{Ag}(\text{CN})_2]^-$ Ni is purified by Mond's process



Zr and Ti are purified by Van Arkel method.

28. An Ellingham diagram provides information about, the temperature dependence of the standard gibbs energies of formation of some metal oxides.

29. zinc is refined by distillation

30. Theory Based

31. Anode mud contains Sb, Se, Te, Ag, Au and Pt

32. (A) Aluminium is reactive metal so Aluminium is extracted by electrolysis of Alumina with molten mixture of Cryolite.

(B) Cryolite, Na_3AlF_6

Here Al is in +3 O.S.

So Answer is 4.

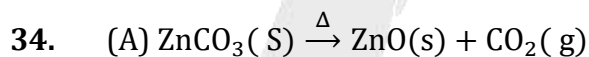
33. (Name of ore/mineral)

(a) Calamine ZnCO_3

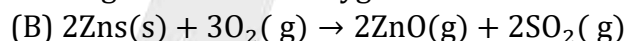
(c) Siderite FeCO_3

(b) Malachite $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$

(d) Sphalerite ZnS



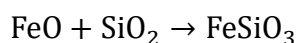
Heating in absence of oxygen in calcination.



heating in presence of oxygen in roasting

Hence (A) is calcination while (B) in roasting.

35. Silica is used to remove FeO impurity from the ore of copper



36. Reduction of $\text{Al}_2\text{O}_3 \rightarrow \text{Al}$ is carried out by electrolytic reduction of its fused salts.

ZnO , Fe_2O_3 & Cu_2O can be reduce by carbon.

37. (1) Baryte : BaSO_4

(2) Galena : PbS

(3) Zinc blende : ZnS math

(4) Copper pyrite : CuFeS_2

sulphide (S^{2-})
ores

(Inorganic Chemistry)

METALLURGY

38. $\text{Au} + \text{NaCN} \rightarrow \text{Na}[\text{Au}(\text{CN})_2]$
 $\text{Zn} + \text{Na}[\text{Au}(\text{CN})_2] \rightarrow \text{Na}_2[\text{Zn}(\text{CN})_4] + \text{Au}$
39. For ZnS, KCN is used as depressant.
 For Gold and silver \Rightarrow leaching [Cyanide process]
40. Statement –I is incorrect because cast iron is obtained by heating pig iron with scrap iron
 Statement-II is also incorrect because pig iron has more carbon content ($\sim 4\%$) than cast iron ($\sim 3\%$)
41. Calcination and leaching are the methods of concentration of ore and not that of refining.
42. Liquation process is used for metal having low melting point such as tin in which they are heated and brought to molten state and made to flow down the slope while impurities with higher melting point left on the top.
43. $\text{CuFeS}_2 + \text{O}_2 \xrightarrow{\text{Partial roasting}}$
 $\text{Cu}_2\text{S} + \text{FeO} + \text{SO}_2 + \underset{\text{very small}}{\text{FeS}} + \underset{\text{very small}}{\text{Cu}_2\text{O}}$
 $\text{Cu}_2\text{S} + \text{O}_2 \rightarrow \text{Cu}_2\text{O} + \text{SO}_2$
 $\text{FeS} + \text{O}_2 \rightarrow \text{FeO} + \text{SO}_2$
 $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeSiO}_3$
 No formation of calcium silicate (CaSiO_3) in extraction of Cu.
45. Methods involved in concentration of ore are
 (i) Hydraulic Washing (ii) Froth Flotation (iii) Magnetic Separation
46. Van - Arkel process is used for purification of Ti, Zr, Hf and B.
47. FeS and Cu_2S , present in copper matte

EXERCISE – VI (ADVANCED)

6. In hall Heroult process Al_2O_3 is reduced to Al in the presence of $\text{Na}[\text{AlF}_6]$ (cryolite) which forms a melt with lower melting temperature.
9. $\text{Roasted gold ore} + \text{CN}^- + \text{H}_2\text{O} \rightarrow [\text{Au}(\text{CN})_2]^- + \text{OH}^-$
 (x)
 $[\text{Au}(\text{CN})_2]^- + \text{Zn} \rightarrow [\text{Zn}(\text{CN})_4]^{2-} + \text{Au} \downarrow$
 (y)

(Inorganic Chemistry)

METALLURGY

11. Chalcopyrite – CuFeS_2
14. $\text{CuFeS}_2 + \text{O}_2 \xrightarrow{\Delta} \text{Cu}_2\text{S} + \text{FeO} + \text{SO}_2$
15. $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeSiO}_3$
(slag)
16. S^{-2} acts as reducing agent in self reduction method.
20. $\text{SnO}_2 + \text{C} \rightarrow \text{SnO} + \text{CO}$
 $\text{SnO} + \text{CO} \rightarrow \text{Sn} + \text{CO}_2$
 CuSO_4 & FeSO_4 impurities are removed by dissolving in water.
23. Ag, Cu & Pb have greater affinity for sulphur
24. Al & Mg are extracted via electrolytic reduction.
25. (i) $\text{Cu}_2\text{S} + \text{CuO} \rightarrow \text{Cu} + \text{SO}_2$
(ii) $\text{Cu}_2\text{S} + \text{Cu}_2\text{O} \rightarrow \text{Cu} + \text{SO}_2$
(iii) $\text{Cu}_2\text{S} + \text{CuSO}_4 \rightarrow \text{Cu} + \text{SO}_2$
27. Siderite - FeCO_3
Malachite - $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$
Bauxite - $\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$
Argentite - Ag_2S
29. (B)
Calamine:- ZnCO_3 Malachite:- $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$
Magnetite:- Fe_3O_4 Cryolite:- Na_3AlF_6
30. (ACD)
Mac - Arthur forest cyanide process for gold (Au) :
 $4\text{Au} + 8\text{NaCN} + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{Na}[\text{Au}(\text{CN})_2] + 4\text{NaOH}$
(Q) (R)
 $2\text{Na}[\text{Au}(\text{CN})_2] + \text{Zn} \rightarrow \text{Na}_2[\text{Zn}(\text{CN})_4] + 2\text{Au} \downarrow$
(R) (T) (Z)
31. Refer topic metallurgy
a) Extraction of aluminium (Hall's process and Hall Heroult's electrolytic cell):
The process involved in extraction of aluminium is Hall Heroult's process.
During process, Al_2O_3 is obtained as precipitate.
When CO_3 is bubbled through a solution of sodium aluminate.
The reaction is given as:
 $2\text{Na}[\text{Al}(\text{OH})_4] (\text{aq.}) + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + 2\text{Al}(\text{OH})_3 (\text{ppt})$ or $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O} (\text{ppt})$
Refer topic metallurgy
b) Electrolytic reduction of pure alumina takes place in steel box with lining of carbon

(cathode) with cryolite (Na_3AlF_6) and fluorspar (CaF_2) which lowers the melting point and increases the conductivity of electrolyte.

Refer topic metallurgy

c) Electrolysis process in Hall's process:

Graphite rods acts as anode:

At cathode: $\text{Al}^{+3} + 3\text{e}^- \rightarrow \text{Al}$

At anode: The oxygen liberated at anode reacts with the carbon of anode to produce CO and CO_2 .

$\text{C} + \text{O}^{2-} \rightarrow \text{CO} + 2\text{e}^-$

$\text{C} + 2\text{O}^{2-} \rightarrow \text{CO}_2 + 4\text{e}^-$

Refer topic metallurgy

d) Here the cathode is a steel vessel with a lining of carbon.

32. (A) The reduction of Al_2O_3 with coke (C) at a temperature $> 2500^\circ\text{C}$ is not carried out due to the formation of carbides.
 (B) It is correct as neutralisation of aluminate solution is done by passing CO_2 gas to precipitate hydrated alumina.
 (C) Reaction of powdered one is carried out with hot concentrated NaOH at 473 K – 523 K and 35 – 36 bar pressure.
 (D) Electrolysis of Al_2O_3 is done mixed with Na_3AlF_6 to produce Al and CO_2 . It is a correct statement.

33. (A) Limestone is added to remove silica as impurity.
 (B) Pig iron obtained from blast furnace contains 4% carbon and many other impurities (eg. S, P, Si, Mn) in small amount.
 (C) Coke (c) converts CO_2 in CO.

$\text{C} + \text{CO}_2 \rightarrow 2\text{CO}$

(D) Exhaust gases consist of CO and CO_2 .
 Hence, (A, B, C) are correct.

34. $\text{Cu}(\text{OH})_2 \cdot \text{CuCO}_3 \rightarrow \text{CuO} + \text{H}_2\text{O} + \text{CO}_2$
 $\text{ZnCO}_3 \xrightarrow{\Delta} \text{ZnO} + \text{CO}_2$
 Calamine Zincite
 $\text{CuFeS}_2 + \text{O}_2 \rightarrow \text{Cu}_2\text{S} + \text{FeS} + \text{SO}_2$
 $\text{FeS} + \text{O}_2 \rightarrow \text{FeO} + \text{SO}_2$
 $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeSiO}_3$
 Slag
 $4\text{Ag} + 8\text{CN}^- + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4[\text{Ag}(\text{CN})_2]^- + 4\text{OH}^-$
 $2[\text{Ag}(\text{CN})_2]^- + \text{Zn(s)} \rightarrow [\text{Zn}(\text{CN})_4]^{2-} + 2\text{Ag}$