Chapter -13
Principles of Metallurgy

SYNOPSIS

Metallurgy is the process of extraction of metals from their ores. There are three stages in the extraction of metals from the ores. They are 1) Concentration or dressing 2) Extraction of crude metal 3) Refining or purification of the metal.

Corrosion is an electrochemical reaction and prevention of corrosion is of prime importance. It not only saves money but also helps in preventing accidents.

The important processes used in metallurgy are 1) Smelting, 2) Roasting, 3) Calcinations.

2 Mark Questions

1. List 3 metals that are found in nature as Oxide ores. (AS1)

A. Aluminum, manganese, ferrous (Iron) and zinc are the metals which are found in nature as Oxide ores.

Aluminum — $Al_2O_3.2H_2O$ [Bauxite]

Manganese — pyrolusite [MnO_2]

Ferrous — Haematite [Fe_2O_3]

Magnetite [Fe_3O_4]

Zinc — Zincite[Zno]

2. List three metals that are found in nature in uncombined form. (AS1)

A. Gold (Au), Silver (Ag) and Copper (Cu) are some metals that are found in the nature in uncombined form because they are least reactive.

3. Write a note on dressing of ore in metallurgy? (AS1)

A. Concentration or dressing of the ore:

Concentration or dressing means, simply getting rid of as much of the unwanted rocky materials as possible before the ore is converted into the metal. The impurities are known as "gangue".

Physical methods like hand picking, washing, froth floatation and magnetic separation are used to enrich the ore depending on the physical properties of ore and gangue.

4. What is an Ore? On what basis a mineral is chosen as an ore? (AS1)

A. Ore: The mineral from which the metals are extracted without economical loss are called ores.

A mineral is chosen as an ore based on the following conditions.

1) Availability of metal in a high percentage.
2) Economically profitable while extracting the metal from mineral.

5. When do we use magnetic separation method for concentration of an ore? Explain with an example.

A. Magnetic Separation Method: In the ore and gangue, if one of them is magnetic and the other is non-magnetic. Then they are separated by magnetic separation method.

Eg: The magnetic ores like Iron pyrites (Fe_3) and magnetic (Fe_3O_4) are concentrated by this method. The crushed ore is allowed to pass through electromagnetic belts, then the mineral particles are retained and gangue particles are thrown away.

6. What is the difference between roasting and calcinations? Give one example for each.

A.

Roasting	Calcinations
1. The ore is heated in the presence of air.	1. The ore is heated in the absence of air.
2. It is used for sulphide ores	2. It is used for carbonate ores
Eg: $2znS+3O_2 \rightarrow 2ZnO+2SO_2$	Eg: $CaCO_3 \rightarrow CaO + CO_2$

7. Define the terms-
a) Gangue
b) Slag

A. a) Gangue:

In unwanted rocky materials (or) impurities in the ore are called as gangue.

b) Slag:

The impurities obtained during the poling process get oxidized to form scum (slag) over the surface of the molten metal.

8. Which method do you suggest for extraction of highly reactive metals? Why?

A. High reactivity metals like K, Ca, Mg, Ca etc, can be extracted by electrolysis.

Reason:

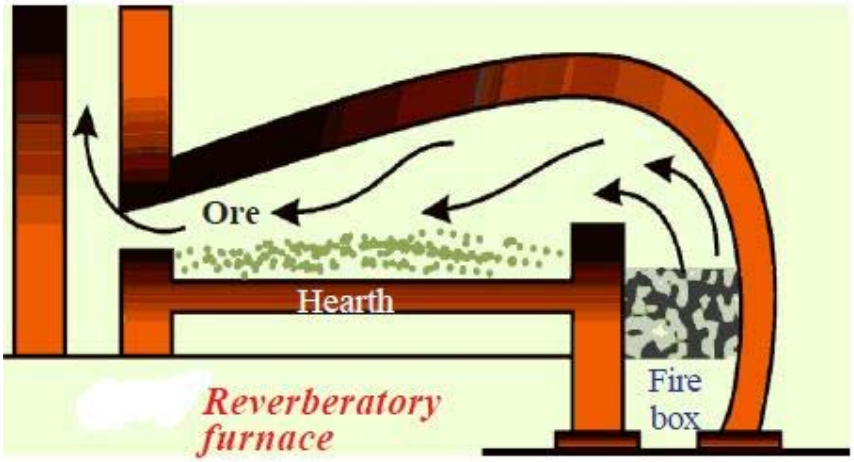
i. Simple reduction methods like heating with C, Co, etc. to reduce the ores of these metals are not feasible.

ii. The temperature required for the reduction is too high and more expensive.

iii. Hence electrolysis is the suggestible method to extract high reactive metals.

9. Draw a neat diagram of reverberatory furnace and label it neatly?

A.



1 Mark Questions

1. Write the names of any 2 ores of iron?

A. The two ores of Iron are Haematite (Fe_2O_3) and Magnetite (Fe_3O_4).

2. Magnesium is an active metal if it occurs as a chloride in nature, which method of reduction is suitable for its extraction?

A. Magnesium is an active metal. It occurs in chloride form as $Mgcl_2$. Hence electrolysis is suitable method for its reeducation.

3. Mention two methods which produce very pure metals?

A. Electrolysis and reduction are the two methods that produce pure metals.

4. In nature, Ag, Au, Cu available in free state. Justify the statement?

A. In nature, Ag, Au and Cu are available in free state due to their least reactive nature with their surroundings.

5. What are minerals?

A. The elements (or) compounds of the metals that occur in nature in earth crust are called as Minerals.

6. Define Ores?

A. The minerals from which metals are extracted profitably are known as ores.

7. VI group was known as chalcogens, Justify?

A. VI group was known as chalcogens, Since, most of the ores are in the form of oxides (or) sulphides and so on. These are called as chalcogens which means ore forming elements.

8. Define the process of refining of metal?

A. The process of obtaining of pure metal from the impure metal is known as refining of metal.

4 Mark Questions

1. How do metals occur in nature? Give examples to any two types of minerals. (AS1)

A. The earth's crust is the major source of metals. In that, some metals are available in nature in free state as they are least reactive.

Eg: Gold (Acl), silver (Ag) and copper (Au).

Most of the metals are found in nature in the combined form due to their move reactivity.

The compounds of the metals which occur in nature in the earth crust are called minerals.

The compounds of the metals which occur in nature in the earth crust are called minerals.

There are many types of minerals or ores. Some of them are-

Oxide minerals:

Bauxite ($Al_2O_3.2H_2O$)

Haematite (Fe_2O_3)

Zinncite (zno)

Sulphide Minerals:

Zinc Blende (zns)

Cinnabar (Hgs)

Galena (pbs)

Chloride Minerals:

Horn silver (AgCl)

Rock salt (NaCl)

Carbonate Minerals:

Magnesite ($MgCo_3$)

Limestone ($CaCo_3$)

2. Write a short note on froth floatation process?

A. Froth floatation process:

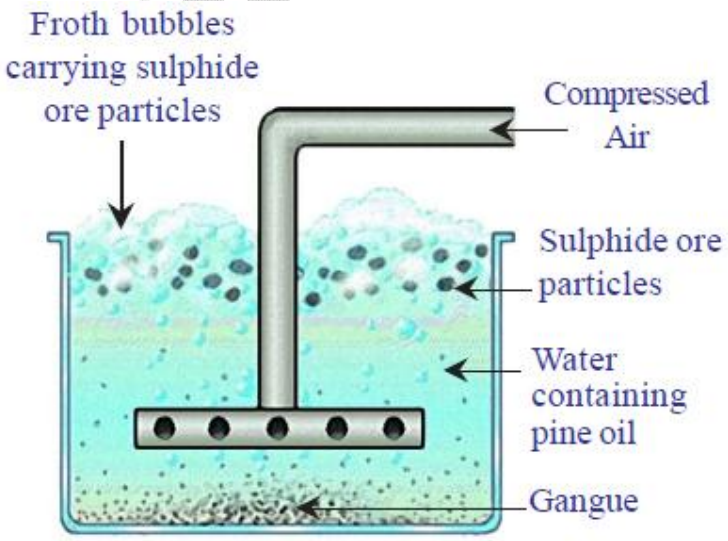
i. This method is mainly useful for sulphide ores which have no wetting property where as the impurities get wetted.

ii. The ore with impurities is finely powdered and kept in water, containing pine oil taken in a floatation cell.

iii. Air under pressure is blown to produce froth in water.

iv. Froth so produced, takes the ore particles to the surface, whereas impurities settle at the bottom.

v. Forth is separated and washed to get ore particles.



Froth floatation process for the concentration of sulphide ores

3. Write a short note on each of the following.

a) Roasting

b) Calcination

c) Smelting

A. a) Roasting:

i. Roasting is a pyrochemical process in which the ore is heating in the presence of Oxygen (or) air below its melting point.

ii. The sulphide ores are converted to oxides by roasting.

iii. The products obtained in this process also are in solid state.

Eg: $2znS+3O_2 \rightarrow 2ZnO+2SO_2$

b) Calcination:

Calcination is a pyrochemical process in which the ore is heated in the absence of air.

i. The ore is generally decomposed in the process.

Eg:

$$\underset{(s)}{MgCo_3} \longrightarrow \underset{(s)}{MgO} + Co_{2g}$$

$$\underset{(s)}{CaCo_3} \longrightarrow \underset{(s)}{CaO} + Co_{2g}$$

c) Smelting:

i. Smelting is a pyrochemical process, in which the ore is mixed with flux and fuel, and then it is strongly heated.

ii. During smelting, the impurities (gangue) in the ore react with flux to form slag which is removed.

iii. For haematite ore, coke is used as fuel and lime stone is used as flux.

Eg:

$$Fe_2O_3 + 3CO \rightarrow 2\ Fe + 3Co_2$$

4. Suggest an experiment to prove that the presence of air and water are essential for corrosion. Explain the procedure.

A. Corrosion: corrosion is the deterioration of a metal, as a result of chemical reactions between it and its surrounding environment.

Experiment:

Aim: To prove that the presence of air and water are essential for corrosion

Materials required: 3 test tubes, 3 iron nails, oil, water, anhydrous calcium chloride, rubber corks.

Procedure:

i. Take 3 test tubes and place clean iron nails in each of them. Label the test tubes A, B and C.

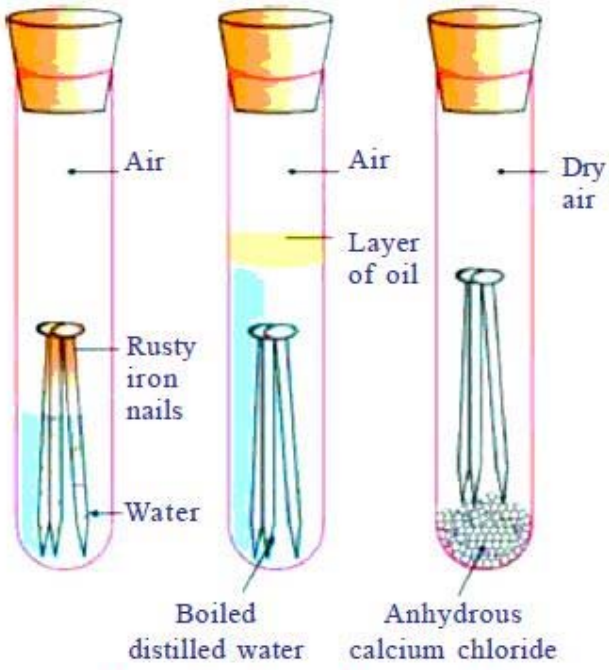
ii. Pour some water in test tube A and cork it.

iii. Pour boiled distilled water in test tube B, and about 1ml of oil and cork it.

iv. Put some anhydrous calcium chloride in test tube C and cork it.

v. Leave these test tubes for a few days and then observe.

vi. After a few days, we will observe that iron nails rust in test tube A, but they do not rust in test tubes B&C.



Investigating the conditions under which iron rusts

Reason:

i. In test tube A, the nails are exposed to air and water. Hence the nails rusted.

ii. In test tube B, the nails are exposed only to water, but not to air, because the oil float on water and prevent the air not rested.

iii. In test tube c, the nails are exposed to dry air, because anhydrous $CaCl_2$ will absorb the moisture, if any from the air. Hence the nails are not rusted.

From the above experiment, we can prove that air and water are essential for corrosion.

5. Collect information about extraction of metals of low reactivity silver, platinum and gold and prepare a report.

A.

i. Metals of low reactivity such as silver, mercury, platinum and gold are often found in free state

ii. Their reactivity with other atoms is very low.

iii. The Oxides of these metals can be reduced to metals by heat alone and sometimes by displacement from their aqueous solution.

Eg:

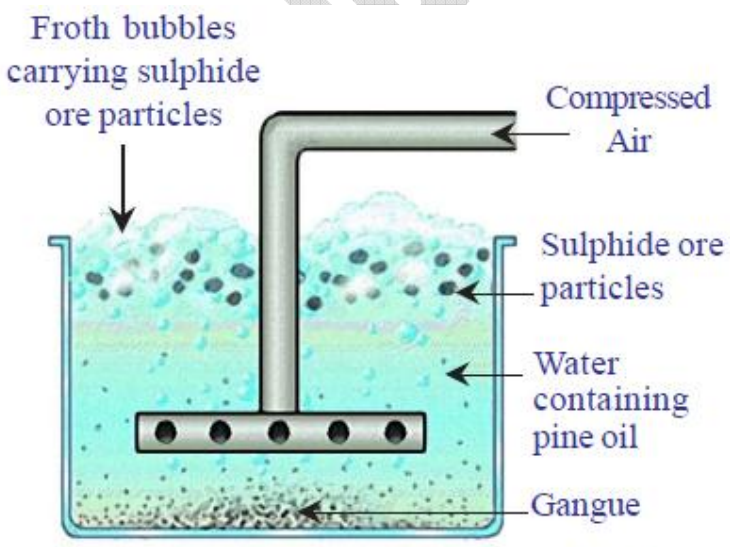
i. When cinnabar (Hgs) heated in air, first converted into Hgo, then get reduced to mercury on further heating.

$2Hgs + 3O_2 \rightarrow 2HgO + 2\ SO_2$

$Hgo \xrightarrow[\Delta]{} 2Hg + O_2$

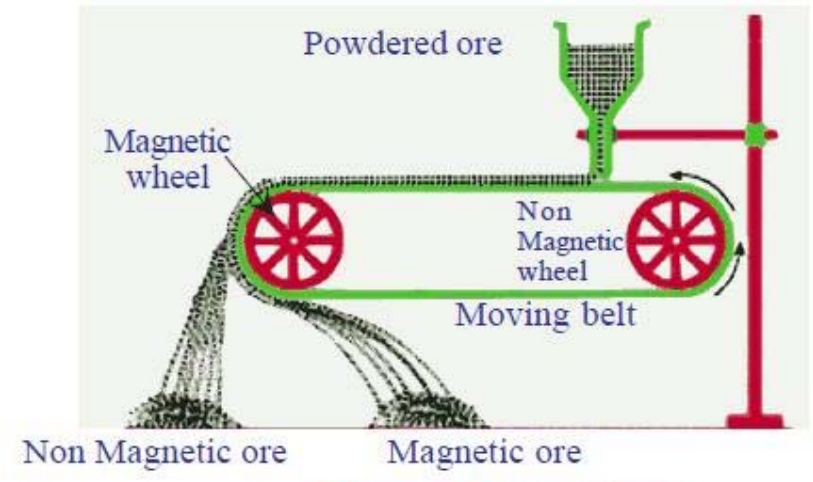
6. Draw the diagram showing.
i) Froth floatation
ii) Magnetic separation.

A. i) Froth floatation



Froth floatation process for the concentration of sulphide ores

ii) Magnetic separation.



Magnetic separation

7. What is activity series? How it helps in extraction of metals?

A. Activity series:

To understand the order of reactivity of metals that are very familiar, we study their chemical reactions with cold water, steam, diluted and strong acids and cl_2 and based on their rigorous activity order in these reactions, we frame out activity series.

Arrangement of the metals in decreasing order of their reactivity is known as activity series.

Use of Activity series in extraction of metals:

i. The method used for a particular metal for the reduction of its ore to the metal depends mainly on the position of the metal in the activity series.
Eg: 1) The metals at the top of the activity series (highly reactive) can be extracted by electrolysis.

ii. The metals at the middle of the activity series can be extracted by
1) Reduction of metal oxide with carbon
2) Reduction of oxide ores with co(Carbon monoxide)
3) Self reduction of sulphide ores
4) Reduction of ores with more reactive metals (thermite process)

iii. The metals at the bottom of the activity series (less reactive) can be extracted by heating alone, because they are often found in free state.

8. What is thermite process? Mention its applications in daily life.

A.

1) The thermite process involves the reaction of metal oxides with Aluminum.
2) When highly reactive metals such as sodium (Na), calcium (Ca) aluminum (Al) are used as reducing agents, they displace metals of lower reactivity from the compound.
3) These displacement reactions are highly exothermic. The amount of heat evolved is so large that metals produced would be in molten state.
   Ex:

$$TiCl_4 + 2Mg \xrightarrow{350^\circ c} Ti + 2MgCl_2$$

$$TiCl_4 + 4Na \xrightarrow{350^\circ c} Ti + 4NaCl$$

Applications of thermite processes:

1) The reaction of Iron Oxide (Fe_2O_3) with aluminum is used to join railings of railway tracks (or) cracked machine parts.
2) Joining of cracked metal utensils in the house.

9. Where do we use handpicking and washing methods in our daily life? Give examples. How do you correlate these examples with enrichment of ore?

A. Hand pickling:

Hand pickling can be used in cleaning rice, cereals, grading of vegetables and fruits etc, in our daily life.

In the ore, particles and the impurities are different in size, colour etc, using that property, the ore particles are handpicked separating them from other impurities.

Washing:

1) Washing can be used in our daily life to separate the impurities from cloth, rice, cereals etc.
2) Ore particles are crushed and kept on a soapy surface they are washed with controlled flow of water. Less densive impurities are carried away by water flow, leaving the more densive ore particles behind.

10. Collect information about extraction of metals of low reactivity silver, platinum and gold and prepare a report.

A.

1) Silver occurs in both combined state as well as in free state. The important ores of silver are Argentite (Ag_2S) copper, Silver glance, Horn silver, Ruby silver etc.
2) Silver is extracted from the ore-Argentite (Ag_2S)
3) The ore is crushed, concentrated and then treated with sodium cyanide solution.
4) The reaction forms sodium argento cyanide [$Na[Ag(CN)_2]$]

$Ag_2S + 4\ NacN \rightarrow 2\ Na\ [Ag(cN)_2] + 2\ Ag.$

5) This solution of sodium argento cyanide combined with zinc dust forms tetra ayano zincate and principle silver. This precipitated silver is called spongy silver.
$zn + 2\ Na\ [Ag(cN)_2] \rightarrow Na_2\ [zn(cN)_4] + 2\ Ag.$
6) The spongy silver is fused with potassium nitrate to obtain pure silver. Then the silver obtained is purified by electrolytic process.

Extraction of Platinum:

1) Platinum is rarely found on its own, but in combination with other base & precious metals.
2) The extraction process of platinum is quite complex, which includes milling the ore and smelting it at high temperatures. This removes base metals notably the concentrate PGM (platinum Group Metals) – gold, platinum & palladium.
3) The PGM matter is further processed by electrolysis to remove nickel, cobalt & copper.
4) The high grade concentrate is treated by solvent extraction distilling, ion-exchange treatments to separate the PGM's into its separate metals.

Extraction of Gold:

1) Gold is usually found alone or alloyed with mercury (or) silver
2) In all methods of gold ore refining, the ore is usually washed and filtered at the mine, then sent to the mill. At the mill, the ore is ground into smaller particles with water, then ground again in a ball mill to further pulverize the ore.
3) Several processes can be used to separate the gold from its ore, They are-

a) Cyanide process:

i) The ground ore is put in a tank containing a weak cyanide solution and then zinc is added.
ii) The zinc causes a chemical reaction which separates the gold from the ore.
iii) The gold is then removed from the solution with a filter press.

b) Carbon-in-pulp Method:

i. In this method, the ground ore is mixed with water before cyanide is added. Then carbon is added to bond with the gold.
ii. The carbon-gold particles are put into caustic carbon solution, separating out in the gold.

c) Heap leaching:

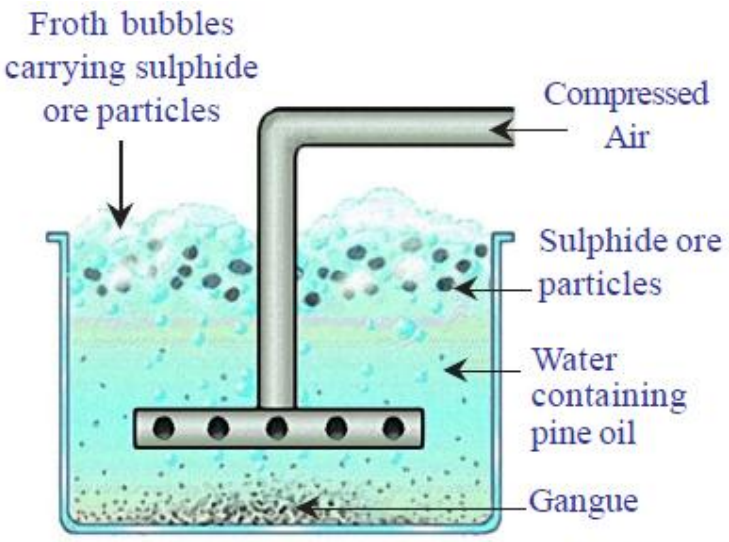
i. The ore is placed on open-air pads and cyanide is sprayed over them, taking several weeks to leach down to an imperious base.

ii. The solution then poured and pad into a pound and is pumped from there to a recovery plant, where the gold is recovered.

iii. Heap-leaching helps recover gold from ore that would be otherwise too expensive to process.

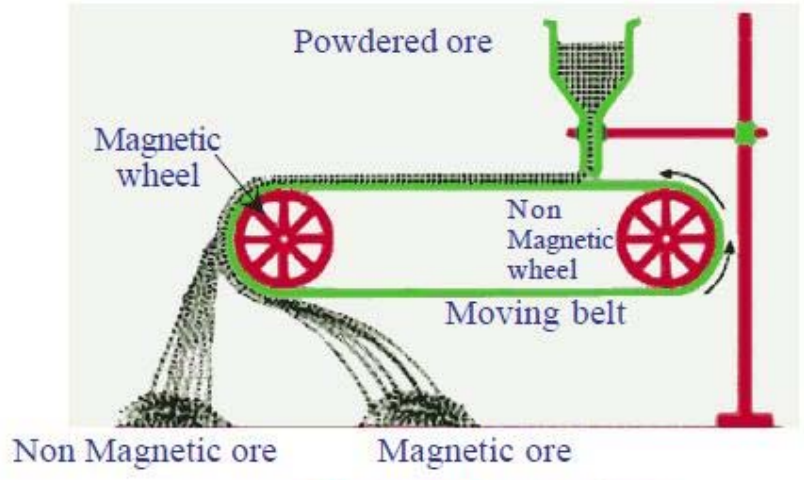
5 Mark Questions

1. Froth floatation:



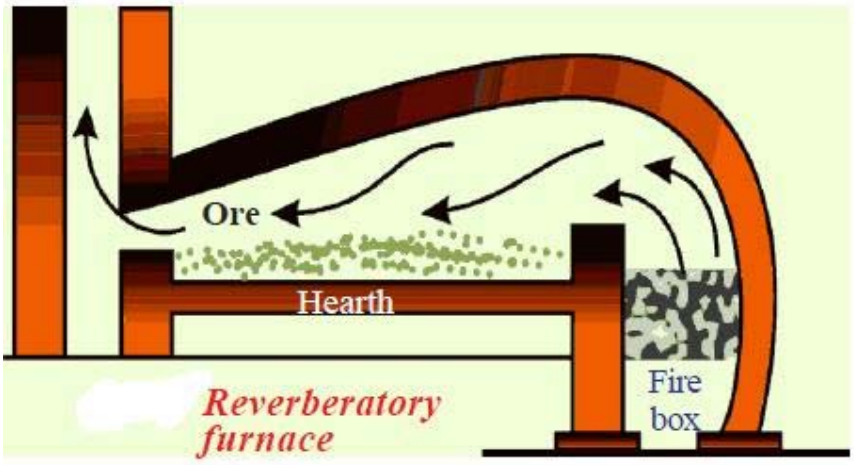
Froth floatation process for the concentration of sulphide ores

2. Magnetic separation:



Magnetic separation

3. Reverberatory furnace:



Multiple Choice Questions

1. The impurity present in the ore is called as _____ [ ]
   a) Gangue b) flux c) Slag d) Mineral

2. Which of the following is a carbonate ore? [ ]
   a) Magnesite b) Bauxite c) Gypsum d) Galena

3. Which of the following is the correct formula of Gypsum? [ ]
   a) $CuSO_4.\ 2H_2O$ b) $CaSO_4.\ ½\ H_2O$
   c) $CuSO_4.\ 5H_2O$ d) $CaSO_4.\ 2H_2O$

4. The oil used in the froth floatation process is _____. [ ]
   a) Kerosene oil b) Pine oil c) Coconut oil d) Olive oil.

5. Froth floatation is method used for the purification of _____ore. [ ]
   a) Sulphide b) Oxide c) Carbonate d) Nitrate

6. Galena is an ore of ————————. [ ]
   a) Zn b) Pb c) Hg d) Al

7. The metal that occurs in the native form is _____. [ ]
   a) Pb b) Au c) Fe d) Hg

8. The most abundant metal in the earth's crust is ————. [ ]

a) Silver b) Aluminum c) Zinc d) Iron

9. The reducing agent in thermite process is _____ [ ]
   a) Al b) Mg c) Fe d) Si
10. The purpose of smelting an ore is to _____ it. [ ]
   a) Oxidise b) Reduce c) Neutralize d) none of these

Key:

1.a; 2. a; 3. a; 4. b; 5. a; 6. b; 7. b; 8. b; 9. a; 10. b.

Fill in the Blanks

1. The method suitable to enrich the sulphide ores is_____
2. Arranging metals in the decreasing order of their reactivity is called _____.
3. The method suitable for purification of low boiling metals is _____.
4. Corrosion of iron occurs in the presence of _____ and _____.
5. The chemical process in which the ore is heated in the absence of air is called _____.
6. Mention the ores of zinc (zn) _____ Zns(Zinc blende)
   Manganese (Mn) _____ pyroluite(Mno_2)
   Silver (Ag) ____ Horn silver (Agcl).

Key:

1) Roasting; 2) Activity series; 3) distillation; 4) air, water;
5) calcinations; 6) zno (zincite);

Match the following

I.	Group – I		Group – II
i)	Bauxite	[ ]	a) Fe_2O_3
ii)	Magnetite	[ ]	b) Fe_3O_4
iii)	Haematite	[ ]	c) $MgSO_4.7H_2O$
iv)	Epsom salt	[ ]	d) $Al_2O_3.2H_2O$
v)	Magnetite	[ ]	e) $MgCO_3$

Key:

i) d; ii) e; iii) a; iv) c; v) b;

II.	Group - I		Group - II
i)	Handpicking	[ ]	a) Gangue
ii)	Washing	[ ]	b) Magnetic & non-magnetic substances are separated
iii)	Froth floatation	[ ]	c) Particles are handpicked
iv)	Magnetic separation	[ ]	d) Densive impurities are carried away by water flow
v)	The impurities	[ ]	e) used for sulphide ore

Key:

i) c; ii) d; iii) e; iv) b; v) a;

III.	Group – I		Group – II
i)	Horn silver	[ ]	a) Hgs
ii)	Rock salt	[ ]	b) $CaCo_3$
iii)	Cinnabar	[ ]	c) Agcl
iv)	Galena	[ ]	d) NaCl
v)	Lime stone	[ ]	e) Dbs

Key:

i) c; ii) d; iii) a; iv) e; v) b;

IV.	**Group – I**		**Group – II**
i)	Copper iron pyrites	[ ]	a) $CaSO_4.2H_2O$
ii)	Zinc blende	[ ]	b) Mno_2
iii)	Pyrolusite	[ ]	c) $CuFes_2$
iv)	Zincite	[ ]	d) zns
v)	Gypsum	[ ]	e) zno

Key:

i) c; ii) d; iii) b; iv) e; v) a;