CHAPTER 16
METALS AND THEIR EXTRACTION

Q1. Write down chemical differences between metals and non-metals?

CHEMICAL DIFFERENCES BETWEEN METALS AND NON-METALS:

<u>REACTION WITH ACIDS</u>:

METAL:

Metals which are more electropositive than hydrogen react hydrogen react with dilute acids to liberate H_2 gas, forming their salts by the loss of electrons.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

NON-METAL:

Non-metals react with hot concentrated acids, some of the non-metals get oxidized into oxides or some oxy-acids.

$$C+4HNO_3 \longrightarrow CO_2+4NO_2+2H_2O$$

<u>REDUCING AND OXIDIZING AGENT</u>:

METAL:

Metals area generally reducing agents because they have greater tendency to donate their electrons readily during chemical reactions.

$$\underset{\text{Metal}}{2Na} + \underset{\text{Non-metal}}{Cl_2} \longrightarrow 2Na^{+1}\,Cl^{1-}$$

NON-METAL:

Non-metal are generally oxidizing agents because of their tendency to accept electrons readily during chemical reactions.

$$\underset{\text{Metal}}{2Al^0} + \underset{\text{Non-metal}}{3S^0} \longrightarrow Al_2^{3+}\,S_3^{2-}$$

NATURAL OF CHLORIDES:

METAL:

Metallic chlorides are electrovalent i.e; ionic compounds. They are non-volatile crystalline solids.

$$Na^+Cl^- \; [Na^+\tfrac{1}{2}Cl_2 \qquad\qquad Na^+Cl^-]$$

NON-METAL:

Non-metals form covalent chlorides by the sharing of electrons, which are usually volatile liquids, easily hydrolyzed in water in most of the cases.

$$PCl_3(2P+3Cl_2 \longrightarrow 2PCl_3)$$

NATURE OF HYDRIDES:

METAL:

Metals form very few compounds with hydrogen like Na, K , Ca etc. combine with hydrogen to form ionic hydrides.

$$Na^+H^-[Na^+\tfrac{1}{2}\,H_2 \longrightarrow Na^+H^-)$$

NON-METAL:

Non-metals combine with hydrogen to form stable covalent hydrides by the sharing of electrons, such as NH_3,H_2S, HCl etc.

Q2. Define minerals and ores? Write down important ores with their formulae?

MINERALS:

"The metals are found in nature in the combined states with other chemical substances known as minerals."

<u>OR</u>

"The combined forms of metals with less definite chemical impurities are known as minerals."

ORES:

"The minerals are often mixed with earthy materials called as ores."

Ores mostly consists of a mixture of minerals with worthless rocky materials. These rocky materials present in ores are called gangue particles.

IMPORTANT ORES WITH THEIR FORMULAE:

ORES OF IRON:

Iron is the second most abundant metals after aluminum found in the earth's crust. The most common ores of iron are:

S.NO.	ORE	FORMULA
1.	Haematite	Fe_2O_3
2.	Magnetite	Fe_3O_4
3.	Iron pyrite	FeS_2
4.	Siderite or spathic	$FeCO_3$
5.	Limonite	Fe_2O_3-$3H_2O$(hydrated)

ORES OF COPPER:

Copper is very useful and important metal, copper ores are present in Baluchistan Pakistan. The important ores of copper are:

S.NO.	ORE	FORMULA
1.	Copper pyrite	$CuFeS_2$
2.	Cuperite	Cu_2O
3.	Chalcocite	Cu_2S
4.	Malochite	$CuCO_3.Cu(OH)_2$

ORES OF ALUMINUM:

Aluminum is the third most abundant element after oxygen and silicon in the earth's crust, and the most abundant metal in the earth's crust. The important ores of aluminum are:

S.NO.	ORE	FORMULA
1.	SILICON ORES: i. Kaolin ii. potash Felspar iii. Potash mica	 i. $Al_2O_3.2SiO_2.2H_2O$ ii. $K_2O.Al_2O_3.6SiO_2$ ii. $K_2O.3Al_2O_3.6SiO_2.2H_2O$
2.	FLUORIDE ORE: i. Cryolite	 i. Na_3AlF_6
3.	SULPAHTE ORE: i. Alunite	 i. $K_2SO_4.Al_2(SO_4)_3.4Al(OH_3)$
4.	OXIDE ORES: i. Bauxite ii. Diaspore	 i. $Al_2O_3.nH_2O$ or $Al_2O_3.2H_2O$ ii. $Al_2O_3.H_2O$

OCCURRENCE OF CHROMIUM:

Chromium is a silvery white metal. The main ores of chromium is chromite or chrome iron.; $Fe_2O_3.Cr_2O_3$. Chrome ore is found in Baluchistan and in Malakand at NWFP.

Q3. Define metallurgy? Also write the names of basic operations involved in the metallurgy of metals.

METALLURGY:

"The extraction of metal from its ore is termed as metallurgy. Thus metallurgy is the science and technology of extracting metals from their natural sources."

Metallurgy usually involves some simple processes such as:

1. Concentration of the ore.
2. Roasting of the concentrated ore.
3. Smelling of the ore.
4. Reduction.
  a. Chemical reduction.
  b. Thermal reduction.
  c. Reduction by electrolysis.

Q4. Define extraction of iron from its oxide ore (Haematite ore Fe_2O_3)?

EXTRACTION OF IRON FROM ITS OXIDE ORES:

The most important raw materials or ores from which the iron metal is extracted are oxides ores i.e. haematite (Fe_2O_3) or limonite ($Fe_2O_3.3H_2O$).

This involves the crushing of the oxide ore to produce lumps. These lumps are then pre-heated using hot gases from the blast furnace. This removes water and other volatile impurities present in the ore.

In the second stage the roasted iron ores are charged with coke and lime stone ($CaCO_3$) which are fed from the top of the furnace. Hot air is introduced into it from the bottom through small pipes known as tayeres.

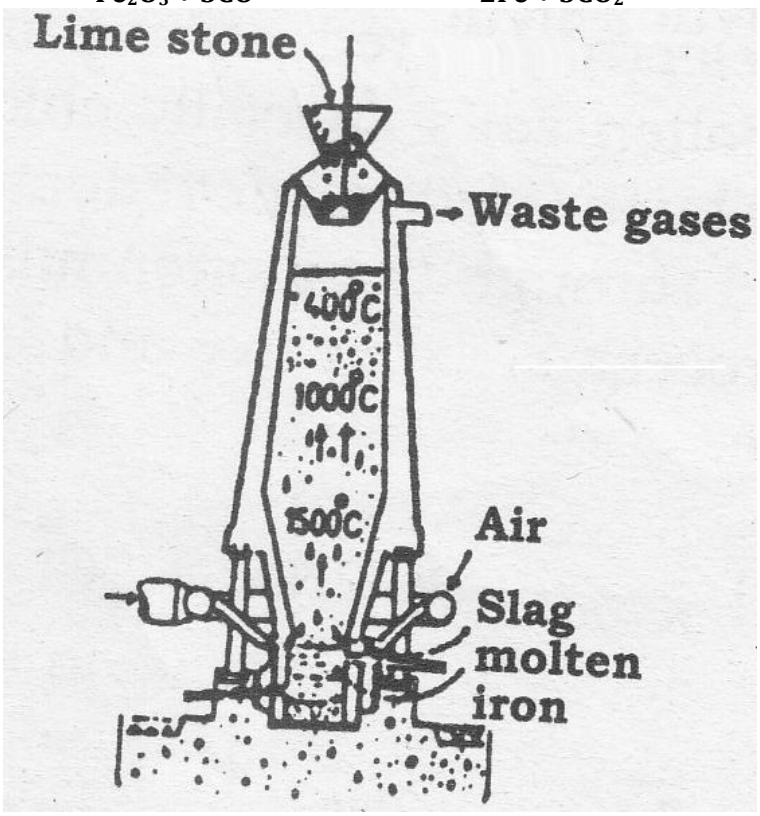
The temperature inside the furnace varies from about 2000°C near the bottom to about 200°C at the top. The blast of hot air oxidizes the coke to carbon dioxide with the liberation of heat.

$$C + O_2 \longrightarrow CO_2 \; ; \triangle H = -394 KJ/Mole$$

The reaction is highly exothermic. This rizes the temperature. As CO_2 gas rises up the furnace it reacts with more coke forming CO gas.

Carbon monoxide (CO) gas, thus produced then reduces the iron oxide ores of free iron metal in the upper parts of the furnace. Here temperature is between 477°C to 727°C.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$



Diagrammatic representation of blast furnace

Q5. What is pig iron? Write down the percentage of main components of pig iron? Also writes its properties and uses?

PIG IRON:

"Pig iron is the iron which is obtained directly from the blast furnace and is quite impure."

THE MAIN COMPONENTS OF PIG IRON:

S.NO.	COMPONENT	PERCENTAGE
1.	Iron	94 – 96%
2.	Carbon	3.5 - 4%
3.	Silica (Silicon)	1.2%
4.	Sulphur	0.05 - 0.1%
5.	Phosphorous	0.05 - 1.5%
6.	Manghese	0.01 - 1.0%

PHYSICAL PROPERTIES OF PIG IRON:

1. It is low grade and low quality iron.
2. It contains 3.5 to 4% carbon and other impurities like graphite and iron carbide FeC_3.
3. Because of the presence of impurities its melting point is from 1200 to 1530°C.

USES OF PIG IRON:

1. Pig iron is hard and brittle and therefore, has limited industrial uses.
2. Pig iron may be used directly to make steel.

Q6. Define cast iron and wrought? Write down their properties and uses?

CAST IRON:

"Cast iron is obtained from pig iron which is re-melted with some scrap steel and then cooled in moulds of required shapes."

PHYSICAL PROPERTIES OF CAST IRON:

1. Cast iron has a slightly lower percentage of impurities than pig iron and almost has the same physical properties.
2. It is brittle and cannot be welded or forged.

USES OF CAST IRON:

1. It is used for machinery objects.
2. It is also used in tools, lamp posts, gates, pipes, railings, the base of Bunsen burners, engine blocks etc.

WROUGHT IRON:

"Wrought iron is the purest commercial iron. It contains only about 0.1% carbon."

PHYSICAL PROPERTIES OF WROUGHT IRON:

1. Wrought iron is obtained by heating cast iron in a furnace with haematite(Fe_2O_3).
2. Wrought iron is almost pure iron. Therefore it is soft but very tough and malleable.
3. It can be shapes by hammering at about 500°C to 1000°C before its melting point.
4. It can easily be welded or forged.

USES OF WROUGHT IRON:

1. It is used for making, nails chains, iron rods, sheets and horse shoes.

Q7. Define steel? Write down the methods of making steel? Also write 3 common stainless steel with composition?

STEEL:

Most of the pig iron manufactured now a days is used for the production of steel. About 90% of pig iron is converted into steel. Steel is an alloy of iron with carbon and others elements such as mangnese nickel, chromium, tungsten and vanadium. There are several methods of making steel.

1. The basic oxygen process.
2. Open health process.
3. The electric arc process.

SOMECOMMON STAINLESS STEEL:

There are three main types of stainless steel which have different percentage of base metals and are as follows:

1. Stainless steel containing 13% Cr and 0.1-0.4 % C.
2. Stainless steel containing 17% Cr and 2% Ni.
3. Stainless steel containing 18% Cr and 6% Ni.

Q8. Write differences between iron and steel.

S.NO.	IRON	STEEL
1.	It is a pure substance.	It is made up of carbon and iron.
2.	Its flooring is rusty.	Its flooring stays shiny.
3.	It is available in nature.	It is not available in nature.
4.	It is used for building device and vehicles.	It is used for buildings, railways, cars and construction.

Q9. Define the term matte. Write down the process of refining of blister copper with diagram and electrode reactions.

MATTE:

In the extraction of copper, when the cuperous sulphide (Cu_2S) mixed with ferrous sulphide (FeS). This mass is called matte.

REFINING OF BLISTER COPPER:

Blister copper contains Fe, Zn, Pb, Ag, Au as impurities so, Blister copper is refined by the electrolytic process.

CONSTRUCTION:

In this process blocks of impure copper act as anode and very thin sheets of pure copper act as cathode. The anodes and cathodes are suspended in copper sulphate solution ($CuSO_4$), acidified with little amount of dilute sulphure acid (H_2SO_4).

DETAILED OF THE PROCESS:

The electrolysis is carried out at 50°C temperature by passing electric current of 1.3 Volt, which helps to deposit pure copper metal at cathodes by dissolving impure (Blister) copper anodes forming Cu^{2+} ions. The impurities of less active metals like Zn, Ag, Au etc are left over un-dissolved and fall at bottom of the cell as anode mud. The electrically refined copper is 100% pure.

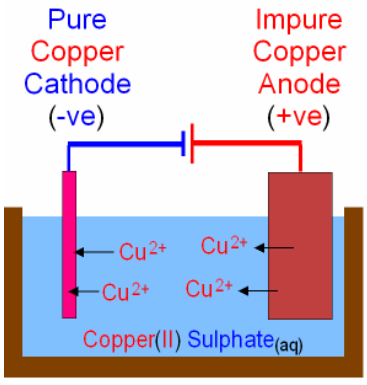
REACTIONS:

AT ANODES:

$$\underset{\text{Blister copper}}{Cu} \longrightarrow Cu^{2+} + 2e^-$$

AT CATHODE:

$$Cu^{2+} + 2e^- \longrightarrow \underset{\text{Pure copper metal}}{Cu}$$



Electrolytic of copper

Q10. How is aluminum metal extracted from its bauxite are ($Al_2O_3.2H_2O$)? Describe the process with chemical equivalent?

EXTRACTION OF ALUMINUM:

INTRODUCTION:

The most important ore for the extraction of aluminum metal is bauxite (impure hydrated aluminum oxide, $Al_2O_3.2H_2O$), form which Al metal is obtained. The industrial process was invented independently in 1886 by C.M. Hall and L.T.Heroult for the extraction of aluminum metal from bauxite ore, known as Hall-Heroult process.

PURIFICATION OF BAUXITE:

The bauxite ore contains major impurities of farric oxide (Fe_2O_3) and silica (SiO_2).

In this step the bauxite ore is grinded and crushed to finely divided bauxite ore. It is then heated with concentrated caustic soda (NaOH) solution under pressure to form sodium aluminate ($NaAlO_2$) or $NaAl(OH)_4$.

$$Al_2O_3\,2H_2O + 2NaOH + 3H_2O \longrightarrow 2NaAl(OH)_4 + \text{impurities}$$

(Bauxite) (Hydrated sodium aluminate)

OR

$$Al_2O_3.2H_2O + 2NaOH \longrightarrow 2NaAlO_2 + 3H_2O + \text{impurities}$$

(Sodium aluminate)

The filtrates which is sodium aluminate is hydrolysed with excess of water to precipitates aluminium hydroxide or aluminium oxide trihydrates A($Al_2O_3.3H_2O$) which is filtered, washed and dried.

$$2NaAlO_2 + 4H_2O \longrightarrow AlO_3.3H_2O + 2NaOH$$

OR

$$2NaAl(OH)_4 \longrightarrow 2Al(OH)_3 + 2NaOH$$

$Al_2O_3.3H_2O$ or $Al(OH)_3$ obtained is strongly heated upto 1500°C to yield pure aluminia (Al_2O_3) on dehydration.

$$2Al(OH)_3 \xrightarrow{1500\,^oC} Al_2O_3 + 3H_2O$$

Pure aluminia

OR

$$Al_2O_3.3H_2O \xrightarrow{1500\,^oC} Al_2O_3 + 3H_2O$$

Pure aluminia

Q11. Described the electrolysis of pure aluminum with labelled diagram?

ELECTROLYSIS OF PURE ALUMINA:

The electrolysis of alumina is carried in a steel tank lined inside with graphite which acts as cathode, while anodes are the graphite rods dipped in the molten mixture of pure alumina dissolved in molten cryolite (Na_3AlF_6) with some fluorspar (CaF_2). Cryolite lowers the melting point of pure alumina upto 950°C and maintains the temperature throughout the electrolysis, while fluorspar increase the fluidity of molten Al-metal. Al^{3+} ions would be discharged at cathode.

On passing the electric current reactions take place as:

IONIZATION REACTION:

$$2Al_2O_3 \underset{950°C}{\overset{\text{cryolite}}{\rightleftharpoons}} 4Al^{3+} + 6O^{2-}$$

AT CATHODE:

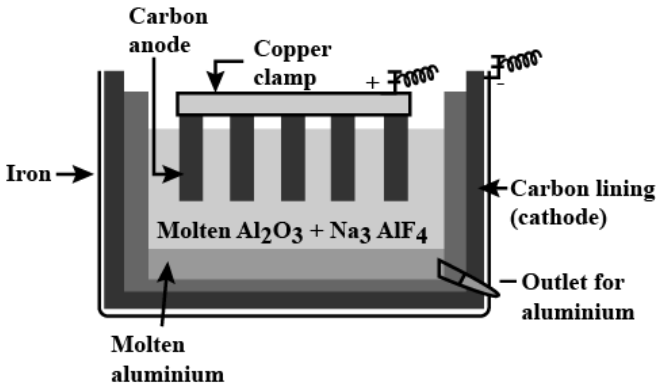
$$4Al^{3+} + 12e^- \xrightarrow{950^\circ C} 4Al$$

AT ANODE:

$$6O^{2-} \longrightarrow 3O_2 + 12e^-$$

Molten Al metal is produced at cathode which flows down the cell and is tapped off from the outlet at the bottom of the cell periodically.

Oxygen (O_2) gas is liberated at anode which interacts with the carbon of anode to forms oxides of carbon i.e. CO,CO_2. As a result the anodes and gradually burnt away and must be replaced from time to time.



Electrolysis of pure alumina

Q12. What is alloy? Write down the composition, properties and uses of different alloys?

ALLOYS:

"An alloy is a substance prepared by adding other metals or non-metals to a baser metal." They mixed only physically not chemically.

SOME COMMON ALLOYS:

1. BRONZE:

Composition:

Bronze contains 90-95 copper and 5-10% Tin.

Properties:

It is strong and shows greater resistance to chemical attack. In appearance it is quite attractive.

Uses:

1. It is used for making coins, medals, scalptures and also for general metallic work.

2. BARSS:

Composition:

It contains 60-80% copper and 20-40% Zn.

Properties:

1. Brass is stronger and more malleable than copper.

2. It is of yellow color. It has low melting point and is more attractive in appearance.

Uses:

1. It is used for making moving parts of clocks and watches, nut and bolts, rods, tubes, musical instruments, household utensils and also for general metal work.

3. NICHROME:

Composition:

Nichrome is an alloy that contains 60% nickel, 25% iron and 15% Chromium.

Properties:

1. Nichrome is heat resistance and electric resistance.

Uses:

1. It is used in the making of wires.