JSR IAS ACADEMY

GENERAL SCIENCE

CHEMISTRY

METALLURGY

METALLURGY

Human need to have some metals like **sodium, potassium, calcium, iron**, etc. in the human body.

Metallurgy is a science of extracting metals from their ores and modifying the metals into alloys for various uses.

A metallurgical process involve three main steps as follows:

(i) Concentration or Separation of the ore:

It is the process of removal of impuries from the ore.

(ii) Production of the metal:

It is the convertion of the ore into metal.

(iii) Refining of the metal:

It is the process of purification of the metal.

Terminology in metallurgy

Minerals:

A mineral may be a single compound or a complex mixture of various compounds of metals found in the Earth.

Ore:

The mineral from which a metal can be readily and economically extracted on a large scale is said to be an ore.

For example: Clay ($Al_2O_3 . 2 SiO_2 . 2 H_2O$) and bauxite ($Al_2O_3 .2 H_2O$) are the two minerals of aluminium, but aluminium can be profitably extracted only from bauxite. Hence, bauxite is an ore of aluminium and clay is its mineral.

Gangue or Matrix:

The rocky impurity associated with an ore is called gangue or matrix.

Flux:

It is the substance added to the ore to reduce the fusion temperature and to remove the impurities. E.g. Calcium oxide (basic), Silica (acidic).

Slag:

It is the fusible product formed when a flux reacts with a gangue during the extraction of metals. Flux + Gangue → Slag

Smelting:

Smelting is the process of reducing the roasted metallic oxide from the metal in its molten condition. In this process, impurities are removed as slag by the addition of flux.

Types of separation or concentration of an ore

There are four major types of separation of ores based on the nature of the ore.

(i) Hydraulic (Gravity Separation) method

Principle: The difference in the densities or specific gravities of the ore and the gangue is the main principle behind this method. Oxide ores are purified by this method. e.g., **Haematite Fe_2O_3** the ore of iron.

Method: The ore is poured over a sloping, vibrating corrugated table with grooves and a jet of water is allowed to flow over it. The denser ore particles settle down in the grooves and lighter gangue particles are washed down by water.

(ii) Magnetic separation method

Principle: The magnetic properties of the ores form the basis of separation. When either the ore or the gangue is magnetic, this method is employed. e.g., **Tinstone SnO_2** , the ore of tin.

Method: The crushed ore is placed over a conveyer belt which rotates around two metal wheels, one of which is magnetic. The magnetic particles are attracted to the magnetic wheel and fall separately apart from the nonmagnetic particles.

(iii) Froth floatation

Principle: This process depends on the preferential wettability of the ore with oil (pine oil) and the gangue particles by water. Lighter ores, such as sulphide ores, are concentrated by this method. e.g., **Zinc blende (ZnS).**

Method: The crushed ore is taken in a large tank containing oil and water and agitated with a current of compressed air.The ore is wetted by the oil and gets separated from the gangue in the form of froth. Since the ore is lighter, it comes on the surface with the froth and the impurities are left behind. e.g., **Zinc blende (ZnS).**

(iv) Chemical method or Leaching

This method is employed when the ore is in a very pure form.The ore is treated with a suitable reagent such that the ore is soluble in it but the impurities are not. The impurities are removed by filtration. The solution of the ore, ie., the filtrate is treated with a suitable reagent which precipitates the ore.

E.g. **Bauxite Al_2O_3 .$2H_2O$**, the ore of aluminium.

Oxide Ores	Carbonate Ores	Halide Ores	Sulphide Ores
Bauxite ($Al_2O_3 \cdot 2H_2O$)	Marble ($CaCO_3$)	Cryolite(Na_3AlF_6)	Galena (PbS)
Cuprite(Cu_2O)	Magnesite (($MgCO_3$)	Fluorspar(CaF_2)	Iron pyrite (FeS_2)
Haematite (Fe_2O_3)	Siderite($FeCO_{3)}$	Rock salt (NaCl)	Zinc blende (ZnS)

OCCURRENCE OF ORES IN TAMIL NADU

- **Lime stone:** Coimbatore, Cuddalore, Dindugul
- **Gypsum:** Tiruchi and Coimbatore Distiricts
- **Titanium minerals:** Kanyakumari, Tirunelveli and Tuticorin.
- **Chromite:** Coimbatore and Salem district.
- **Magnetite:**Dharmapuri, Erode, Salem, Thiruvannamalai.
- **Tungsten:** Madurai and Dindugal.

PROPERTIES OF METALS

Physical properties

1. Physical state: All metals are solids at room temperature except mercury and gallium.

2. Lustre: Metals possess a high lustre (called metallic lustre).

3. Hardness: Most of the metals are hard and strong (exceptions: sodium and potassium can be cut with a knife)

4. Melting point and Boiling point: Usually, metals possess high melting and boiling points and vaporize only at high temperatures (exceptions: gallium, mercury, sodium and potassium).

5. Density: Metals have a high density (exceptions: sodium and potassium are less dense than water).

6. Ductility: Metals are usually ductile. In other words, they can be drawn into thin wires without breaking.

7. Malleability: Metals are usually malleable, i.e, they can be beaten into thin sheets without cracking (except zinc and mercury).

8. Conduction of heat and electricity: Metals are good conductors of heat and electricity; silver and copper excel in this property (exception: tungsten)

9. Solubility: Usually, metals do not dissolve in liquid solvents.

Chemical Properties

Valence electrons: Atoms of metals usually have 1,2 or 3 electrons in their outermost shell.

Formation of ions: Metals form Positive ions by the loss of electrons and hence they are electro positive.

Discharge of ions: Metals are discharged at the cathode during the electrolysis of their compounds.

Atomicity: Molecules of metals in their vapour state are usually monoatomic.

Nature of oxides: Oxides of metals are usually basic.

Extraction of metal from metal oxide can be categorized into three types.

More reactive metals	Medium reactive metals	Less reactive metals
Na,K,Ca,Mg,Al	Zn,Fe,Pb,Cu	Ag,Hg
Electrolytic reduction of metal oxide into metal	Chemical reduction of metal oxide into metal using coke	Thermal decomposition of metal oxide into metal

METALLURGY OF ALUMINIUM

Aluminium is the metal found most abundantly in the Earth's crust.

Ores of Aluminium	Formula
Bauxite	$Al_2O_3 \cdot 2H_2O$
Cryolite	Na_3AlF_6
Corundum	Al_2O_3

Bauxite is the chief ore of aluminium. The extraction of aluminium from bauxite involves **two steps:**

(i) Conversion of bauxite into alumina – Baeyer's Process

The conversion of Bauxite into Alumina involves the following steps: Bauxite ore is finely ground and heated under pressure with a solution of concentrated caustic soda solution at 150° C to obtain sodium meta aluminate. On diluting sodium meta aluminate with water, a precipitate of aluminium hydroxide is formed. The precipitate is filtered, washed, dried and ignited at 1000°C to get alumina.

$$2Al(OH)_3 \xrightarrow{1000^\circ c} Al_2O_3 + 3H_2O$$

(ii) Electrolytic reduction of alumina – Hall's Process

Aluminium is produced by the electrolytic reduction of fused alumina in the electrolytic cell.

Cathode: Iron tank linked with graphite

Anode: A bunch of graphite rods suspended in molten electrolyte.

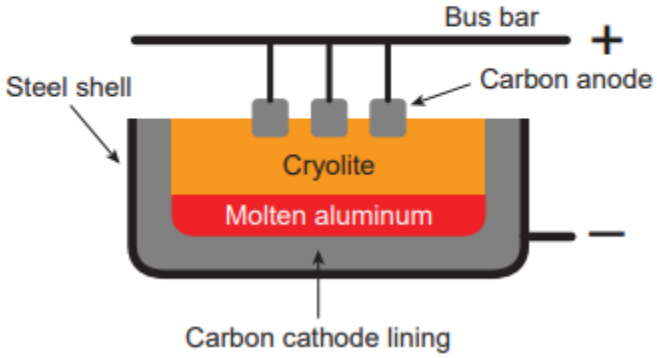
Electrolyte: Pure alumina + molten cryolite + fluorspar (fluorspar lowers the fusion temperature of electrolyte)

Temperature: 900 - 950 °C

Voltage used: 5-6 V

Overall reaction: $2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2\uparrow$

Electrolytic process of manufacturing aluminum



Physical Properties of Aluminium

- It is a silvery white metal
- It has low density (2.7) and it is light
- It is malleable and ductile
- It is a good conductor of heat and electricity.
- Its melting point is 660°C.
- It can be polished to produce a shiny attractive appearance.

Chemical Properties of Aluminium

1. **Reaction with air:** It is not affected by dry air. On heating at 800 °C, aluminium burns very brightly forming it's oxide and nitride.

2. **Reaction with water:** Water does not react with aluminium due to the layer of oxide on it. When steam is passed over red hot aluminium, hydrogen is produced.

3. **Reaction with alkalis:** It reacts with strong caustic alkalis forming aluminates.

4. **Reaction with acids:**
   - With dilute and con. HCl it liberates H2 gas.
   - Aluminium liberates hydrogen on reaction with dilute sulphuric acid.
   - Sulphur dioxide is liberated with hot concentrated sulphuric acid

Dilute or concentrated nitric acid does not attack aluminium, but it renders aluminium passive due to the formation of an oxide film on its surface.

5. **As reducing agent:** Aluminium is a powerful reducing agent. When a mixture of aluminium powder and iron oxide is ignited, the latter is reduced to metal. This process is known as aluminothermic process.

Aluminium Uses

- household utensils
- electrical cable industry
- making aeroplanes and other industrial mechine parts

METALLURGY OF COPPER

It was named as **cuprum** by the Romans because they got it from the Island of **Cyprus.**

Ores of copper	Formula
Copper pyrites	$CuFeS_2$
Cuprite or ruby copper	Cu_2O
Copper glance	Cu_2S

The chief ore of copper is **copper pyrite.** It yields nearly **76%** of the world production of copper.

Extraction of copper from copper pyrites

1. **Concentration of ore:** The ore is crushed and the concentrated by froth floatation process.
2. **Roasting:** The concentrated ore is roasted in excess of air. During the process of roasting, the moisture and volatile impurities are removed. Sulphur, phosphorus, arsenic and antimony are removed as oxides. Copper pyrite is partly converted into sulphides of copper and iron.
3. **Smelting:** The roasted ore is mixed with powdered coke and sand and is heated in a blast furnace to obtain matte (Cu_2S + FeS) and slag. The slag is removed as waste.
4. **Bessemerisation:** The molten matte is transferred to Bessemer converter in order to obtain blister copper. Ferrous sulphide from matte is oxidized to ferrous oxide, which is removed as slag using silica.
5. **Refining:** Blister copper contains 98% of pure copper and 2% of impurities and is purified by electrolytic refining.

Physical Properties of Copper

Copper is a reddish brown metal, with high lustre, high density and high melting point (1356°C).

Chemical Properties of Copper

1. **Action of Air and Moisture:** Copper gets covered with a green layer of basic copper carbonate in the presence of CO_2 and moisture.
2. **Action of Heat:** On heating at different temperatures in the presence of oxygen, copper forms two types of oxides

$$2\,Cu + O_2 \xrightarrow{\text{below 1370K}} 2\,CuO$$
(copper II oxide- black)

$$4\,Cu + O_2 \xrightarrow{\text{above 1370K}} 2\,Cu_2O$$
(copper I oxide – red)

3. **Action of Acids:**
   - Dilute acids such as HCl and H_2SO_4 have no action on these metals in the absence of air.
   - Copper dissolves in these acids in the presence of air.
   - Copper reacts with dil. HNO_3 with the liberation of Nitric Oxide gas.
4. **Action of Chlorine:** Chlorine reacts with copper, resulting in the formation of copper(II) chloride.
5. **Action of Alkalis:** Copper is not attacked by alkalis.

Uses of Copper:

- It is extensively used in manufacturing electric cables and other electric appliances.
- It is used for making utensils, containers, calorimeters and coins,
- It is used in electroplating.
- It is alloyed with gold and silver for making coins and jewels

METALLURGY OF IRON

Iron is the second most abundant metal available next to aluminium.

Ores of iron	Formula
Haematite	Fe_2O_3
Magnetite	Fe_3O_4
Iron pyrite	FeS_2

Iron is chiefly extracted from **haematite** ore (Fe_2O_3)

1. **Concentration by Gravity Separation:** The powdered ore is washed with a steam of water. As a result, the lighter sand particles and other impurities are washed away and the heavier ore particles settle down.
2. **Roasting and Calcination:** The concentrated ore is strongly heated in a limited supply of air in a reverberatory furnace. As a result, moisture is driven out and sulphur, arsenic and phosphorus impurities are oxidized off.
3. **Smelting (in a Blast Furnace):** The charge consisting of roasted ore, coke and limestone in the ratio **8:4:1** is smelted in a blast furnace by introducing it through the cup and cone arrangement at the top.

   There are three important regions in the furnace.

   (a) **The Lower Region (Combustion Zone)-** The temperature is at 1500°C

(b) **The Middle Region (Fusion Zone)** – The temperature prevails at 1000°C.

(c) **The Upper Region (Reduction Zone)-** The temperature prevails at 400°C . In this region carbon monoxide reduces ferric oxide to form a fairly pure spongy iron. The molten iron is collected at the bottom of the furnace after removing the slag. The iron thus formed is called **pig iron**.

Physical properties:

- It is a lustrous metal, greyish white in colour.
- It has high tensility, malleability and ductility.
- It can be magnetized.

Chemical properties:

1. **Reaction with air or oxygen:** Only on heating in air, iron forms magnetic oxide.
2. **Reaction with moist air:** When iron is exposed to moist air, it forms a layer of brown hydrated ferric oxide on its surface. This compound is known as rust and the phenomenon of formation of rust is known as **rusting**.
3. **Reaction with steam:** When steam is passed over red hot iron, magnetic oxide is formed.
4. **Reaction with chlorine:** Iron combines with chlorine to form ferric chloride.
5. **Reaction with acids:**
   - With dilute HCl and dilute **H_2SO_4** it liberates H_2 gas.
   - With dilute HNO3 in cold condition it gives ferrous nitrate.
   - With con. H2 SO4 it forms ferric sulphate.
   - When iron is dipped in con. HNO3 it becomes chemically passive or inert due to the formation of a layer of iron oxide on its surface.

Uses of iron

- **Pig iron** (Iron with 2-4.5% of carbon): It is used in making pipes, stoves, radiators, railings, manhole covers and drain pipes.
- **Steel** (Iron with < 0.25% of carbon): It is used in the construction of buildings, machinery, transmission cables and T.V towers and in making alloys.
- **Wrought iron** (Iron with 0.25-2% of wraught carbon): It is used in making springs, anchors and electromagnets

ALLOYS

An alloy is a homogeneous mixture of two or more metals or of one or more metals with certain non-metallic elements.

The properties of alloys are often different from those of its components.

Pure gold is too soft to be used. The addition of small percentage of copper enhances its strength and utility

Amalgam

An amalgam is an alloy of mercury with another metal.

These alloys are formed through metallic bonding with the electrostatic force of attraction between the electrons and the positively charged metal ions. Silver tin amalgam is used for dental filling.

Reasons for alloying:

- To modify appearance and colour
- To modify chemical activity.
- To lower the melting point.
- To increase hardness and tensile strength.
- To increase resistance to electricity.

Method **of making alloys**

(a) By fusing the metals together

Brass is made by melting zinc and copper.

(b) By compressing finely divided metals.

Wood metal: an alloy of lead, tin, bismuth and cadmium powder is a fusible alloy.

Alloys as solid solutions:

Alloys can be considered solid solutions in which the metal with high concentration is solvent and other metals are solute.

brass is a solid solution of zinc (solute) in copper (solvent).

Types of Alloys

Based on the presence or absence of Iron, alloys can be classified into:

1. **Ferrous alloys:** Contain Iron as a major component. A few examples of ferrous alloys are Stainless Steel, Nickel Steel etc.
2. **Non-ferrous alloys:** These alloys do not contain Iron as a major component. For example, Aluminium alloy, Copper alloy etc.

Copper Alloys (Non- ferrous)

Alloys	Uses
Brass (Cu, Zn)	Electrical fittings, medal, decorative items, hardware
Bronze (Cu, Sn)	Statues, coins, bells, gongs

Aluminium Alloys (Non- ferrous)

Alloys	Uses
Duralumin (Al, Mg, Mn, Cu)	Aircrafts, tools, pressure cookers
Magnalium (Al, Mg)	Aircraft, scientific instruments

Iron Alloys(Ferrous)

Alloys	Uses
Stainless steel (Fe,C, Ni,Cr)	Utensils, cutlery, automobile parts
Nickel steel (Fe,C,Ni)	Cables , aircraftparts, propeller

CORROSION

It is the gradual destruction of metals by **chemical or electrochemical reaction** with the environment.

It is a natural process which **converts a metal into its oxide, hydroxide or sulphide** so that it loses its metallic characteristics.

Rusting

Rust is chemically known as **hydrated ferric oxide** (it is formulated as $Fe_2O_3.xH_2O$). Rusting results in the formation of scaling **reddish brown hydrated ferric oxide** on the surface of iron and iron containing materials.

Types of Corrosion

1. **Dry Corrosion or Chemical Corrosion:**

   The corrosive action in the **absence of moisture** is called dry corrosion. It is the process of a chemical attack on a metal by a corrosive liquids or gases such as O_2, N_2, SO_2, H_2S etc. It occurs at high temperature. Of all the gases mentioned above O_2 is the most reactive gas to impart the chemical attack.

2. **Wet Corrosion or Electrochemical Corrosion:**

   The corrosive action in the **presence of moisture** is called wet corrosion. It occurs as a result of electrochemical reaction of metal with **water or aqueous solution of salt or acids or bases.**

Methods of preventing corrosion

1. **Alloying:**

   The metals can be alloyed to prevent the process of corrosion. E.g: **Stainless Steel**

2. **Surface Coating:**

   It involves application of a protective coating over the metal. It is of the following types:

   a) Galvanization: It is the process of coating zinc on iron sheets by using electric current.

   b) Electroplating: It is a method of coating one metal over another metal by passing electric current.

   c) Anodizing: It is an electrochemical process that converts the metal surface into a decorative, durable and corrosion resistant. **Aluminium** is widely used for anodizing process.

   d) Cathodic Protection: It is the method of controlling corrosion of a metal surface protected is coated with the metal which is easily corrodible. The easily corrodible metal is called Sacrificial metal to act as anode ensuring cathodic protection.

PAMBAN BRIDGE

- It is a railway bridge which connects the town of Rameshwaram on Pamban Island to mainland India.
- Opened on 1914, it was India's first sea bridge in India until the opening of the BandraWorli Sea Link in 2010.