Ganesh Institute of Engineering and Technology

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18/3/25

Unit - 3

Engineering Materials

- Earth crust is a great source of metals. These metals are found to occur in nature in two states either in Free state or in combined state
- A metal is said to be in Free state when it is found in the earth's crust in elementary or uncombined form.
- These are unreactive and have no tendency to react with oxygen and are not attacked by moisture, CO_2 or other non-metals for Ex - Cu, Fe, Au
- Most metals are found in combine state due to their reaction with moisture, air and other substances present in the earth's crust.

Minerals and ores

→ The naturally occuring chemical substances in which metals or their compounds occur either in Free state or in combine state are called minerals.

→ Those minerals from which metals are extracted easily and economically are called ores.

→ Slightly reactive metals occur in sulphide Form. (Copper sulphide, Lead sulphide)

- Moderately reactive metals occurs as oxides Maganese oxide, Aluminium oxide
- While highly reactive metals can occur as Carbonates, sulphates, halides etc

Fe ore

1) Haematite - Fe_2O_3
2) Magnetite - Fe_3O_4

~~Al ore~~

1) Bauxite $Al_2O_3.2H_2O$
2) Cryolite - Na_3AlF_6

Cu ore

1) Cu pyrite - $CuFeS_2$
2) Dolomite - $CuCO_3, MgCO_3$

General principle of Metalogy

Extraction of metals from ore involves the following steps

(1) Crushing and grinding of ore
(2) Concentration of ore
(3) Extraction of Metal from Concentrated ore
(4) Purification of Impure metal

→ **Crushing and grinding of ore**

Ores are found in nature in the form of big rocks. These rocks are crushed into small pieces with the help of a jaw crasor the small pieces are then reduced into fine powder with the help of a ball mill or a stamp mill.

→ **Concentration of Ore**

It is the removal of unwanted impurity called gauge from the ore It is carried out by both physical such as gravity separation, Magnetic

separation, Froth Floatation and chemical mean such as calcination and roasting

4 FLUX

Metal sometime contains non Fusable Impurit they are fused easily with chemical substan called Flux gauge react with Flux Forming Fusable substance called Slag which can b removed easily. It is of two types.

a) Acidic Flux

IF Impurities are basic then acidic Flux a used.

$SeO_2 + FeO \longrightarrow FeSeO_3$

acidic Flux basic Impurity Slag

b) Basic Flux

IF Impurities are acidic then Basic Flux are used

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

basic Flux acidic Impurity slag

7 Extraction of Metals

Etraction of Metal can be done in Following steps

Step 1- Conversion of Metal ore into Metal oxide

Step 2- Conversion of Metal oxide into Metal

Ores can be converted into metal oxides in Following ways.

a) Calcination :-

It is the process of heating the concentrated ore in absence of air. This process is performed For hydrated and carbonated ores during this process moisture and volatile impurity is remo From the ore.

Ex

$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2 \uparrow$

$Fe_2O_3\ 3H_2O \xrightarrow[H_2O]{\Delta} Fe_2O_3 + 3H_2O$

$CuCO_3 \cdot Cu(OH)_2 \xrightarrow{\Delta} CuO + CO_2 + H_2O$

b) Roasting

It is the process of heating the concentrated ore in excess of air. This process is performed for sulphides ores. During this process moisture and volatile impurities are removed

$2ZnS + 3O_2 \longrightarrow 2ZnO + 2CO_2 \uparrow$

$ZnS + 2O_2 \rightarrow ZnSO_4$

→ Conversion of Metal oxide into metal

It depends upon the reactivity of metal

i) If the metal oxide shows low reactivity then it can be converted into metals by only heating

$HgO \xrightarrow{\Delta} 2Hg + O_2$

Mercury oxide

If the metal is moderately reactive then it can chemically reduced with carbon

$PbO + C(s) \longrightarrow Pb + CO$

ii) If the oxide cannot be reduced by carbon then aluminium is used

$Cr_2O_3 + 2Al(s) \longrightarrow Cr + Al_2O_3$

iii) If it is highly reactive then electrolysis is performed

$Al^{3+} + 3e^- \longrightarrow Al$ at cathode

4) Purification of Impure metal

a) Liquation
When a fusable metal contains non fusable impurity then by heating the liquified metal can be separated from the impurity

b) Distillation
When a non-volatile impurity the volatile can be collected in a receiver and then separated from the impurity

c) Electric Refining
The impure metal when taken as anode of an electrolytic cell containing an electrolytic solution the impurity gets removed under the anode that is refer to as anode mole

Extraction of iron from Hecmatite ore

1) Crushing and grinding of ore

The heamatite ore is crushed in a Jaw crosser and turned into fine powder in a ball mill.

2) ~~Concentration~~ Extraction
Heamatite ore is converted into iron oxide by Calcination which is then chemically reduced

by carbon in a blast furnace.

3) Concentration
The heamatite ore is concentrated through gravity separation process.

Wrought iron.
It is the purest form of commercially used iron with 0.2 - 0.5 % of carbon content
It can be prepared from cast iron by reducing its carbon content.

Steel
It can be prepared from cast and wrought iron it has 0.2 - 2 % carbon content

Extraction of aluminium from bauxite ore.
Aluminium is extracted from bauxite ore by reducing the ore. As electrode potential of aluminium is very high, the ore cannot be reduced chemically. Hence, electrolysis method is applied to reduce the ore this is done in the following ways
Purification of ore
Electrolysis of ore
Purification of ore Al

Purification of ore Bauxite.
Bauxite ore contains 55 % of aluminium oxide $Al_2CO_3 \cdot 2H_2O$ along with impurities like silicon dioxide SiO_2, ferric oxide Fe_2O_3 titanium dioxide TiO_2 These impurities can be

removed in the following three ways.

- Hall's process - SeO_2, Fe_2O_3
- Bayer's process - FeO
- Seopeh's process - SiO_2

Hall's process

$$Al_2O_3 \cdot 2H_2O + Na_2CO_3 \xrightarrow{\Delta} NaAlO_2 + H_2O + (Na_2CO_2)$$

The ore is fused with sodium carbonate to form sodium aluminate ($NaAlO_2$) silica and iron oxide do not react with sodium carbonate and hence reaction mixture. The sodium aluminate is then agitated with water in presence of carbon dioxide to form aluminium hydroxide. is a heated to from aluminium oxide.

$$NaAlO_2 + H_2O \xrightarrow{CO_2} Al(OH)_3 + Na_2CO_3$$

$$Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + H_2O$$

Bayer's Process

FeO

The ore is roasted to convert Ferrous oxide into Ferric oxide Fe_2O_3 then it is treated with sodium hydroxide to get sodium aluminate. $NaAlO_2$ the sodium aluminate is then agitated to Aluminium oxide $Al(OH)_2$ which is then heated to form hydroxide Aluminium hydroxide Al_2O_3

$FeO \xrightarrow{\Delta} Fe_2O_3$

$Al_2O_3 + NaOH \rightarrow NaAlO_2 + H_2O$

$AlO_2 + H_2O \xrightarrow{\Delta} Al(OH)_2 + NaOH$

$Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + H_2O$

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Electrolysis of Bauxite

In this process Bauxite is mixed with a small amount of Cryolite. Cryolite dissociates into Flourides of Sodium and alluminium in e next stg. step of reaction takes place as Follows.

Cryolite

$Na_3AlF_6 \rightleftharpoons NaF + ALF_3$; upon electrolysis

At anode $3F^- \rightarrow 3F + 3e^-$ $\cdot AlF_3 \rightleftharpoons Al^{3+} + 3F^-$

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

The Floride liberated at anode reacts with bauxite as Follows :-

$Al_2O_3 + 3F \rightarrow AlF_3 + O_2$

Purification of alluminium

The metal obtained From the above process contains impurities like Iron and silicon. This alluminium can be purified by using hoopes method.

In an iron tank three layers of liquid is of different density is taken the bottom of the tank

is lined with carbon that acts as anode the middle layer consists of a fused mixture of Florides of sodium, Alluminium, Bessium the top layer contains pure molten alluminium in which a carbon rod is dipped that acts as cathode when electricity is passed through the tank alluminium ion migrates to the top to cathode where it gets reduced to form pure alluminium.

Alloy
Homogeneous
It is a mixture of Metals or metals or non-metals.

Benefits of alloy
Alloyes have increased resistance to corro
Increased hardness, increased tensile strength, lower melting point. They produce good cast the chemical reactivity of a metal can be altered by alloying with other metals.

Classification of alloyes
alloyes are classified into two components

① Ferrous alloy - These type of alloyes have iron as there main component
Ex- Stainless steel
It is prepared by combining steel with chromium and nickel.

② Non-Ferrous alloy
In these type of alloyes iron is not the main component Ex- Brass
It is prepared by alloing of copper and Zinc

Cement

Cement is a Finely ground mixture OF various Metals and non-metal oxides OF diFFerent composition with adhesive and Cohesive properties.

Portland Cement

Cement manufactured From chalk and clay which hardnes in contact with water resembling portland stone is called port land cement.

Hardening OF Portland Cement

The setting and hardening OF Cement are mainly due to hydration and hydrolysis reaction. Unhydrous compounds react with water and undergo hydration resulting in the Formation OF insoluble gels and crystaline products.

Hydrolysis

a) $C_3S + (x+1)H_2O \longrightarrow C_2S \cdot xH_2O + C \cdot H_2O$
gel Crystalline.

b) $C_4AF + 7H_2O \longrightarrow C_2A \cdot 6H_2O + CF \cdot H_2O$
Crystalline gel.

Hydration

a) $C_3S + xH_2O \rightarrow C_2S \cdot xH_2O + CaO$
gel lime

b) $C_3A + 6H_2O \rightarrow C_3A\,6H_2O + Heat$
Crystaline

Here gel acts as the binding material it holds the crystalline components together

Application of Portland cement

- It is used for the production of Concrete
- It is applied for laying Floors, roof, stair pillars etc.
- Construction of bridges, dams, tunnels etc.
- Making Joints for drains and pipes.
- Preparation of Foundation, water tight Floors, Foth path etc.

→ Glass

Glass is an amorphous, hard, Brittle, transparent or translucent or super cooled liquid of Infinite viscocity having no definite melting point It is obtained by fusing a mixture of several metallic silicates or borates of Na, K, Ca, Pb

→ Properties of Glass

- Glass is hard, Brittle, weather and Fire resistance.
- It can provide insulation against heat, electric and radiation.
- It can withstand chemical reaction.

* Refractory

It is an inorganic non-metallic material which can withstand high temperature without undergoing physiochemical changes.

Ex - Hot Blast stove

Composite Material

It is a mixture of two or more micro constituents combine to give properties superior to individual constituents.

Ex - Reenforced Cement Concrete

Polymer

- Polymer is a high molecular weight compound consisting of repeating units
- The repeating unit of a polymer is called a monomer

Ex - $H_2C=CH_2 \xrightarrow{\text{Polymerisation}} (H_2C-CH_3)_n$

ethene — polythene

- When the monomer consists of a similar molecule it is called a homomer.

$HC(Cl)=CH_2 \xrightarrow{\text{Polymerisation}} (HC(Cl)-CH_2-)_n$

vinyl chloride — poly vinyl chloride

- When the monomer of dissimilar molecule it is called a co-polymer

$n\,H_2N-(CH_3)NH_2 + HO-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH$

Hexamethyl diene — Adipose acid — Nylon 6, 6

$n(CH_2=CH(Cl)) \xrightarrow{\text{Polymerisation}} (CH(Cl)-CH_2)_n$

vinyl chloride — PVC

Classification of Polymer

a) According to the source of its formation polymers are classified into natural and synthetic polymer.

$$n\,CH(Cl)=CH_2 \xrightarrow{\text{Polymerisation}} \left(CH(Cl)-CH_2\right)_n$$

Cl
vinyl chloride

Cl
PVC

Ex of natural polymer : protein

$$H_2N-CH_2-COOH + NH_2-CH_2-COOH \xrightarrow{-H_2O} H_2N-CH_2-C$$

CH_2-NH_2

b) Based upon the chemical reaction involved in the formation polymers are classified into addition and condensation polymer.

Ex of addition polymer - polyethene

$$H_2C=CH_2 \xrightarrow{\text{Polymerisation}} \left(CH_2-CH_2\right)_n$$

ethene — polythene

Ex of Condensation reaction - Nylon 6,6

c) Polymers are also classified into thermo setting and thermo plastic polymer.

Thermosetting polymers can't be reshaped upon heating while thermo plastic polymer can be reshaped upon heating

Ex of Thermosetting polymer - Dekalite

Ex of thermoplastic polymers - PVC

Serpak's process :-

Excess silica (SiO_2) crushed ore heated with C & N, ore converts to AlN, silica converted to silica which is volatile, so escapes the mixture.

$$Al_2O_3 + C + N_2 \xrightarrow[\Delta]{1800^\circ C} AlN + CO \cdot SiO_2 + 2C \rightarrow CO + Si$$

$$AlN + 3H_2O \longrightarrow Al(OH)_3 + NH_3$$

$$2Al(OH)_3 \xrightarrow[\Delta]{1800^\circ C} Al_2O_3 + 3H_2O$$