



# Ratna Sagar

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# ICSE

# Living Science

# Chemistry

Class 10

**Chapter-7 Metallurgy**

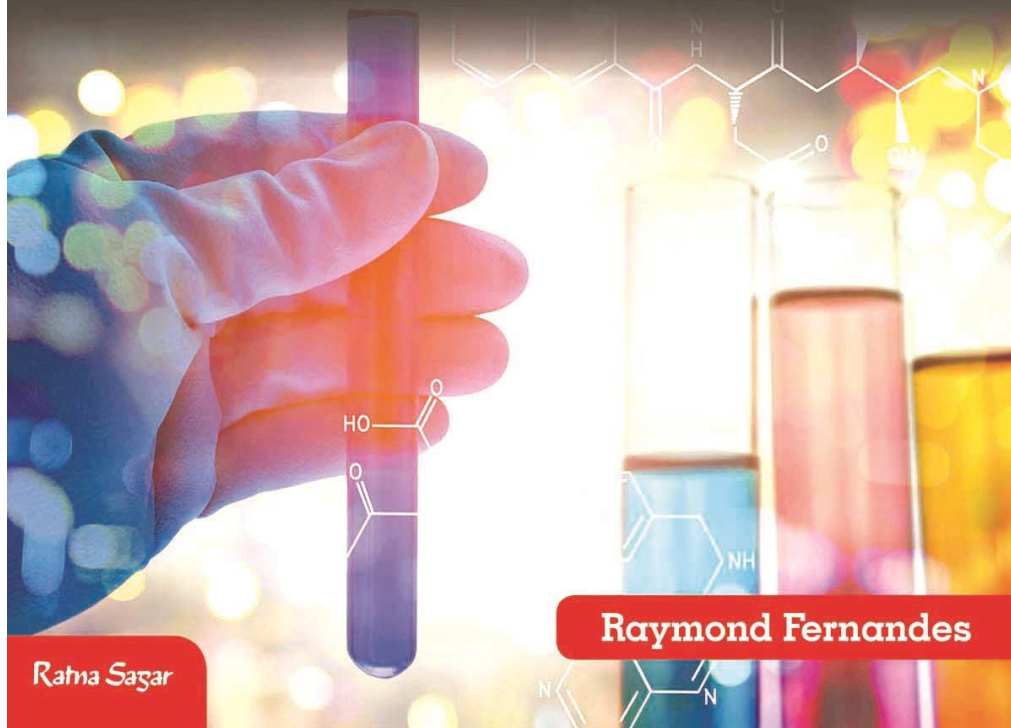


As per the latest ICSE syllabus

10



# Living Science CHEMISTRY



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EDUCATION, OUR MISSION



## LEARNING OBJECTIVES

Reactivity series and metallurgical processes

Metallurgy

❖ Processes involved in metallurgy

- Concentration of ore
- Conversion of concentrated ore into metal oxide
- Extraction of the metal by the reduction of metal oxide
- Refining of impure metals

Aluminium

❖ Extraction of aluminium

❖ Electrolytic reduction of fused alumina

❖ Purification of aluminium

Alloys

❖ Purpose of making alloys

## What are Minerals and Ores?

The elements or compounds, which occur naturally in the earth's crust are known as **minerals**.

The naturally occurring minerals from which metals can be extracted profitably are called **ores**.



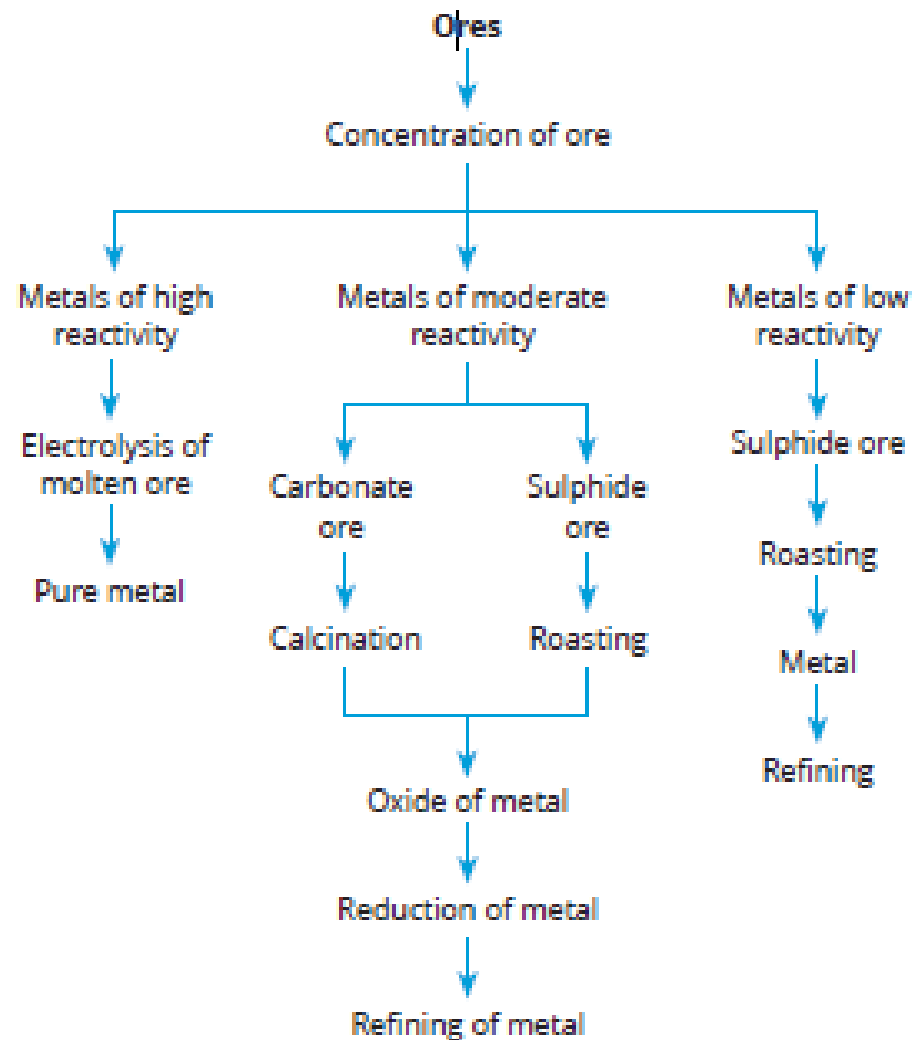
## Reactivity series and metallurgical processes

On the basis of reactivity, metals can be grouped into three categories.

- Metals of high reactivity
- Metals of medium reactivity
- Metals of low reactivity.

Most reactive metal	K	} Electrolytic reduction method
↓ Reactivity of metals decreases ↓	Na	
	Ca	
	Mg	
	Al	
	Zn	} Reduction using carbon
	Fe	
	Sn	
	Pb	} Reduction by heat alone
	Cu	
	Hg	
	Ag	} Found in native state in the earth's crust
Au		
Pt		
Least reactive metal		

## Steps involved in the extraction of metals from ores





## Metallurgy

Metallurgy is the process of extracting metals economically from their ores and refining the extracted raw material into purer form. The process of extraction of a metal depends on the nature of the ore, impurities present in the ore and physical and chemical properties of the metal to be extracted.

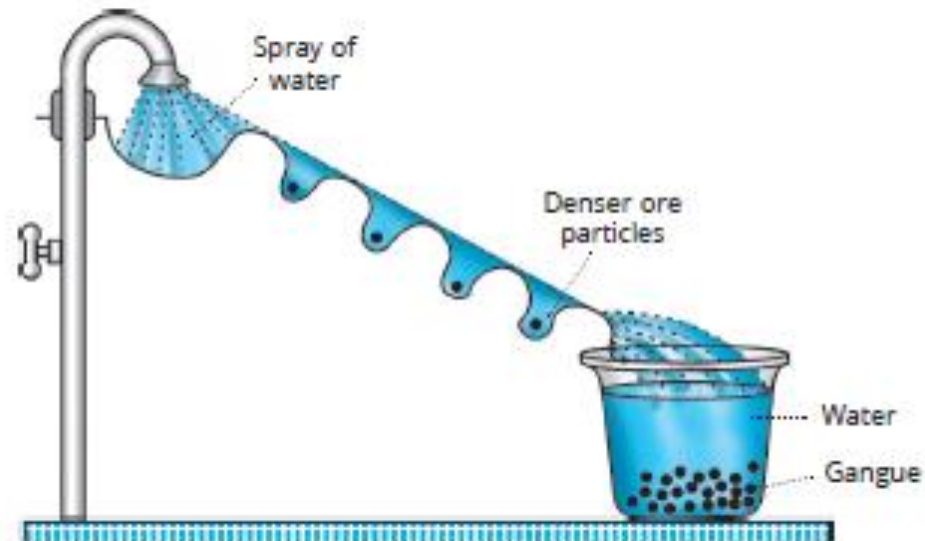
### Processes involved in metallurgy

The process of metallurgy consists of the following steps:

**1. Concentration of ore:** The impurities present in an ore are called **gangue**. The process of removal of unwanted material (gangue) from an ore is called **concentration, dressing or benefaction of ore**. The following methods are used for the concentration of ores.

#### a. Gravity separation or hydraulic washing

This method is based upon the difference in the densities of the ore and the gangue particles. The powdered ore is spread on tables having grooves on the top. The powdered ore is then washed with upward stream of water.

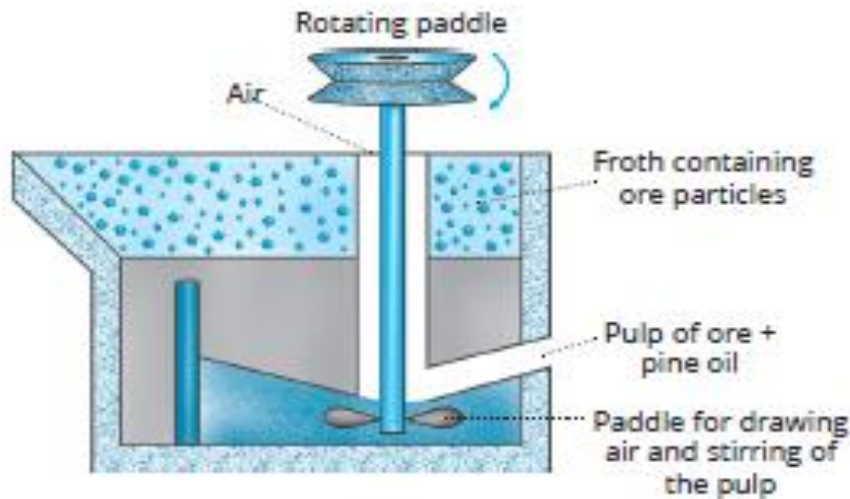




The lighter gangue particles are washed away and the heavier ore particles are left behind. This method is used for the oxide ores of heavy metals such as iron and tin and native ores of silver, gold and platinum.

## b. Froth floatation process

This method is based on the principle that the ore particles are preferentially wetted by oil while the gangue particles are wetted by water. The powdered ore is taken in a tank containing water and a little pine oil. The mixture is agitated by means of a rotating shaft and the air is blown through the mixture to create froth.

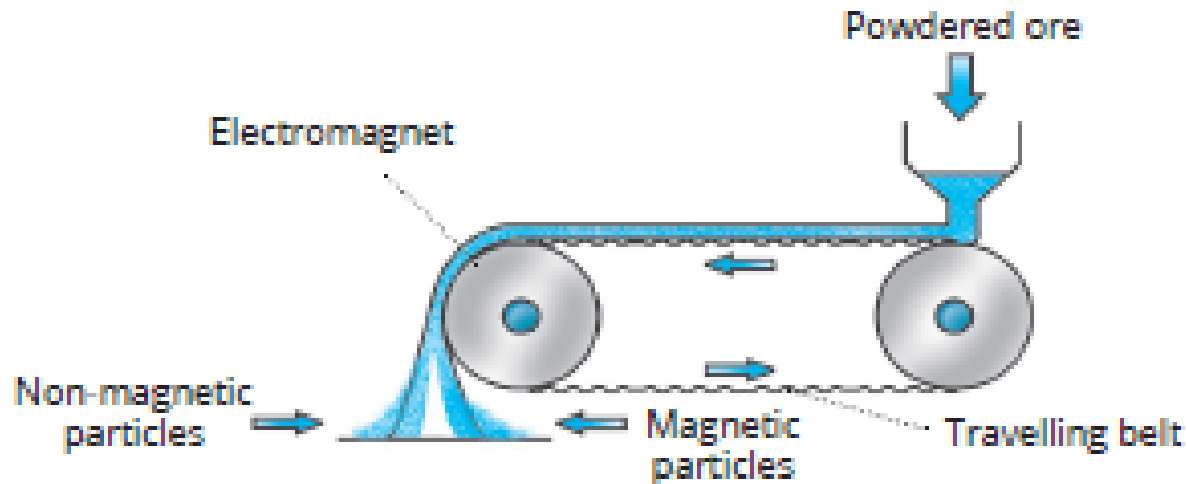


Enlarged view of air bubble showing the ore particles attached to it.



### c. Magnetic separation

This method is used where either the ore or the impurities are magnetic in nature. The powdered ore is fed onto a conveyer belt which moves over two rollers, one of them being magnetic. The magnetic constituents are attracted by the magnetic roller whereas the non-magnetic constituents are collected separately



### d. Chemical separation or leaching process

This method is based on the difference in the chemical reactivity of the ore and the gangue towards a particular reagent. The powdered ore is treated with a suitable chemical reagent. The reagent selectively dissolves the desired metallic component of the ore to form a soluble product. On filtration, impurities are left behind. The filtrate, is treated with suitable chemical reagent which precipitates the ore.





## **2. Conversion of concentrated ore into metal oxide**

The concentrated ore is subjected to any one of the following processes.

### **a. Calcination**

Calcination is the process of heating the concentrated ore below its melting point in the absence or limited supply of air. This removes the volatile impurities and the mass becomes porous.

### **b. Roasting**

Roasting is the process in which the concentrated ore is heated strongly below its melting point in the presence of excess of air. This removes the volatile impurities and the ore changes to its oxide.

## **3. Extraction of the metal by the reduction of metal oxide**

The metals are grouped into the following three categories for the purpose of their extraction:

**a.** Metal of high reactivity

**b.** Metals of moderate reactivity.

**c.** Metals of low reactivity.

The techniques used for the extraction of metals from their oxides belonging to the above three categories are given below.



Highly reactive metals	[ K Na Ca Mg Al ]	By electrolysis
Moderately reactive metals	[ Zn Fe Pb Cu ]	By reduction of oxide ore with carbon
Less reactive metals	[ Cu Hg Ag ]	By self-reduction of sulphide ore (by heating alone)
Least reactive metals	[ Au Pt ]	Occur in nature in the native state

**Reduction of oxides of highly reactive metals:** The highly reactive metals such as potassium, sodium, calcium, magnesium and aluminium are obtained by the electrolysis of their molten or fused oxides or chlorides

**Reduction of oxides of moderately reactive metals:** The oxides of moderately reactive metals cannot be reduced by heating alone. The oxides are reduced to corresponding metals by using suitable reducing agent such as carbon (coke), carbon monoxide or aluminium.



**Reduction of oxides of very less reactive metals:** The oxides of very less reactive metals (Cu, Hg, Ag, Pt and Au) can be reduced to free metals by the action of heat alone. No reducing agents is required. Mercury occurs in nature as the sulphide ore, cinnabar (HgS). When concentrated cinnabar is roasted in the presence of excess of air, mercury(II) sulphide is converted into mercury(II) oxide which is thermally unstable and decomposes to form mercury.

#### 4. Refining of impure metals

The metals obtained after the reduction of the metallic oxides are often associated with small amounts of various impurities. The presence of impurities within a metal alters the properties of a metal, therefore, impurities should be removed from the metal. The process of purifying a metal is called **refining**. Depending upon the nature of the metal and the nature of the impurities present within the metal, the following refining process can be used:

**a. Liquation   b. Distillation   c. Oxidation   d. Electrorefining**

#### Aluminium

Aluminium belongs to group IIIA of the periodic table. Aluminium never occurs free in nature and its most common ore is bauxite. The three ores of aluminium are: Bauxite:  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ,

Cryolite:  $\text{Na}_3\text{AlF}_6$    Corundum:  $\text{Al}_2\text{O}_3$



## Extraction of aluminium

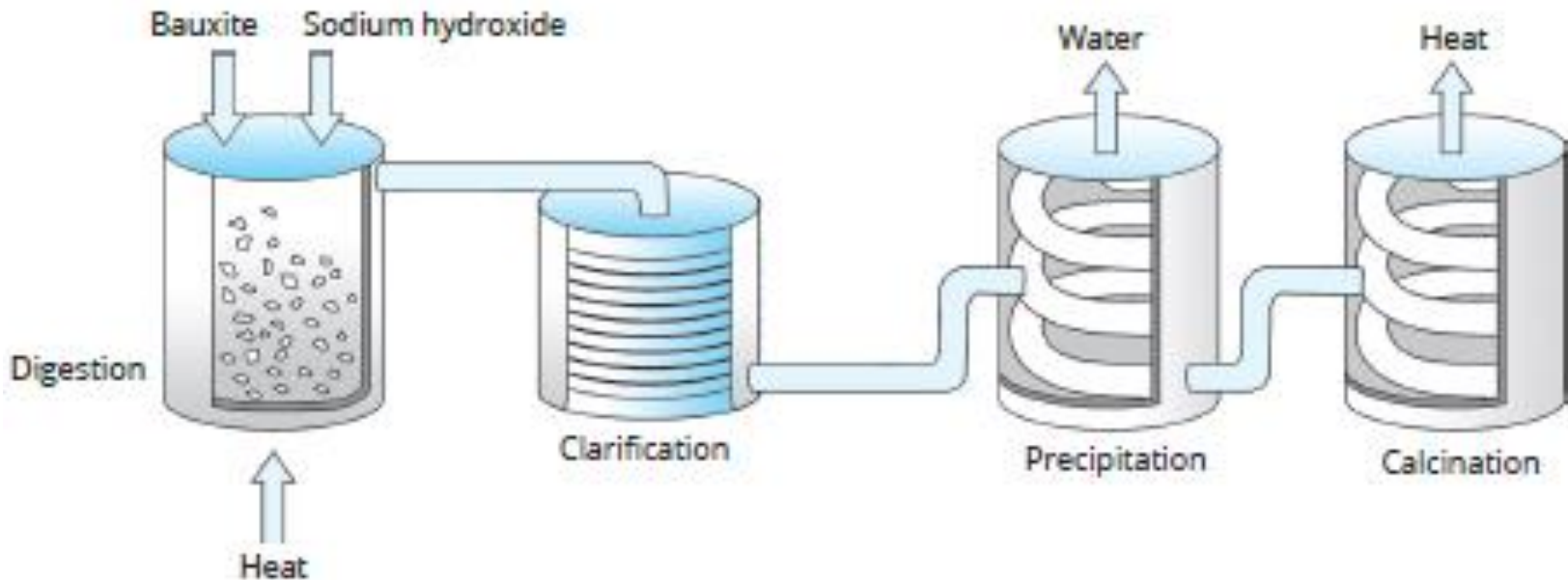
Aluminium is extracted mainly from bauxite,  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ .

### Dressing of ore

The ore is crushed, pulverized and ground into a fine powder and prepared for concentration.

### Concentration of ore

Bauxite is not concentrated by conventional physical methods but by chemical processes. It is concentrated by the Bayer's process.



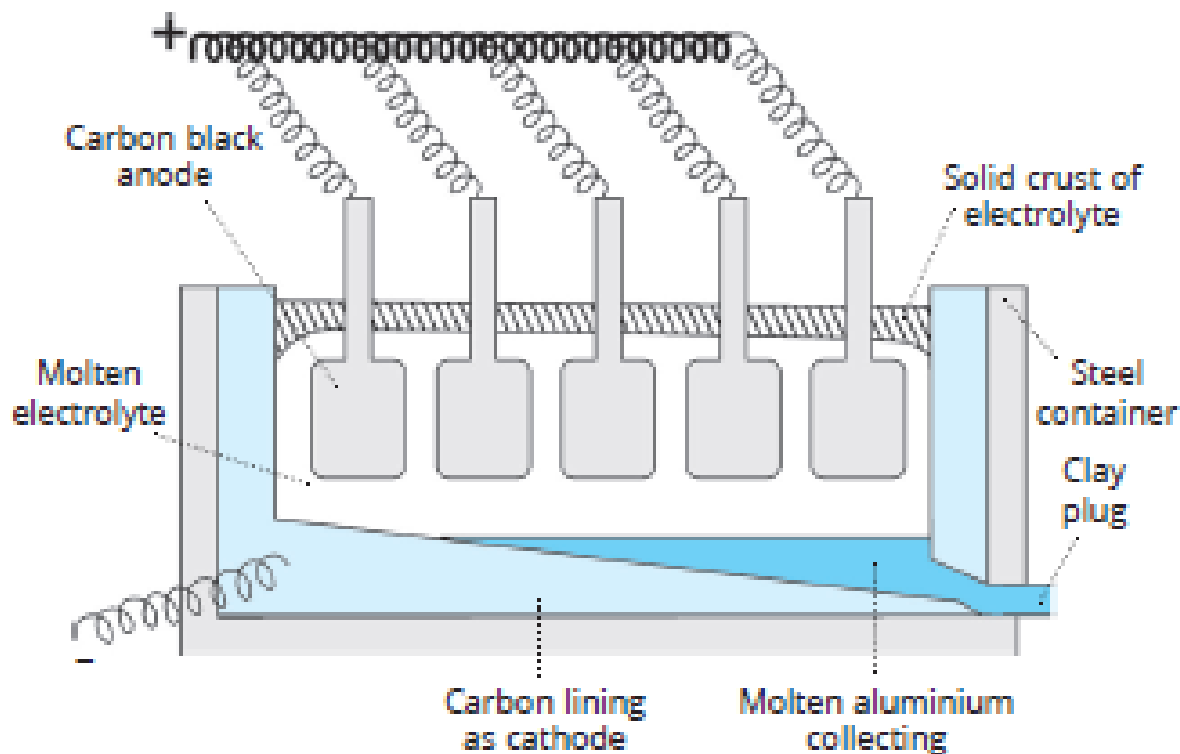
**Note:** Pl. refer to p112-113 of the book for steps in the Bayer's process



## Electrolytic reduction of fused alumina

Aluminium is usually extracted by the Hall-Heroult's process. Alumina is mixed with cryolite and fluorspar (1 : 3 : 1) and the electrolytic mixture is covered with carbon dust. The inner lining of the electrolytic cell acts as the cathode and thick graphite rods connected to the positive terminal of the electrical output act as anodes.

1. Cryolite and fluorspar acts as a solvent for the alumina and also lowers the fusion temperature; the mixture melts at  $950^{\circ}\text{C}$  instead of  $2050^{\circ}\text{C}$  thereby saving electrical energy.
2. Addition of fluorspar enhances the conductivity of the mixture since alumina is almost a nonconductor of electricity.

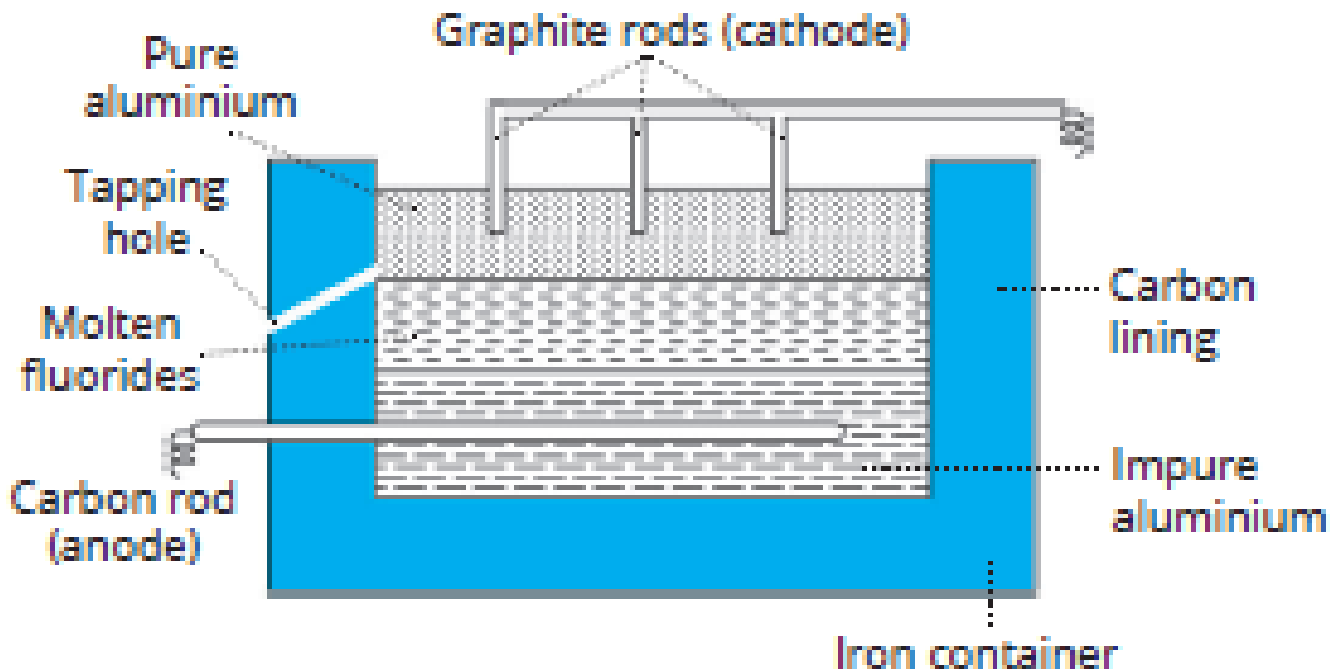




3. A layer of powdered coke is sprinkled over the electrolytic mixture to reduce heat loss due to radiation. It also prevents the carbon anode from burning in air at the point above the electrolyte.
4. The carbon anode has to be replaced periodically as the oxygen released oxidizes it.

## Purification of aluminium

Aluminium obtained can be purified further by electrolysis by a process called Hoopé's process.



Hoopé's process



**Refining of aluminium by Hoopé's electrolytic method:** The electrolytic cell consists of iron box lined inside with carbon. The cell consists of three layers of fused mass which differ in specific gravities. The upper layer of pure aluminium acts as a cathode. The middle layer consists of a mixture of fluorides of Al, Ba and Na. The lowest layer consists of impure aluminium which acts as anode. On passing electric current, aluminium is deposited at cathode from the middle layer and an equivalent amount of aluminium is taken up by the middle layer from the bottom layer. Thus, aluminium is transferred from bottom to the top layer through middle layer while impurities are left behind.

## Alloys

An alloy is a homogeneous mixture of two or more metals or a metal and a non-metal. Alloys are prepared to enhance the properties of the metal. The properties of alloys are entirely different from the constituent metals. This makes them more useful than the pure metals.

### Purpose of making alloys

- 1. To increase hardness:** Gold becomes hard when copper is added to it.
- 2. To increase tensile strength:** Chrome steel prepared by mixing iron and chrome has high tensile strength.



- 3. To improve the colour of a metal:** Alloy of a metal has a different colour. For example, when copper and aluminium are alloyed, aluminium bronze is formed which has a beautiful yellow colour. It is used for interior decoration.
- 4. To prevent the metal from corrosion:** Iron rusts in moist air. However, stainless steel made of iron, chromium, nickel and carbon does not rust easily.
- 5. To alter the chemical reactivity of a metal:** Chemical reactivity of a metal is altered by making its alloys. For example, sodium is highly reactive towards water but when alloyed with mercury, it reacts with water very slowly.
- 6. To alter the melting point of a metal:** The melting points of lead ( $327^{\circ}\text{C}$ ) and tin ( $232^{\circ}\text{C}$ ) are very high. But the alloy solder melts at  $180^{\circ}\text{C}$ . Thus, alloying of a metal lowers their melting point.

**Note:** Pl. refer to Table 7.2 , P- 115 for Alloys – composition, properties and uses





## SUMMARY

1. Metallurgy is the process of extracting metals from their ores.
2. An ore is the mineral from which the metal can be extracted profitably.
3. Minerals are compounds or elements that occur naturally in the earth's crust.
4. Gangue is the impurity associated with the minerals; these impurities are usually clay and silicates.
5. The process of metallurgy consists of the following stages:
  - a. Crushing and grinding of ore, i.e. dressing of ore
  - b. Concentration (or purification) of ore to remove gangue particles. It is done by
    - i. Hydraulic washing: Carried out for iron oxide ores
    - ii. Froth flotation: Carried out for sulphide ores
    - iii. Magnetic separation: Carried out for magnetic ores or impurities
    - iv. Chemical separation: For alumina



- c.** Conversion of metal ore into metallic oxide by:
  - i.** Calcination: Heating a carbonate ore in the absence of air.
  - ii.** Roasting: Heating a sulphide ore in the presence of air
- d.** Reduction of metal oxide to metal
  - i.** Oxide of metals of moderate reactivity reduced by heating oxide with carbon (coke), carbon monoxide, aluminium, hydrogen
  - ii.** Metal oxides of very low reactivity reduced by heating alone.
  - iii.** Metals of very high reactivity are reduced by electrolytic reduction.
- 6.** Extraction of aluminium: Aluminium is extracted from bauxite.
- 7. Alloy:** Homogeneous mixture of two or more metals or metals and non-metals
- 8. Amalgam:** An alloy of a metal with mercury

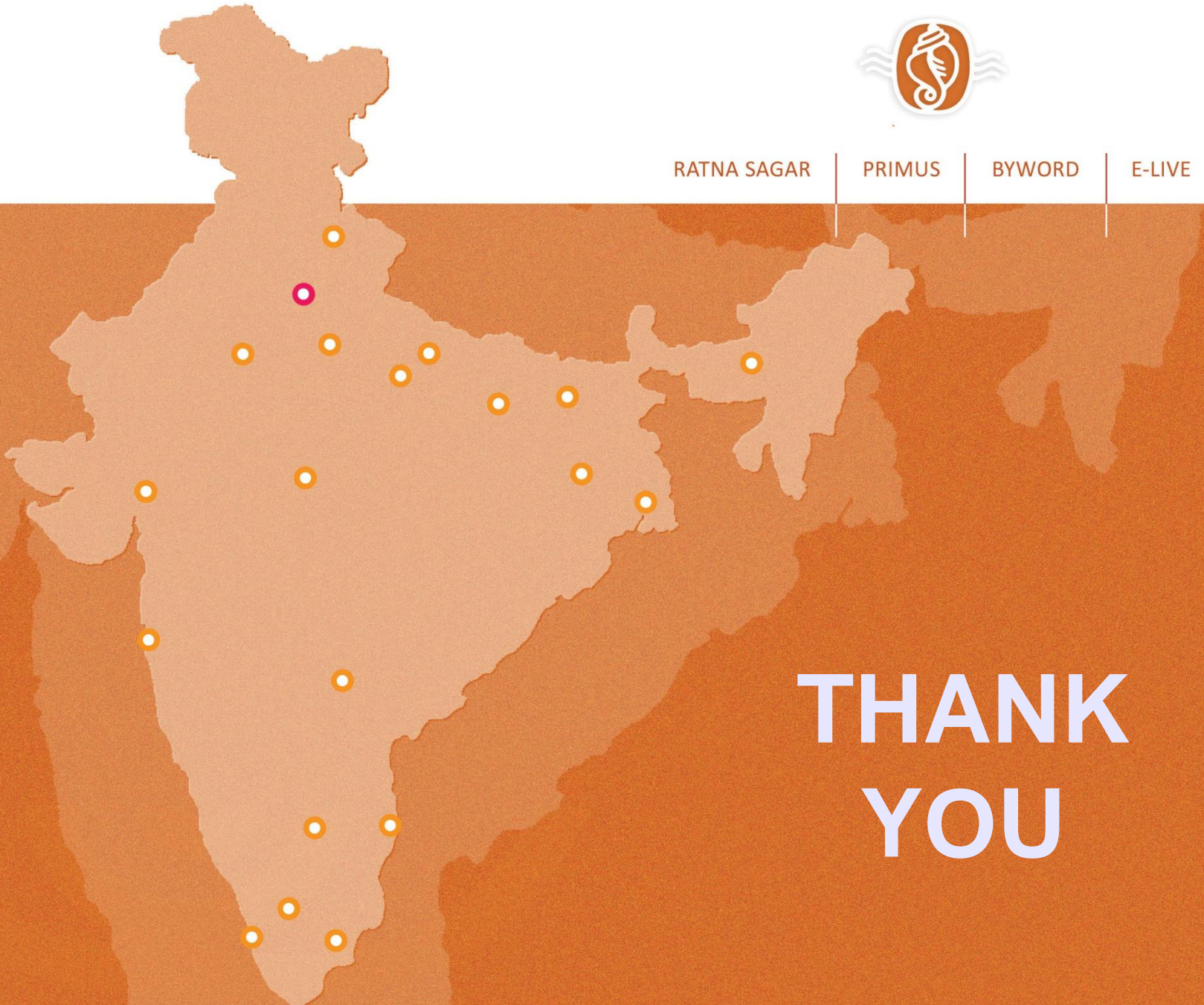


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