4 Production of Metals

Iron is used in making equipments ranging from pins to aeroplanes. Copper and aluminium have various uses in our daily life. Gold, silver and platinum used for making jewellery.

The chemically reactive metals are found in the combined state while the relatively unreactive metals (platinum, gold etc.) are found in the native state in the earth's crust.

Minerals

The metallic compounds generally seen in the earth's crust are called minerals.

Example : Bauxite ($Al_2O_3\,2H_2O$), Cryolite (Na_3AlF_6), Clay ($Al_2O_3\,2SiO_2\,2H_2O$) etc. are some of the minerals of aluminium.

1. What are the characteristics possessed, by minerals that are used for the extraction of metals?

• Abundance • Easily and cheaply separable •High metal content

Ore

*A mineral from which a **metal is economically, easily and quickly extracted**, is called the ore of the metal.*

Some metals and their ores are given below.

Metal	Ores	Chemical formula
Aluminium	Bauxite	$Al_2O_3\,2H_2O$
Iron	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
Copper	Copper pyrites	$CuFeS_2$
	Cuprite	Cu_2O
Zinc	Zinc blende	ZnS
	Calamine	$ZnCO_3$

2.All ores are minerals, but are all minerals ores. Justify.

The metallic compounds generally seen in the earth's crust are called minerals. But ore is a mineral from which the metal is economically, easily and quickly extracted.

Metallurgy

It involves all the processes leading to the separation of a pure metal from its ore.

There are three important stages in metallurgy.

1.Concentration of ores
2. Extraction of metal from concentrated ore
3. Refining of metals

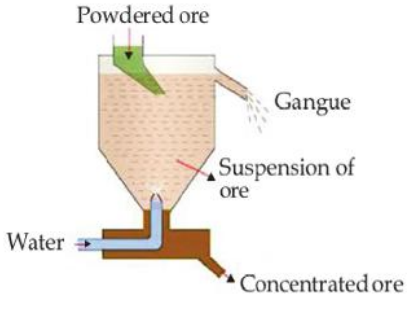
I. Concentration of ores

The process of removing the impurities (*gangue*) from the ore obtained from the earth's crust is termed concentration of the ore. Depending on the nature of the ore and the impurities, there are different methods of concentration.

1. Levigation or hydraulic washing

When the ***impurities are lighter and the ore particles are heavier***,the lighter impurities are removed by washing in a current of water

e.g.concentration of oxide ores, concentration of the ores of gold.



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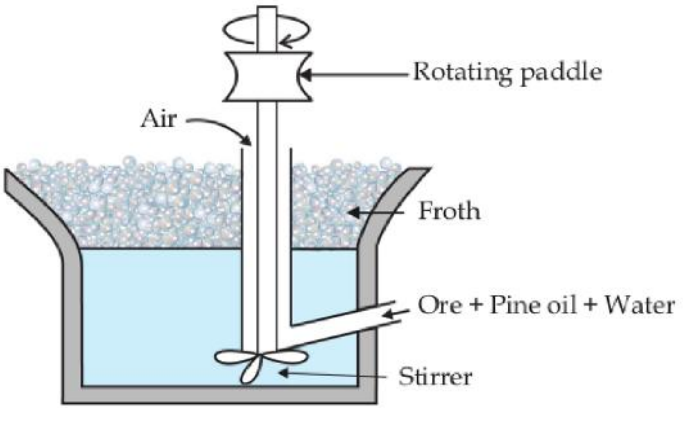
2. Froth floatation

This process is used when the ***impurities are heavier and the ore particles are lighter*** .

Sulphide ores are usually concentrated by this method.



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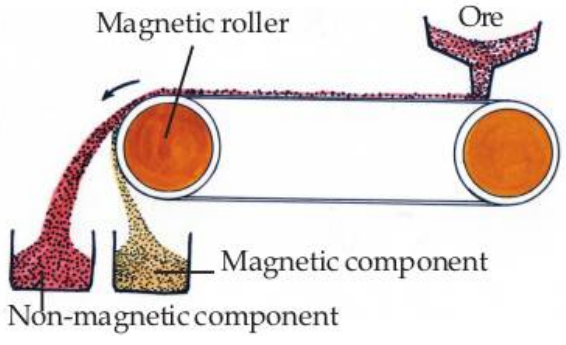
3. Magnetic separation

If ***either the ore or the impurity has magnetic nature***, concentration is done by this method. This method is used for the concentration of ***magnetite***, ore of iron and also to separate ***iron tungstate,*** the magnetic impurity from ***tin stone (SnO_2), the non-magnetic ore of tin.***



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4.Leaching

On adding the ore ***to a suitable solution***, a chemical reaction takes place and ***the ore dissolves. The insoluble impurities are filtered off.*** The pure ore is separated from the filtrate by a chemical reaction.

Bauxite, the ore of aluminium is concentrated by this method.

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3.Complete the table given below

Properties of ores	Properties of the impurities present in the ore	The method of concentration
High density	Low density	.....
Magnetic in nature	Non - magnetic nature	.....
Lighter sulphide ores	High density	.....
Aluminium ores that get dissolved in a solution	Insoluble in the same solution	.....

Answer:

Properties of ores	Properties of the impurities present in the ore	The method of concentration
High density	Low density	Levigation
Magnetic in nature	Non - magnetic nature	Magnetic separation
Lighter sulphide ores	High density	Froth floatation
Aluminium ores that get dissolved in a solution	Insoluble in the same solution	Leaching

4.Write the suitable method of concentration of the following.

1.Tinstone 2. Bauxite 3.Zinc Blende

Answer:

Tinstone	Magnetic separation
Bauxite	Leaching
Zinc Blende (Zn**S**)	Froth floatation

(Why froth floatation for Zinc blende? . Answer: It is the sulphide ore)

II.Extraction of metals from concentrated ore

It has usually two stages.

a) Conversion of the concentrated ore into its oxide.

b) Reduction of the oxide.

(a) Conversion of concentrated ore into its oxide

i)***Calcination :*** *Calcination* ***is the process of heating the concentrated ore in the absence of air at temperature below its melting point. Carbonates and hydroxides of metals decompose to form their oxides.***

ii) Roasting : *Roasting* ***is the process of heating the concentrated ore in a current of air at a temperature below its melting point. When the concentrated ore is subjected to roasting, the moisture present in it is removed as vapour. Sulphide ore combines with oxygen to form oxide.***

e.g. Cu_2S ore is converted to Cu_2O by roasting.

b) Reduction of the oxide

The process of extraction of metal from the oxide is reduction. Suitable reducing agents can be used for this purpose.

During the process of the production of metal, ***electricity, carbon, carbon monoxide etc. are used as reducing agents*** on the **basis of the reactivity** of the metal.

Electricity is used as the reducing agen***t to extract highly reactive metals like sodium, potassium and calcium*** from their ores.

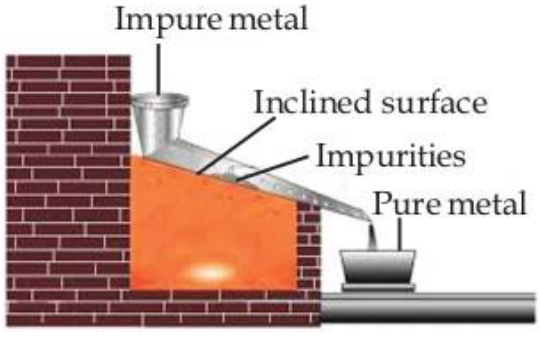
III.

III. **Refining of metals**

The metal obtained by reduction may contain other metals, metal oxides and small quantities of non metals as impurities. Refining of metals is the process of removal of these impurities to get the pure metal. Depending on the nature of metals and the impurities present in them, different methods are used for the refining of metals. Some methods are given below.

a. Liquation

Low melting metals like tin and lead may contain other high melting metals or metal oxides as impurities. On heating such metals on the inclined surface of a furnace, the pure metal melts and flows down leaving the impurities behind. This process is termed liquation.



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b. Distillation

This method is used for the refining of metals with ***low boiling points such as zinc, cadmium and mercury.*** When the impure metal is heated in a retort, the pure metal alone vapourises. The vapours are condensed to get the pure metal. This method is termed distillation.

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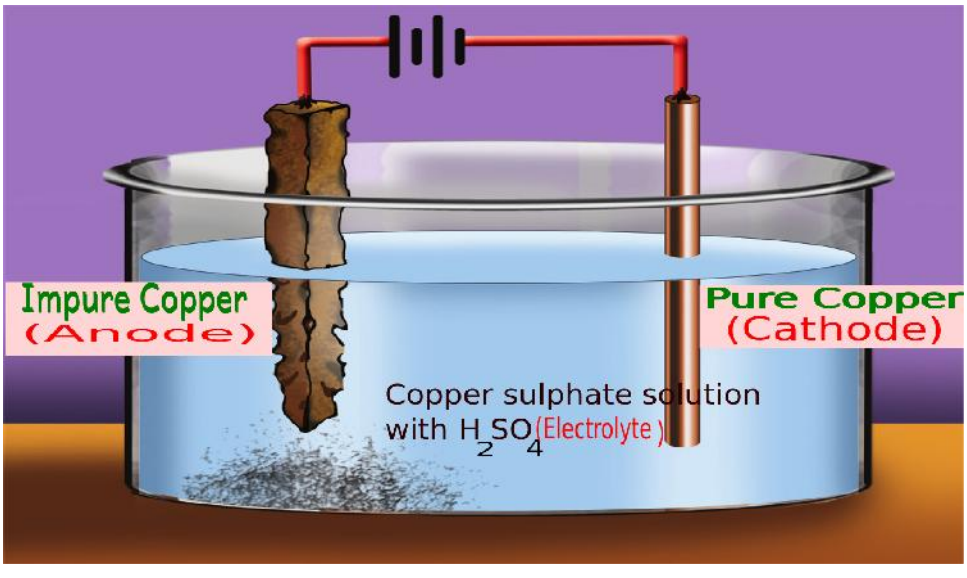
c.Electrolytic refining

Electrolytic refining is the process of refining a metal by the electrolysis of a solution of the salt of the metal, using a small piece of pure metal as the negative electrode and the impure metal as the positive electrode. Copper can be refined by this method.



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5. Observe the above picture and complete the following table.

Anode	
Cathode	
Electrolyte	
Equation of the chemical reaction taking place at anode	
Equation of the chemical reaction taking place at cathode	

Answer:

Anode	Impure Copper
Cathode	Pure Copper
Electrolyte	Copper sulphate solution
Equation of the chemical reaction taking place at anode	$Cu \longrightarrow Cu^{2+} + 2\bar{e}$
Equation of the chemical reaction taking place at cathode	$Cu^{2+} + 2\bar{e} \longrightarrow Cu$

Industrial production of iron

Have a look at a student's science diary related to the production of iron.

September 14

Today's class

Industrial production of iron(Day 1)

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• Minerals of iron- Haematite, magnetite, iron pyrites etc.

• Iron pyrites - fool's gold. Reason : It has a yellow brazen colour which resembles gold.

• Ores of iron- Haematite(Fe_2O_3) , Magnetite(Fe_3O_4)

Iron is industrially prepared **mainly from** haematite.

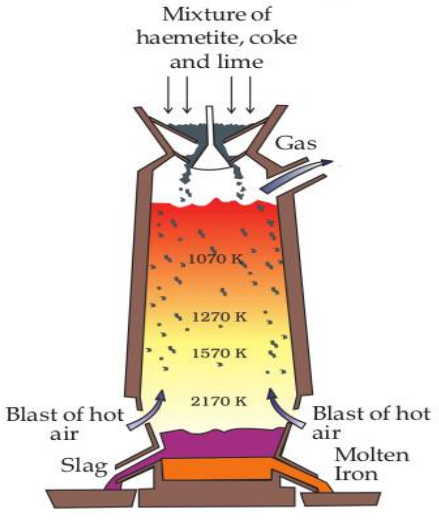
Impurities having low density are removed by **washing**.

Magnetic separation is also employed .

Roasting . During roasting , impurities like sulphur, arsenic, phosphorous etc. are removed as their gaseous oxides. Water is also expelled along with this.

[Washing. Magnetic separation. Roasting]

*But the **gangue, silica (silicon dioxide)** present in the ore is not removed.*



Haematite is converted into iron by using the blast furnace.

Blast of hot air is passed through the bottom of the furnace.

That is why this furnace is called blast furnace.

September 15

Today's class

Industrial production of iron (Day 2)

Process

Raw materials : **Haematite(Fe_2O_3), limestone($CaCO_3$) and coke(C).**

Hematite, limestone and coke are fed into the furnace through a special arrangement at the top of the furnace.

Reactions

$$C + O_2 \rightarrow CO_2 + Heat$$

$$CO_2 + C + Heat \rightarrow 2CO$$

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

The reduction of haematite into iron is done mainly by this carbon monoxide.

(CO is the reducing agent)

Calcium carbonate decomposes to give calcium oxide and carbon dioxide at high temperature in the furnace.

$$CaCO_3 \rightarrow CaO + CO_2$$

This calcium oxide (flux) reacts with SiO_2 (gangue) in the ore to form easily melting calcium silicate(slag).

$$CaO + SiO_2 \rightarrow CaSiO_3$$

Flux + Gangue → Slag

If the gangue is acidic in nature, basic flux is to be used.

If the gangue is basic in nature, acidic flux is to be used.

The molten slag being less dense, floats over the molten iron.

Pig iron

The molten iron obtained from the blast furnace is called pig iron.

It contains 4% carbon and other impurities like manganese, silicon, phosphorus etc.

Ore of iron	Haematite(Fe_2O_3)
Raw materials fed into the blast furnace	Haematite(Fe_2O_3), limestone($CaCO_3$) and coke(C)
The compound used for reducing haematite	Carbon monoxide (CO)
Gangue	SiO_2
Flux	CaO
Slag	$CaSiO_3$
Equation of formation of slag	$CaO + SiO_2 \rightarrow CaSiO_3$ Flux + Gangue → Slag

Different types of Alloy steels

Alloy steels are prepared by adding other metals to steel. Alloy steels have properties different from those of steel.

Alloy steels	Constituent elements	Properties	Uses
Stainless steel	Fe, Cr, Ni, C	Hard	For the manufacture of utensils, parts of vehicles
Alnico	Fe, Al, Ni, Co	Magnetic nature	For the manufacture of permanent magnets
Nichrome	Fe, Ni, Cr, C	High resistance	For making heating coils

Even though nichrome and stainless steel contain the same components they posses different properties. Find out the reason.

Answer: The percentage of various components are different. Different types of alloys are prepared *by changing the constituent elements and also by varying their proportion.*

Different types of alloys are prepared by changing the constituent elements and also by varying their proportion.

Extraction of Aluminium

Look at the following table

Aluminium	
Uses	**Characteristics**
Transmission of electricity	Aluminium is a very good electrical conductor
Kitchen Utensils	Aluminium is a very good thermal conductor
Reflectors	Metallic Lustre
Parts of aeroplanes in the form of alloys	Light weight and strength

In olden days, the cost of extraction of Aluminium was very high and hence it was costlier than gold.

Science Diary

September 21

Extraction of Aluminium

Main Ore – Bauxite

Aluminium is industrially produced through two important stages.
They are
1.Concentration of bauxite
2. Electrolysis of concentrated alumina.

1.Concentration of bauxite

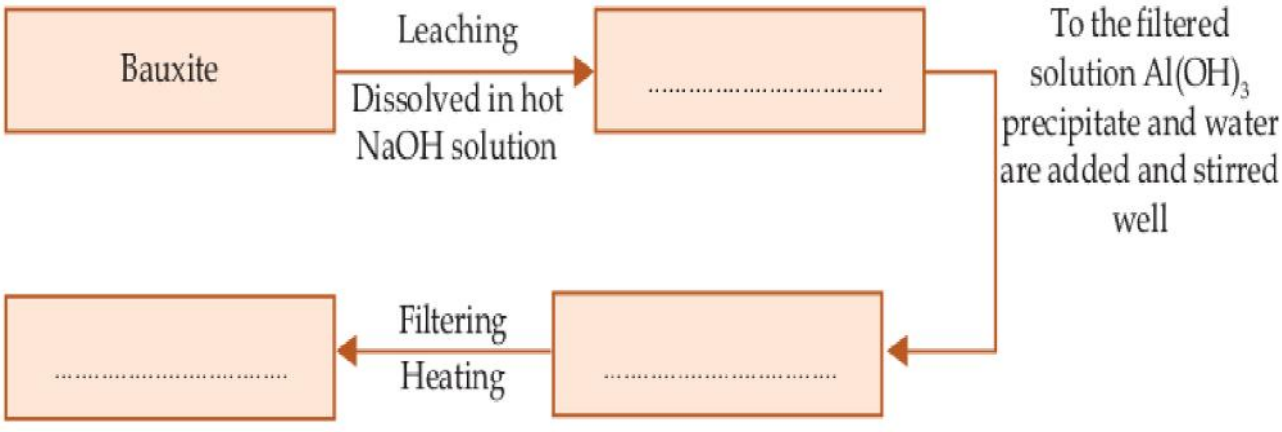
Bauxite is concentrated through the leaching process. Impure bauxite is added to hot concentrated NaOH solution, where it gets converted into sodium aluminate. Impurities are then filtered off. A small quantity of freshly prepared aluminium hydroxide precipitate is added and diluted with water, to get more amount of $Al(OH)_3$ precipitate. The precipitate is separated, washed and then heated strongly to get alumina.

Summary

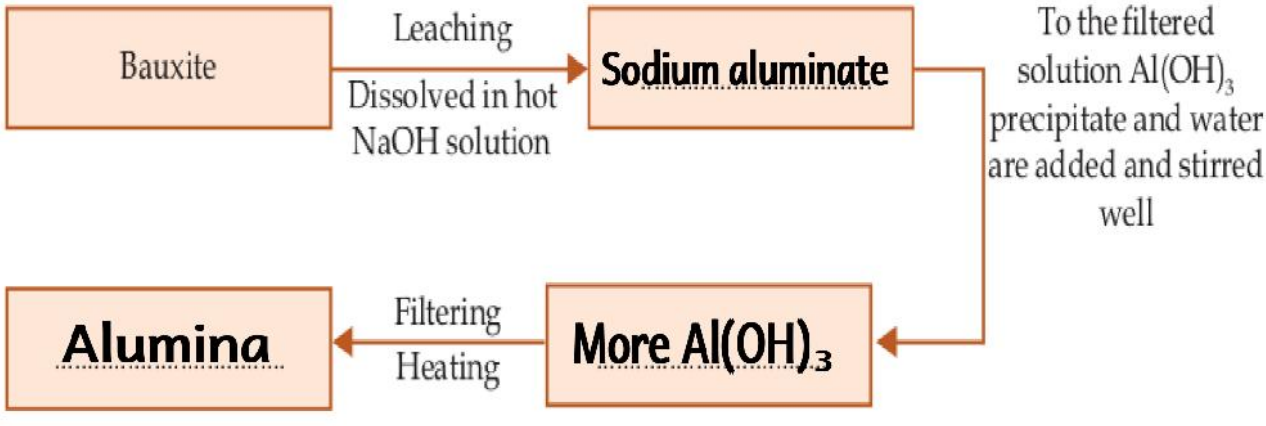
Leaching

- Hot Concentrated NaOH + Impure Bauxite → Sodium aluminate.
- Sodium aluminate + ***small*** quantity of freshly prepared aluminium hydroxide → ***More amount*** of $Al(OH)_3$ precipitate
- The precipitate is separated, washed and then heated strongly → Alumina

6. Complete the following table.



Answer:



7.Complete the chemical equation for the reaction taking place when Aluminium hydroxide is heated.

Answer: $2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O$

8.Which method can be used for separating aluminium from alumina? **Answer:** Electrolysis

9. Can we use carbon as the reducing agent? **Answer:**No.

Reason: Aluminium is manufactured by the reduction of alumina using electricity as as reducing agent since the reactivity of aluminium is very high.

2. Electrolysis of concentrated alumina.

Science Diary

September 22

- For Electrolysis :

  The Concentrated alumina (Al_2O_3) + Molten cryolite (Na_3AlF_6)

- For Electrolyte :

  The Concentrated alumina (Al_2O_3) + Molten cryolite (Na_3AlF_6)

- Why Cryolite is added? :

  1. **To reduce the melting point of alumina**
  2. **To increase its electrical conductivity.**

- Reactions while electricity is passed through it :

  $Al_2O_3 \rightarrow 2Al^{3+} + 3O^{2-}$

- Cathode

  Carbon lining

- Anode

  Carbon rods

- Reaction at the negative electrode(cathode) / Reaction of aluminium ion

  $Al^{3+} + 3\bar{e} \rightarrow Al$

- Reaction at the positive electrode(anode) / Reaction of oxide ion

  $2O^{2-} \rightarrow O_2 + 4\bar{e}$

  $C + O_2 \rightarrow CO_2$

- In this process carbon anodes are replaced from time to time. Why?

Answer: Here carbon rods are the anode. At the anode, the following reaction occurs

$2O^{2-} \rightarrow O_2 + 4\bar{e}$

$C + O_2 \rightarrow CO_2$

This slowly burns away the anode. Hence anodes need to be replaced periodically.

Let us Assess

1.Which of the properties of metals is utilized in the following instances?

(a) Aluminium utensils are used for cooking.

(b) Copper is used for making vessels.

(c) Gold wires are used in ornaments.

Answer:

(a) Aluminium utensils are used for cooking **-High thermal conductivity**

(b) Copper is used for making vessels **- Low reactivity**

(c) Gold wires are used in ornaments**- Low reactivity, Metallic Lustre**

2. What are the factors to be considered while selecting minerals for the extraction of metals?

Answer: **Abundance · Easily and cheaply separable ·High metal content**

3. Write the different stages involved in metallurgy?

(Already discussed)

4. What are the different methods for the refining of metals?

(Already discussed)

5. How is iron extracted industrially?

(Already discussed)

6. Write the uses of the following:

Nichrome, Stainless steel, Alnico

(Already discussed)

7. Explain the process of producing alumina from bauxite.

(Already discussed)

8. Explain the method of obtaining pure aluminium from alumina by electrolysis.

(Already discussed)

Production of Metals

Stages of metallurgy - A Quick Review

Concentration of ores	Extraction of metal from concentrated ore	Refining of metals
It is the process of removing the impurities (*gangue*) from the ore.	It has two stages (1) Conversion of concentrated ore into its oxide	It is the process of removal of impurities like other metals, metal oxides and small quantities of non metals remained after the reduction.
1. Levigation (Hydraulic washing)	**i)Calcination**	**a.Liquation**
Impurities are lighter and the ore particles are heavier.	Heating the concentrated ore in **the absence of air** at a temperature below its melting point.	On heating low melting metals on an inclined surface of a furnace, the pure metal melts and flows down leaving the impurities behind.
Oxide ores , ores of gold	*Carbonates and hydroxides of metals*	*Low melting metals like tin and lead*
2. Froth floatation	**ii) Roasting**	**b. Distillation**
Impurities are heavier and the ore particles are lighter.	Heating the concentrated ore **in a current of air** at a temperature below its melting point.	The impure metal is heated in a retort, the pure metal alone vapourises The vapours are condensed to get the pure metal.
Sulphide ores	The moisture present in it is removed as vapour. Sulphide ore combines with oxygen to form oxide. **Cu_2S ore is converted to Cu_2O** by roasting.	For metals with low boiling points such as **zinc, cadmium and mercury.**

3. Magnetic separation	(2) Reduction of the oxide	c.Electrolytic refining
Either the ore or the impurity has magnetic nature	*Electricity, carbon, carbon monoxide etc. are used as reducing agents on the basis of the reactivity of the metal.*	*Using a solution of the salt of the metal.* *A small piece of pure metal as the negative electrode* ***and the impure metal as the positive electrode.***
1.**Magnetite,** ore of iron. 2.***Iron tungstate, the magnetic impurity*** from tin stone(SnO_2), the non-magnetic ore of tin	Electricity is used as the reducing agent to extract highly reactive metals like sodium, potassium and calcium from their ores.	Refining of copper
4.Leaching		
Ore + Suitable solvent. Chemical reaction occurs and ore dissolves. The insoluble impurities are filtered off. The pure ore is separated from the filtrate by chemical reaction.		
Bauxite, the ore of aluminium		