

# Mineral Resources– Metals and Non-metals

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We use large number of materials but very few of them occur naturally. Most of these are obtained by transforming a relatively small number of naturally occurring raw materials chemically into more useful substances. You have learnt in earlier lessons that environment provides all the necessary support for the existence of mankind through its various components and resources both biotic and abiotic. In this lesson you will learn about some abiotic resources and how they are used to obtain useful substances and materials.

## OBJECTIVES

After completing this lesson, you will be able to:

- differentiate between metals and non-metals on the basis of their properties;
- distinguish between minerals and ores;
- recognize various metallurgical processes in the extraction of common metals–Fe, Al and Cu;
- explain the corrosion of metals;
- list various uses of metals and their alloys;
- explain the preparation, properties and uses of various non-metals–H, Si and P;
- describe the allotropes of P and S and state the use of sulphuric acid.

## 19.1 MINERAL RESOURCES

### 19.1.1 Minerals and ores

There are 83 naturally occurring elements. The remaining ones can be produced in the laboratory only by nuclear reactions about which you learned in lesson 14.

Out of all the naturally occurring elements oxygen (O), silicon (Si), aluminium (Al) and iron (Fe) are four most abundant elements (arranged in the decreasing order) and account for more than 87% of earth's crust (lesson 2, fig. 2.2). Only few elements are found in the **free or native state** i.e. in the uncombined state. Cu, Ag, Au and Platinum are some of them.

The remaining elements are found only in chemically combined state, that is, in combination with one or more other elements as minerals. A **mineral** is a

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*naturally occurring homogeneous inorganic substance having a definite chemical composition and characteristic crystalline structure, colour and hardness.* Although all minerals are sources of metals, it is not always possible to recover metals from them economically. A mineral from which it can be done is called an **ore**. *Thus, ore is a mineral from which a metal can be extracted profitably.* For example, copper pyrite ( $\text{CuFeS}_2$ ) is a mineral of copper. Copper can be profitably extracted from it only if its copper content is 4% or more. If so, it is called the **ore** of copper otherwise a mineral.

### 19.1.2 Metals and non-metals

There are 83 naturally occurring elements. They can be broadly divided into two categories namely, metals and non-metals. The two differ widely in their physical and chemical properties. The properties which distinguish metals from non-metals are given in the tabular form below.

**Table 19.1(A): Differences in physical properties of metals and non-metals**

| Property                            | Metals   | Non-metals  |
|-------------------------------------|--|---|
| State                               | They are solids at ordinary temperature and usually non-volatile (exception: mercury which is a liquid).     | They exist in all the three states, i.e. solid, liquid and gas. They are either gases or volatile liquids at low temperatures (exception: diamond and boron which are hard solids). |
| Density                             | Their density is generally high.   | Their density is generally low.   |
| Metallic lustre                     | They possess metallic lustre and take a high polish.   | Generally they do not possess metallic lustre (exception: graphite and iodine).   |
| Malleability and ductility          | They are malleable and ductile. They can be beaten into thin sheets and drawn into wires (exception: Bi)     | They are neither malleable nor ductile.   |
| Alloy formation                     | They form alloys with other metals and some non-metals.  | They do not form alloys (except carbon, silicon and phosphorus).  |
| Thermal and electrical conductivity | They are good conductors of heat and electricity (exception: lead which is a poor conductor of electricity). | They are poor conductors of heat and electricity (exception: graphite and gas carbon).  |

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**Table 19.1(B): Differences in chemical properties of metals and non-metals**

| Property               | Metals  | Non-metals  |
|------------------------|---|---|
| Nature of oxides       | They generally form basic oxides which form alkalis with water For example:<br>$4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$<br>sodium          sodium oxide<br>$\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$<br>sodium<br>hydroxide<br>(alkali) | They form acidic oxides only.   |
| Hydrides               | They either form no compound with hydrogen or form unstable hydrides.   | They form stable hydrides with hydrogen.  |
| Electrochemical nature | They are electropositive elements and form cations. They are liberated at cathode during electrolysis. Some metals like chromium and manganese form some anions also with other elements like oxygen.   | They are electronegative elements and form anions. They are liberated at the anode during electrolysis (exception: hydrogen).   |
| Action of acids        | They generally dissolve in mineral acids forming a salt with the evolution of a gas. For example:<br>$\text{Zn} + \text{H}_2\text{SO}_4 \rightarrow \text{ZnSO}_4 + \text{H}_2$<br>zinc sulphuric acid    zinc hydrogen sulphate  | They either do not dissolve in mineral acids or form the corresponding oxacids*. For example:<br>$\text{P}_4 + 20\text{HNO}_3 \rightarrow 4\text{H}_3\text{PO}_4 + 20\text{NO}_2 + 4\text{H}_2\text{O}$ |
| Solubility             | They generally dissolve by a chemical reaction.   | Many non-metals dissolve without any chemical change-taking place. For example: chlorine, bromine or iodine dissolves in water.   |

\* Acids which contain oxygen are called oxoacids or oxyacids.

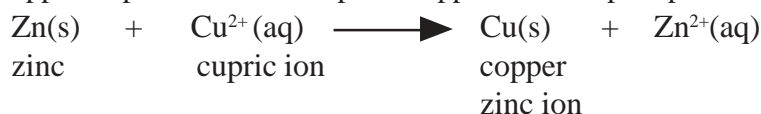
### 19.1.3 Activity series of metals

In the last section you learned that metals are electropositive in nature. In all their chemical reactions metals give off their electrons i.e. they act as reducing agents and themselves get oxidized. This process may be written as:



Metals can give off their electron to the atoms of non-metals, hydrogen ions and even to ions of other metals. Electropositive character varies in different metals. A metal that can lose electrons more easily is more electropositive and would be more active in nature. Such a metal when dipped in a solution of salt of a less

active metal would displace it (less active metal). Thus if a zinc rod is dipped in a solution of copper sulphate it would displace copper which is precipitated.



This happens because zinc is more electropositive in nature than copper. The arrangement of metals in the decreasing order of their activities is known as **activity series** or **electrochemical series**. It is also known as **reactivity series**. A portion of this series is given below:

Ca, Na, Mg, Al, Zn, Cr, Fe, Pb, (H), Cu, Hg, Ag

Hydrogen is the only non-metal that stands in this series. It is because hydrogen also shows electropositive character like metals. Any metal can displace all the metals that are on its right-side and which follow it. In other words, a metal can be displaced by only those metals which precede it and are on its left-hand side. Thus, Zn can displace any of Cr, Fe, Pb, H, Cu, Hg and Ag, metals which follow it and are placed on its right-hand side. But zinc can be displaced only by those metals which precede it and are on its left-hand side i.e. Ca, Na, Mg and Al.

#### 19.1.4 Mineral resources in India

India is very fortunate to have been gifted by nature with rich mineral resources. It is the chief producer of *mica* and has monopoly for *monazite*, a mineral of thorium and has vast reserves of many important minerals. You will learn more about our mineral wealth in the discussion of various metals later in this lesson.

#### CHECK YOUR PROGRESS 19.1

1. Name two most abundant elements in earth's crust.
2. Which two of the following metals occur in native state?  
Na, Cu, Zn, Ag, Fe
3. An element A forms basic oxide whereas another element B forms an acidic oxide. Which of them is expected to be malleable and ductile?
4. A non-metallic element forms a cation and is liberated at cathode during electrolysis. Which element could it be?
5. Which of the following metals can displace hydrogen from solutions of acids?  
Ag, Zn, Cu

#### 19.2 METALS

We see a large variety of machines around us. Today man cannot live without machines. Some of them perform simple mechanical operations and substitute for the weak muscles of man like bulldozers, diggers, machine tools, and agricultural equipments. Others do very precise jobs that man can never do himself like high precision machine tools. Yet others substitute in many cases for human brain like computers. The pace of progress in any field- industry, transport or agriculture, is controlled by the number of machines that are produced and are usefully employed. But all machines are made of metals. Indirectly, the rate of development of a nation can be measured by the rate at which it produces and

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consumes various metals. In this section we will learn about various metallurgical operations which are used for extraction of metals from their ores and also about extraction, purification and properties of three important metals namely iron, aluminium and copper.

### 19.2.1 Basic metallurgical processes

**Metallurgy** is the branch of science dealing with extraction of metals from their ores. The three main steps in extraction of a metal from its ores are (i) concentration of ore, (ii) production of the metal and (iii) purification of metals. Now we will learn about these steps.

#### 19.2.1a Concentration of ore

The preliminary treatment of an ore to separate the waste materials from it is called its concentration. The waste materials usually associated with the ore are clay and silicates. They are collectively called the *gangue*. The method used for concentration of ore depends on the nature of gangue associated with it as well as its own nature. Various methods used are:

##### (a) Magnetic separation

This method is used when a mineral is magnetic in nature and is attracted towards a magnetic field whereas the gangue is not. A schematic diagram of the process is shown in Figure 19.1 For example, separation of *magnetite* ( $\text{Fe}_3\text{O}_4$ ) and *pyrolusite* ( $\text{MnO}_2$ ) from gangue can be done using strong electromagnets.

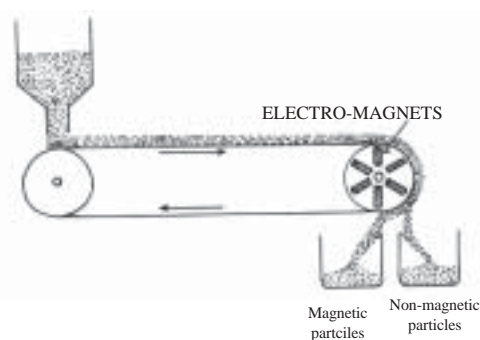


Fig. 19.1 Schematic diagram of magnetic separation

##### (b) Hydraulic washing

This method is used due to a large difference in densities of ore which is heavy and of the gangue which is light. The lighter gangue particles are washed away in a stream of water while heavier minerals stay back.

##### (c) Froth floatation

This method is used for the concentration of sulphide ores. The powdered ore is mixed with water and oil and air is bubbled through it as shown in Figure 19.2.

This produces froth which floats on the surface. The oil preferentially wets the sulphide mineral particles which are carried by air bubbles to the surface of the mixture and are skimmed off. The froth is allowed to collapse and dried to recover the mineral.

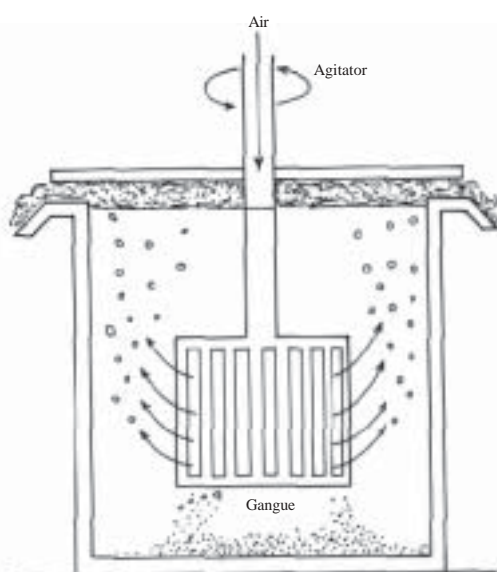


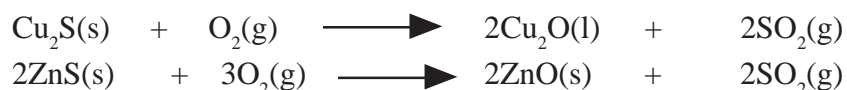
Fig. 19.2 Froth floatation process

**(d) Calcination**

It is used to remove volatile matter like moisture or water of crystallization from the ore by simple heating.

**(e) Roasting**

It is used to remove volatile impurities and to convert a sulphide or carbonate ore into oxide by heating it in a stream of air. For example

**19.2.16 Production of metal**

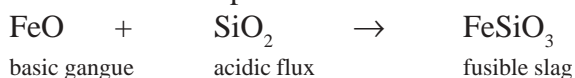
After enriching the ore, it is converted into free metal. Metals in their combined state are always present as cation in their minerals. Therefore, **production of a free metal is always a reduction process**. The method of reduction depends upon the activity of the metal. Different methods employed are shown in the following table in which metals have been arranged in the decreasing order of their activity. Highly reactive metals are reduced by carrying out electrolysis of their molten salts like chlorides or oxide. The less reactive metals are produced by reduction of the metal oxide with a more reactive metal, or reduction with coke (carbon) and carbon monoxide. Table 19.2 lists the reduction processes which are employed for extraction of some metals.

**Table 19.2: Reduction processes employed to obtain some metals from their ores**

| Metals                              | Reduction process  |
|-------------------------------------|--|
| Lithium, sodium, magnesium, calcium | Electrolytic reduction of their chlorides  |
| Aluminium                           | Electrolytic reduction of its oxide $\text{Al}_2\text{O}_3$  |
| Chromium, iron, manganese, zinc     | Reduction of the metal oxide with a more reactive metal, or reduction with coke (carbon) and carbon monoxide |
| Copper, gold, silver                | Roasting of their sulphide ores  |

**Removal of impurities associated with ores**

Some impurities are also associated with most of the ores which are called **gangue**. They are usually infusible in nature and are removed with the help of a flux. **Flux** is a material that is added during its reduction in a furnace to convert infusible impurities (gangue) into a fusible substance that is called **slag** which is separated from the molten metal and removed. The nature of flux depends upon the nature of impurity to be removed. An acidic flux (like sand) is added to remove basic impurities like FeO:



A basic flux (e.g. CaO) is added to remove acidic impurities (e.g. sand):



### 19.2.1c Refining of metals

The metals obtained by the metallurgical processes described in the preceding sections usually need further treatment to remove the impurities. The refining process removes undesirable impurities from the metal. The following are the most commonly used methods of refining.

#### (a) Distillation or sublimation

This removes nonvolatile impurities from volatile metals like zinc and mercury which are obtained in the pure state.

#### (b) Liquation

Readily fusible metals like lead, tin and bismuth are refined by this method. Impure metal is melted on the sloping surface (called hearth). Pure metal melts and flows down and is collected separately while impurities are left behind.

#### (c) Electrolytic refining

It is the most commonly used method of refining of metals and produces highly pure metals. Impure metal is made the anode (positive electrode) and a piece of pure metal the cathode (negative electrode). These electrodes are dipped in a solution of a soluble salt of the metal. When electric current is passed, impure metal from the anode gradually passes into the solution and pure metal from the solution gets deposited on the cathode. Thus, effectively pure metal from anode passes to cathode gradually. Impurities either collect below the anode as **anode mud** or dissolve in the solution. Copper, aluminium etc. are purified in this way.

#### (d) Oxidation

Impurities like carbon, phosphorus, silicon etc. are removed as oxides by passing air through molten impure metal. Iron is purified by this method.

#### (e) Zone refining

This method is used for obtaining extremely pure metals and silicon. The metal (or silicon) rod which has already been purified extensively is placed in a quartz tube filled with a noble gas. It is moved slowly through a heating coil that melts only a small portion of the metal rod. Pure metal crystallizes from the melt. The impurities are more soluble in the molten metal and are carried to the end of the rod. The metal rod is moved repeatedly through the heating coil. Impurities collect at the end of the metal rod (Figure 19.3). This end of the metal rod is cut off and discarded. The remaining metal is extremely pure.

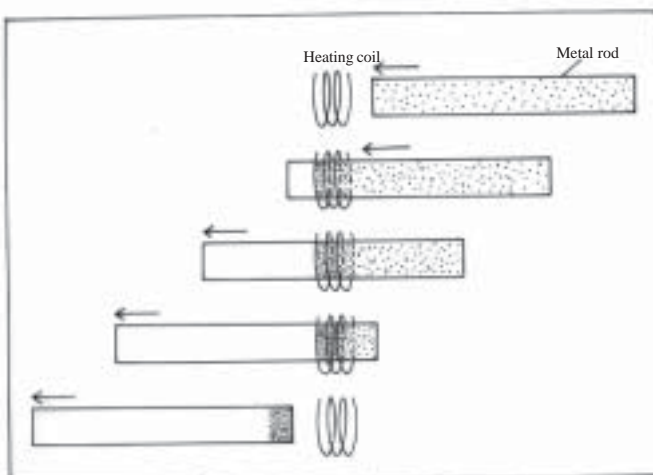


Fig. 19.3 Zone refining



After learning about steps involved in extraction of metals from their ores we will now learn how three important metals, iron, aluminium and copper are extracted from their ores.

### 19.2.2 Iron

Iron is the chief metal used for making machinery and therefore plays very important role in growth of industry. It has been in use since long time. In India the art of making iron had reached an advanced state. This is testified by Ashok's Iron Pillar in Delhi and iron joints used in the temple of Puri which remained rust-free even centuries after they were made. Aristotle in 340 B.C. provided a description of the manufacture of a type of steel called *wootz steel* which was first produced in India but later on became famous as Damascus steel. It was renowned for its suppleness (bending easily), its ability to maintain a cutting edge and its use in making swords.

#### 19.2.2a Ores of iron

Haematite ( $\text{Fe}_2\text{O}_3$ ) is the most abundant ore of iron which is a reddish brown ore. Some other ores of iron are magnetite ( $\text{Fe}_3\text{O}_4$ ), lemonite ( $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ ), siderite ( $\text{FeCO}_3$ ) and pyrite ( $\text{FeS}_2$ ). Out of these, haematite and magnetite are more suitable for the extraction of iron. Huge deposits of haematite are available in India in Mayurbhanj, Singhbhum and Mysore. Iron and steel are manufactured at Asansol, Jamshedpur, Durgapur, Bhilai and other places.

#### 19.2.2b Extraction of iron

The following are the main steps in the extraction of iron from its ores:

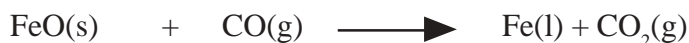
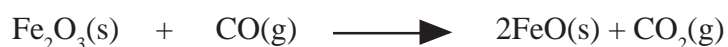
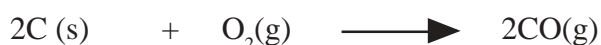
##### a. Concentration of ore

Ore is first broken into small pieces and if necessary it is washed with water. Usually the ore is rich enough and does not need any concentration.

In case the carbonate (*siderite*) or sulphide (*pyrites*) ores are used, they are roasted to convert to oxide and in case hydrated oxide (*limonite*) is used it is calcinated to remove the water of crystallization. In case of oxide ore (*haematite* or *magnetite*) these treatments are not required.

##### b. Reduction to iron

The oxide ore is reduced chemically by carbon monoxide which is formed in a *blast furnace* by reaction of coke with air (shown in the box). A mixture of iron ore, limestone,  $\text{CaCO}_3$ , and coke, called *charge* is fed into the furnace. The main reactions that occur are given below.





### Blast Furnace

Blast furnace is a chimney-like structure made of steel plates and lined inside with firebricks.

A mixture of iron ore, limestone,  $\text{CaCO}_3$ , and coke, called **charge** is introduced into the furnace from the top. A blast of hot air, fed from near the bottom into it. The oxygen in the air reacts with coke to form mainly carbon monoxide and some carbon dioxide. These reactions are highly exothermic in nature and a lot of heat is generated. The hot gases rise in the furnace and react

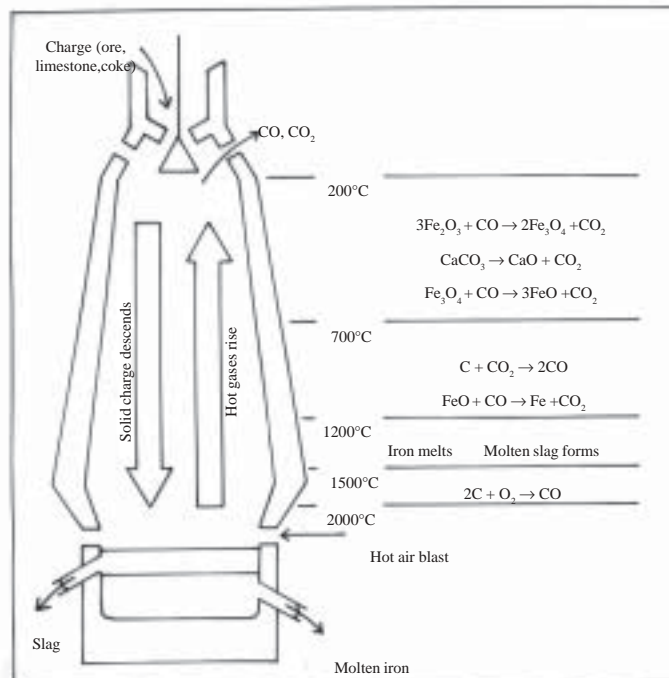
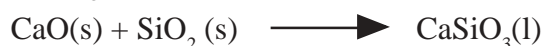


Fig. 19.4 Manufacture of iron in a blast furnace

with iron oxide ore. Before the iron ore falls to the bottom of the furnace most of it is reduced to iron. At the bottom of the furnace the temperature is high enough to keep it in the molten state. It is taken out from the outlet near the bottom of the furnace. Lime stone decomposes into calcium oxide which then reacts with impurities ( $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$ )



The mixture of calcium silicate and calcium aluminate, known as *slag*, remains in molten state and being lighter than molten iron floats on it and is removed from time to time from a separate outlet.

The iron obtained from blast furnace is called **cast iron**. It is also called **pig iron**. It contains about 95% iron and about 5% carbon along with many other impurities in small amounts like silicon, phosphorus, manganese and sulphur. It has a relatively low melting point and can be cast into desired shapes.

#### 19.2.2c Properties of iron

##### (A) Physical properties

- (i) Pure iron is a silver white metal.
- (ii) It is strongly attracted by magnets.

Commercially it is obtained in three forms: cast iron, wrought iron and steel.

(B) Chemical properties

- (i) When exposed to atmosphere, iron gets rusted. Rust is hydrated ferric oxide in which the amount of water associated varies. It is therefore represented as  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ . For the rusting process oxygen (air) and water are required. It is accelerated by acidic substances like  $\text{CO}_2$ ,  $\text{SO}_2$  and retarded by alkalis. Presence of NaCl and other salts also increases the rusting rate. Completely homogeneous iron does not rust.

**ACTIVITY 19.1**

**Aim:** To study the rusting process

**What is required?** A few test tubes, corks, common salt, sodium hydroxide *or* washing soda, iron nails, small piece of zinc from used cells and a small piece of copper wire.

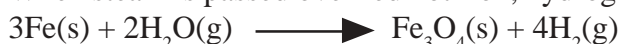
**How to do?** Take 7 test tubes. Paste labels on each of them and mark them as 1, 2 and so on. Prepare the test tubes as given below. (Fill about half the test tube with the liquid/solution mentioned.)

| Test tube no. | Liquid solution   | What to observe?   |
|---------------|---|--|
| 1             | Boiled water + iron nail and cork the test tube                                       | Practically no rust is formed  |
| 2             | Tap water + iron nail   | A small amount of rust is formed. A reddish brown coloured solid is formed on and around the nail.                           |
| 3             | Solution of common salt in tap water + iron nail                                      | A little more amount of rust is formed than in test tube 2. A reddish brown coloured solid is formed on and around the nail. |
| 4             | Solution of common salt and vinegar in tap water + iron nail                          | Amount of rust formed is much more. A reddish brown coloured solid is formed on and around the nail.                         |
| 5             | Solution of common salt and sodium hydroxide or washing soda in tap water + iron nail | Practically no rusting occurs.   |
| 6             | Solution of common salt + iron nail with a small piece of zinc attached to it.        | White coloured precipitate is formed.  |
| 7             | Solution of common salt + iron nail with a small piece of copper wire around it.      | A large amount of rust is formed. A reddish brown coloured solid is formed on and around the nail.                           |

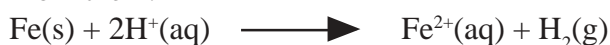
**What do we conclude?**

- In test tube 1 practically no rusting occurs although iron nail was in contact with water. The nail was not in contact with oxygen of air. Boiling of water had expelled the air from test tube and cork prevented the contact later.
- In test tube 2 the nail was in contact with air and water and it rusted.
- In test tube 3 the addition of sodium chloride increases the rusting process.
- In test tube 4 the addition of an acid (vinegar) further increases the rusting process
- In test tube 5 the addition of an alkali (sodium hydroxide or washing soda) retards the rusting process.
- In test tube 6 corrosion occurs but not of iron but that of zinc which is indicated by the white coloured solid that is formed rather than the reddish brown rust. Contact of iron with a more active metal protects it against rusting. The more active metal zinc gets corroded instead.
- In test tube 7 the corrosion of iron increases when it is in contact with a less active metal.

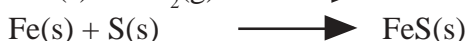
- (ii) When steam is passed over red hot iron, hydrogen is liberated



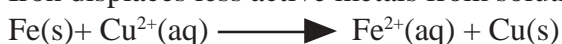
- (iii) It reacts with dilute hydrochloric and sulphuric acids and displaces hydrogen from them.



- (iv) Iron does not react with alkalis. When hot, it combines with halogens and sulphur to give halides and sulphide respectively.



- (v) Iron displaces less active metals from solutions of their salts.

**19.2.2d Commercial forms of iron**

There are three commercial varieties of iron, namely **cast iron**, **wrought iron** and **steel**. These varieties differ from each other mainly in their carbon content.

- **Cast iron** contains from 2.5-4.5% carbon together with traces of sulphur, phosphorus, manganese and silicon. It is hard and brittle and cannot be welded. It has a low melting point and expands on solidification. Therefore it is good for casting. It does not easily rust and is used for making parts exposed to weather such as lamp posts. It is used for making engine blocks, brake drums etc. in automobiles .
- **Wrought iron** is the purest form of iron. It is obtained from cast iron by heating it with ferric oxide in a furnace. Its melting point is higher than that of cast iron. It is malleable and can be forged, hammered, machined and welded. It is used to make iron nails, sheets and machine parts.
- **Steel** is an iron-carbon alloy and contains 0.05–1.5% carbon. It is manufactured from pig iron. While production of iron is basically a reduction process

converting iron oxide into iron, the conversion of iron to steel is an oxidation process in which excess of carbon is oxidized to carbon monoxide. Then, the required amount of carbon is added to it. Its hardness depends upon the amount of carbon in it.

If the carbon content in steel is between cast iron and wrought iron it is called **mild steel**. It is used for manufacture of rails, wheels and building material.

### 19.2.2e Alloy steels

Some very useful properties may be imparted to steel by alloying it with other metals. Composition and properties of some alloy steels are given below.

- (i) **Stainless steel:** It is prepared by mixing 11.5% chromium to steel. It is called stainless steel because it is resistant to rust formation. It is used for making utensils, cycles and automobile parts.
- (ii) **Nickel steel:** It is prepared by mixing 3.5% nickel to steel. It is very strong material. It is used for making cables, propeller shafts, armour plates, automobile and aeroplane parts.
- (iii) **Chrome steel:** It is prepared by mixing 1.5 to 2.0% chromium to steel. It is extremely hard and strong. It is used for making armour piercing projectiles, crushing machinery and cutlery etc.

### 19.2.3 Aluminium

You have learnt in the beginning of this lesson (section 19.1) that aluminium is the third most abundant element. It does not occur free in nature. Therefore it remained unknown until the nineteenth century.

#### 19.2.3a Ores of aluminium

Main ores of aluminium are bauxite, ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ), corundum, ( $\text{Al}_2\text{O}_3$ ), cryolite, ( $\text{Na}_3\text{AlF}_6$ ) and silicates like feldspar ( $\text{KAlSi}_3\text{O}_8$ ).

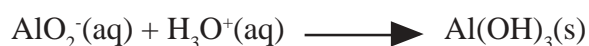
Bauxite is the chief ore of aluminium. In India it is found in Bihar, Kashmir, Madhya Pradesh, Maharashtra and Tamil Nadu. It is manufactured in Muri (Bihar), Belur and Jaykay Nagar (West Bengal), Kalna (Maharashtra), Alwaye (Kerala), etc.

#### 19.2.3b Extraction of aluminium

Aluminium is extracted from bauxite by electrolysis. The ore contains oxides of silicon, iron and titanium as main impurities. The ore is first treated with a strong solution of sodium hydroxide (caustic soda) which converts aluminium oxide ( $\text{Al}_2\text{O}_3$ ) into soluble sodium meta aluminate ( $\text{NaAlO}_2$ ).



Other impurities, oxides of iron and titanium remain unaffected and are filtered off. The solution is then treated with an acid which precipitates insoluble aluminium hydroxide  $\text{Al}(\text{OH})_3$  which is then heated to obtain pure aluminium oxide.



Fused anhydrous aluminium oxide or alumina is then reduced by **Hall process** electrolytically. Aluminium oxide obtained by heating  $\text{Al}(\text{OH})_3$  has an extremely high melting point ( $2045^\circ\text{C}$ ) and its direct electrolysis is not practicable. Instead a few per cent  $\text{Al}_2\text{O}_3$  is dissolved in fused cryolite,  $\text{Na}_3\text{AlF}_6$  which acts as solvent for it. The cell is operated at about  $950^\circ\text{C}$ . Further, molten cryolite is a much better electrical conductor than  $\text{Al}_2\text{O}_3$ . The schematic diagram of the electrolytic cell used in Hall process is shown in Figure 19.5.

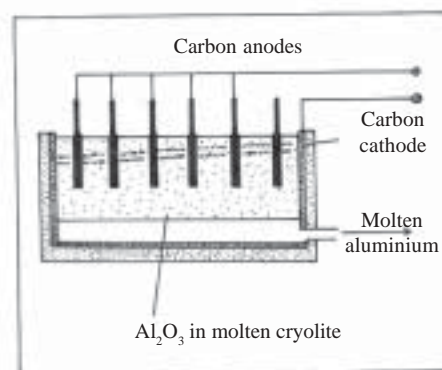
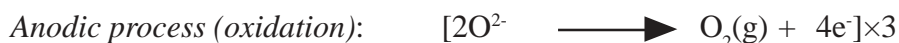


Fig. 19.5 The schematic diagram of electrolytic cell used in Hall's process

This cell consists of an iron tank which is lined inside with gas carbon which acts as cathode. A number of carbon rods are used as anode. Electrolysis of this molten mixture produces aluminium and oxygen gas according to the following net processes:



The liquid aluminium metal (m.p.  $660.2^\circ\text{C}$ ) collects at the bottom of the cell and is drained out from time to time. The metal obtained has the purity of 99.6 – 99.8 %.

### 19.2.3a Properties of aluminium

#### (A) Physical properties

- (i) Aluminium is a bluish white metal and can take high polish.
- (ii) It has extremely low density ( $2.7 \text{ g cm}^{-3}$ ) and high tensile strength i.e. it can be stretched. It is malleable and ductile. It is drawn into wires. It is used for making thin foils used for packing of food articles because it is not involved in living systems and is considered to be non-toxic.
- (iii) It is an excellent electrical conductor. Its conductivity is about 65 % of that of copper and only silver, copper and gold surpass it in this regard. Being cheaper and lighter than copper, it is increasingly taking the place of copper for making electrical wires for domestic use as well as for making high voltage transmission lines.

#### (B) Chemical properties

- (i) It is a trivalent electropositive element.
- (ii) In air its surface gets coated with a protective layer of aluminium oxide. This oxide film protects aluminium from corrosion and also accounts for the unexpected inertness of aluminium. It is thus a self protective metal.
- (iii) If heated to redness, it burns with a brilliant white light with evolution of much heat.



- (iv) Although it is considered as an active metal, it does not react with water as do metals like sodium and magnesium.