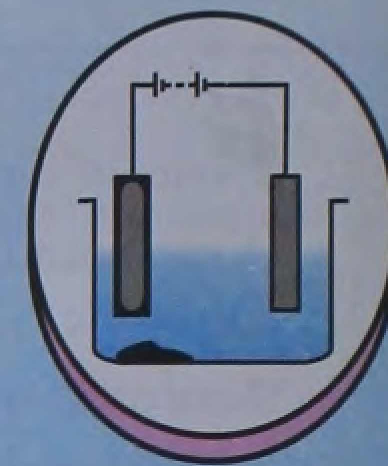
5 METALS AND NON-METALS



In This Chapter You Will Learn :

- *Introduction • minerals, ores and metallurgy*
- *The need to recycle and conserve metals*
- *Physical and chemical properties*
- *Displacement reaction*
- *Uses of common metals and non-metals*
- *Common alloys and their uses*
- *Metal activity series*

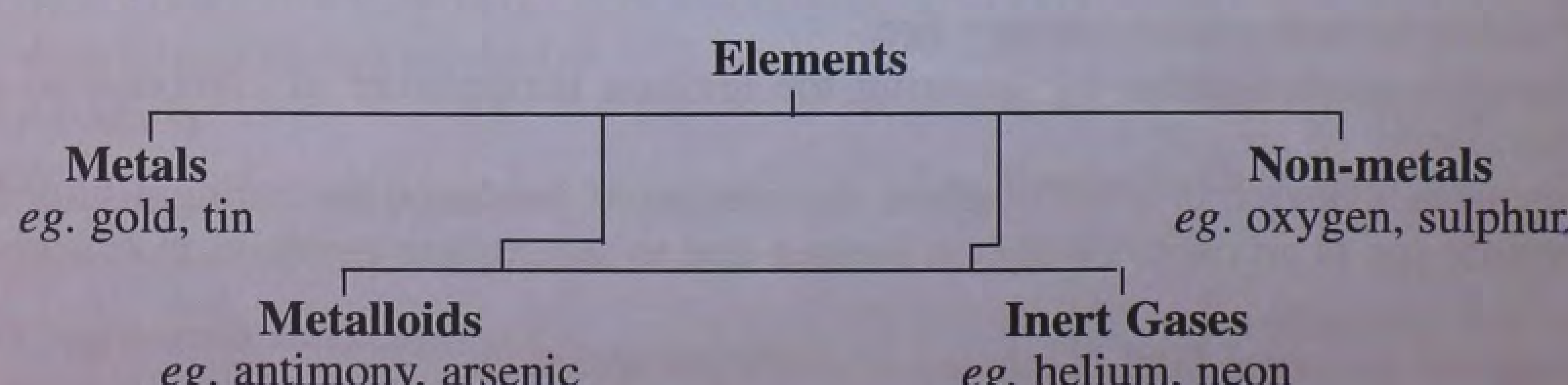
INTRODUCTION

Though there are millions of substances in this world, they are all made up of a limited number of basic substances, which are called *elements*. You have already studied about elements as being pure substances that are made up of one kind of atoms only.

For the sake of study, these elements are divided into two broad classes : **metals** and **non-metals**. This division of elements is based on the fact that there are certain properties that are found only in metals and certain others that are found only in non-metals.

But there are also some elements that show the properties of both metals and non-metals. They are known as **metalloids**. Some common metalloids are arsenic, antimony and silicon. The **noble (inert) gases** form the fourth category of elements.

The majority of the elements known to us are metals. *For example*. gold, silver, platinum, copper, iron, aluminium, tin, nickel, chromium, mercury, calcium, magnesium, lithium, sodium, potassium, zinc, and many more metals.



5.1 DIFFERENCES IN PHYSICAL PROPERTIES OF METALS AND NON-METALS

Metals	*Non-metals*
1. **State :** Metals are crystalline solids (except mercury, which is a liquid).	**State :** Non-metals are either gases or solids [Exception : Bromine is a liquid].
2. **Metallic lustre :** *In their pure state, metals shine. This property is called* ***metallic lustre***. In other words, metals can be polished.	**Lustre :** Non-metals are dull to look at, *i.e.* they cannot be polished [Exceptions: Graphite and iodine are lustrous].
3. **Density :** Metals have high density (except sodium, potassium and lithium).	**Density :** Non-metals have low density [Exception : Diamond has high density].
4. **Hardness :** Metals are hard solids (except sodium and potassium, which are soft and can be cut with a knife).	**Hardness :** Non-metals are not hard. If solid they are soft and brittle. *For example*, phosphorus and sulphur are soft solids and iodine is brittle [Exception : Diamond is the hardest natural substance].
5. **Melting point :** Metals have high melting points.	**Melting point and boiling point :** Non-metals have both low melting and low boiling points [Exceptions : Carbon, silicon and boron have both high melting and high boiling points].
6. **Malleability :** Metals are malleable, *i.e.* they can be hammered into sheets. Gold, silver, copper, aluminium and tin can be beaten into very thin sheets called foils. (But zinc is brittle, *i.e.* it breaks into pieces when it is hammered).	**Malleability :** Non-metals are non-malleable. When they are hammered they turn into a powder, *i.e.* non-metals are of a brittle nature.
7. **Ductility :** Metals are ductile, *i.e.* they can be drawn into wires. Gold, silver, copper and aluminium are highly ductile metals, gold being the most ductile of all metals. [Exception : Zinc, arsenic and antimony *i.e.*, metalloids cannot be drawn into wires].	**Ductility :** Non-metals are not ductile [Exception : Carbon fibre, a recently developed allotrope of carbon, is ductile].
8. **Tensile strength :** Metals have high tensile strength, *i.e.* they can bear a lot of strain [Exception : Zinc].	**Tensile strength :** Non-metals have low tensile strength [Exception : Carbon fibre has high tensile strength].
9. **Thermal and electrical conductivity :** Metals are good conductors of heat and electricity. Silver is the best conductor of heat and electricity. Tungsten is a bad conductor of electricity while lead is a bad conductor of heat.	**Thermal and electrical conductivity :** Non-metals are bad conductors of heat and electricity [Exceptions : Graphite is a good conductor of heat and electricity. Gas carbon is a good conductor of electricity].
10. **Sonority :** Metals produce a twangy sound when they are struck with a hard object, *i.e.* they are sonorous substances.	**Sonority :** Solid non-metals do not produce a sound when they are struck, *i.e.* they are not sonorous substances.
11. **Solubility :** Metals are usually insoluble in water or in organic solvents.	**Solubility :** With regard to solubility in water or organic solvents there is no fixed rule that applies to the non-metals. *For example*, chlorine is soluble in water, but sulphur, carbon and phosphorus are not.

5.2 CHEMICAL PROPERTIES OF METALS AND NON-METALS

Metals	Non-metals
1. **Electronic configuration :** A metal has 1, 2 or 3 electrons in their valence shell.	1. **Electronic configuration :** Non-metallic atom have 4, 5, 6 or 7 electrons in there valence shells. [Exception : Hydrogen and helium have one and two electron in their valence shells respectively.]
2. **Valency :** Metals have valencies +1, +2 or +3. They lose valence electrons during chemical combination to form electropositive ions (cations). $Na - e^- \rightarrow Na^+$, $Mg - 2e^- \rightarrow Mg^{2+}$ (valency + 1) (valency + 2) $Al - 3e \rightarrow Al^{3+}$ (valency + 3)	2. **Valency :** Non-metals have valencies –1, –2 or –3. They gain electrons in their valence shells during chemical combination to complete their octet and form electronegative ions (anions). $Cl + e^- \rightarrow Cl^-$, $O + 2e^- \rightarrow O^{2-}$ (valency + 1) (valency + 2) $N + 3e^- \rightarrow N^{3-}$ (valency + 3) Carbon is tetravalent
3. **Reducing nature :** Metals are good reducing agents since they lose their valence electrons.	3. **Oxidising nature :** Non-metals are good oxidising agents since they gain electrons. [Exception : H_2 and carbon act as reducing agents]
4. **Atomicity :** Molecules of metals are usually monoatomic.	4. **Atomicity :** Molecules of non-metals are usually polyatomic. [Exception : Inert gases are monoatomic].
5. **Reaction of metals with oxygen and nature of oxide :** In presence of heat most metals react with oxygen (or air) to form their respective oxides. These metallic oxides are of basic nature. Therefore they are also known as basic oxides. Some of these oxides dissolve in water to produce alkali. These basic oxides react with acids to produce salt and water. $\text{Metal} + \text{Oxygen} \xrightarrow{\text{heat}} \underset{\text{(Basic)}}{\text{Oxide}}$ $2Cu + O_2 \longrightarrow \underset{\text{(Basic oxide)}}{2\,CuO}$ $CuO + H_2SO_4 \longrightarrow \underset{\text{(Salt)}}{CuSO_4} + \underset{\text{(Water)}}{H_2O}$	5. **Reaction of non-metals with oxygen and nature of oxides :** Non metals react with oxygen (or air) on heating to form their respective oxides. Most of these oxides are acidic in nature and they turn moist blue litmus paper into red. They react with bases to produce salt and water. $\text{Non metal} + \text{Oxygen} \xrightarrow{\text{heat}} \text{Non metallic oxide}$
(i) Metals like sodium and potassium react vigorously with oxygen (even in absence of heat) to form their oxides. Calcium too forms its oxide without being heated.	(i) Carbon burns in oxygen to produce carbon dioxide. $\underset{\text{(Carbon)}}{C} + \underset{\text{(Oxygen)}}{O_2} \xrightarrow{\text{heat}} \underset{\text{(Carbon dioxide)}}{CO_2}$

The metallic oxides so formed are soluble in water and produce respective hydroxides called as alkalis. They turn red litmus into blue.

(a) $4Na$ (Sodium) + O_2 (Oxygen) $\longrightarrow$ $2Na_2O$ (Sodium oxide)

Na_2O (Basic oxide) + H_2O (Water) $\longrightarrow$ $2NaOH$ (Alkali) (Sodium hydroxide)

(b) $4K$ (Potassium) + O_2 (Oxygen) $\longrightarrow$ $2K_2O$ (Potassium oxide)

K_2O (Basic oxide) + H_2O (Water) $\longrightarrow$ $2KOH$ (Potassium hydroxide)

(c) $2Ca$ (Calcium) + O_2 $\longrightarrow$ $2CaO$ (Calcium oxide)

CaO + H_2O $\longrightarrow$ $Ca(OH)_2$ (Calcium hydroxide)

Note : Alkalis are soluble bases. All alkalis are bases but all bases are not alkalis because all bases are not soluble in water.

(ii) Metals like magnesium, aluminium, zinc, iron, lead, copper and mercury react with oxygen on heating to form oxides but these oxides are insoluble in water. However, magnesium oxide is partially soluble and forms weakly alkaline magnesium hydroxide.

$2Mg$ (Magnesium) + O_2 $\xrightarrow{\text{heat}}$ $2MgO$ (Magnesium oxide)

$2Zn$ (Zinc) + O_2 $\xrightarrow{\text{heat}}$ $2ZnO$ (Zinc oxide)

$2Cu$ (Copper) + O_2 $\xrightarrow{\text{heat}}$ $2CuO$ (Copper oxide)

Metals like silver/gold and platinum do not react with oxygen even on strong heating i.e. they are noble metals.

Zinc oxide, aluminium oxide, lead monoxide [ZnO, Al_2O_3 and PbO] are amphoteric oxides because they react both with acids as well as bases to produce salt and water.

(a) ZnO (Zinc oxide) + $2HCl$ (Hydrochloric acid) $\longrightarrow$ $ZnCl_2$ (Zinc chloride) + H_2O

ZnO + $2NaOH$ $\longrightarrow$ Na_2ZnO_2 (Sodium zincate) + H_2O

(ii) Sulphur burns in oxygen to produce sulphur dioxide.

S (Sulphur) + O_2 $\xrightarrow{\text{heat}}$ SO_2 (Sulphur dioxide)

SO_2 + $2KOH$ (Potassium hydroxide) $\longrightarrow$ K_2SO_3 (Potassium sulphite) + H_2O

(iii) Hydrogen burns in oxygen to produce water, which is a neutral oxide and does not change the colour of indicators.

$2H_2$ (Hydrogen) + O_2 $\longrightarrow$ $2H_2O$ (Water)

Note : Some other non-metallic oxides which are neutral in nature are carbon monoxide (CO) nitric oxide (NO), Nitrous oxide (N_2O) *etc*.

(iv) Acidic oxides react with water to form acids.

(a) Carbon dioxide dissolve in water to form carbonic acid.

CO_2 + H_2O $\longrightarrow$ H_2CO_3 (Carbonic acid)

(b) Sulphur dioxide gives sulphurous acid with water.

SO_2 + H_2O $\longrightarrow$ H_2SO_3 (Sulphurous acid)

(v) Acidic oxides react with bases and alkalis to produce salt and water.

Acidic oxide + Base $\longrightarrow$ Salt + Water

CO_2 + $2NaOH$ $\longrightarrow$ Na_2CO_3 (Sodium carbonate) + H_2O

(b) Al_2O_3 (Aluminium oxide) + 6HCl → $2AlCl_3$ (Aluminium chloride) + $3H_2O$

Al_2O_3 + 2NaOH → $2NaAlO_2$ (Sodium meta aluminate) + H_2O

(c) PbO (Lead monoxide) + 2HCl → $PbCl_2$ (Lead chloride) + H_2O

PbO + 2NaOH → Na_2PbO_2 (Sodium plumbite) + H_2O

6. Reaction of metals with water : Depending upon their level of reactivity, metals react with water or steam to form corresponding metallic hydroxides or oxides, alongwith hydrogen gas.

(i) Metals like sodum and potassium react violently with cold water to form their hydroxides as well as hydrogen gas. The reaction is so vigorous that a fire or an explosion can occur. Calcium too reacts with cold water to form its hydroxide and hydrogen, but the reaction is moderate.

Metal + Water → Metal hydroxide + Hydrogen

$$2NO + 2H_2O \xrightarrow[\text{vigorous}]{\text{very}} 2NaOH + H_2$$

$$2K + 2H_2O \xrightarrow[\text{vigorous}]{\text{very}} 2KOH + H_2$$

$$Ca + 2H_2O \xrightarrow{\text{Moderate}} Ca(OH)_2 + H_2$$

(ii) Metals like magnesium, aluminium, zinc and iron react with steam to form their respective oxides as well as hydrogen gas.

Metal + Steam $\xrightarrow{\text{heat}}$ Metal oxide + Hydrogen

$$Mg + \underset{\text{(Steam)}}{H_2O} \xrightarrow{\text{heat}} MgO + H_2$$

$$\underset{\text{(Iron)}}{3Fe} + \underset{\text{(Steam)}}{4H_2O} \overset{\text{heat}}{\rightleftharpoons} \underset{\text{(Triferric tetronide)}}{Fe_3O_4} + 4H_2$$

Metals like gold, silver, copper and mercury react with neither cold water nor steam.

6. Reaction of nonmetals with water : Non-metals do not react with water. However, chlorine dissolves in water to form chlorine water that contains hydrochloric acid.

$$\underset{\text{(chlorine)}}{Cl_2} + \underset{\text{(Water)}}{H_2O} \longrightarrow \underset{\text{(Hydrochloric acid)}}{2HCl} + \underset{\text{(Nascent oxygen)}}{[O]}$$

7. Reaction of metals with acids : Metals above hydrogen in metal activity series react with dilute acids to produce hydrogen.

Metal + dilute acid $\longrightarrow$ Salt + Hydrogen

Metals react with dilute hydrochloric acid or dilute sulphuric acid to produce their corresponding salts and hydrogen gas. Nitric acid is not used because, being a strong oxidising agent, it immediately oxidises hydrogen to produce water.

(i) Sodium and potassium react vigorously with dilute acids with the liberation of a tremendous amount of heat.

$$2Na + 2HCl \xrightarrow{\text{vigorous}} \underset{\text{(Sodium chloride)}}{2NaCl} + H_2$$

(ii) Magnesium, calcium, zinc, aluminium react moderately with acids

$$Zn + \underset{\substack{\text{(dil)} \\ \text{(Sulphuric acid)}}}{H_2SO_4} \longrightarrow \underset{\text{(Zinc sulphate)}}{ZnSO_4} + H_2$$

$$Mg + \underset{\text{(dil)}}{2HCl} \longrightarrow \underset{\text{(Magnesium chloride)}}{MgCl_2} + H_2$$

(iii) Iron reacts with dilute acids very slowly.

$$\underset{\text{(Iron)}}{Fe} + 2HCl \xrightarrow{\text{Slow}} \underset{\text{(Iron (II) chloride)}}{FeCl_2} + H_2$$

(iv) Lead, copper, silver and gold do not react with dilute mineral acids.

(v) Metals like Cu, and Zn react with concentrated acids.

For example, when Cu reacts with conc. H_2SO_4, salt, water and sulphur-dioxide gas are produced.

$$Cu + \underset{\text{(conc.)}}{2H_2SO_4} \longrightarrow CuSO_4 + 2H_2O + SO_2$$

7. Reaction of nonmetals with acids : Non-metals do not react with dilute acids, but they react with concentrated acids. Some of the reactions are as follows :

(i) $$\underset{\text{(Carbon)}}{C} + \underset{\text{(Conc.)}}{2H_2SO_4} \longrightarrow CO_2 + 2SO_2 + 2H_2O$$

(ii) $$S + \underset{\text{(Conc.)}}{2H_2SO_4} \longrightarrow 3SO_2 + 2H_2O$$

(iii) $$P + \underset{\substack{\text{(Conc.)} \\ \text{(Nitric acid)}}}{5HNO_3} \longrightarrow H_3PO_4 + 5NO_2 + H_2O$$

(iv) $$S + \underset{\text{(Conc.)}}{6HNO_3} \longrightarrow H_2SO_4 + 6NO_2 + 2H_2O$$

Indicators : Indicators are the organic compounds that are used to ascertain the nature of a solution [whether a solution is acidic or basic or neutral]. Indicators change colour depending on the nature of the solution in which they are dipped. *For example*, litmus paper turns blue in basic solution and red in acidic solution. The commonly used indicators are litmus, methyl orange and phenolphthalein.

Salt : A salt is a compound with a metal (or ammonium) ion as its basic radical and a non-metal ion (or a group of non-metallic ions) as its acid radical. *Example:* In sodium chloride, Na^+ is the basic radical and Cl^- the acid radical.

5.3 METAL ACTIVITY SERIES

On the basis of the rate of the reaction of metals with oxygen (air), water and dilute acids, they (the metals) have been arranged in the decreasing order of their chemical reactivity.

A list in which the metals are arranged in the decreasing order of their chemical reactivity is called the metal reactivity series.

The most active metal (potassium) is kept at the top of the list and the least active metal (platinum) is at the bottom of the list.

Special features of the activity series :

1. The ease with which a metal in solution loses electron(s) and forms a positive ion decreases down the series, *i.e.* from potassium to gold.
2. Hydrogen is included in the activity series because, like metals do, it too loses an electron and becomes positively charged (H^+) in most chemical reactions.
3. The series facilitates the comparative study of metals in terms of the degree of their reactivity.

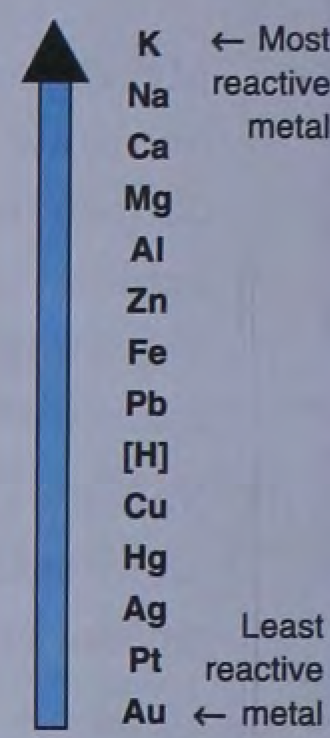


Fig 5.1 Reactivity series of metals

Table 5.1 : The reactivity series of metals.

Elements	*Reaction with oxygen*	*Reaction with water*	*Reaction with acid*
1. K 2. Na 3. Ca	React with oxygen at ordinary temperature to form oxides	K and Na react with cold water vigorously Ca reacts moderately with cold water	K and Na react explosively with dilute acids to give hydrogen but Ca reacts less vigorously.
4. Mg 5. Al 6. Zn 7. Fe	Form oxides on heating, but aluminium also reacts at ordinary temperature	Mg reacts with hot water or steam; others react with steam only to form oxide and hydrogen	Mg, Al, Zn and Fe react moderately with acid, to produce hydrogen
8. Pb 9. Cu 10. Hg	Form oxides on very strong heating	No reaction with hot water or steam	Pb reacts with conc. HCl to give H_2; Cu and Hg do not react with dilute acids
11. Ag 12. Pt 13. Au	Do not react with oxygen even on strong heating	No reaction with hot water or steam	Do not react with dilute acids

4. The compounds of the metals (oxides, carbonates, nitrates and hydroxides) too can be easily compared.

5.4 DISPLACEMENT REACTION

It has been found that a more reactive metal always displaces a less reactive metal from the latter's salt solution. This can be better understood by the following activities.

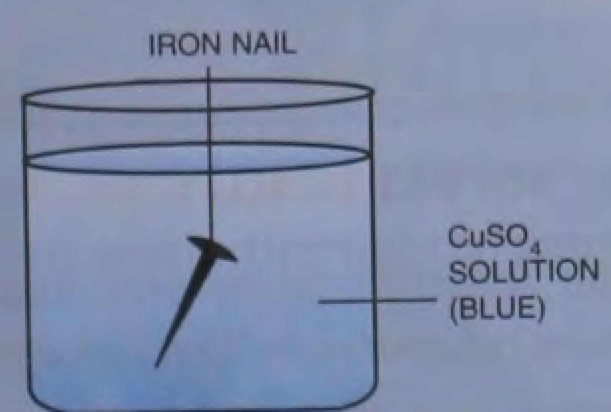
Activity 1

To show that iron is more reactive than copper.

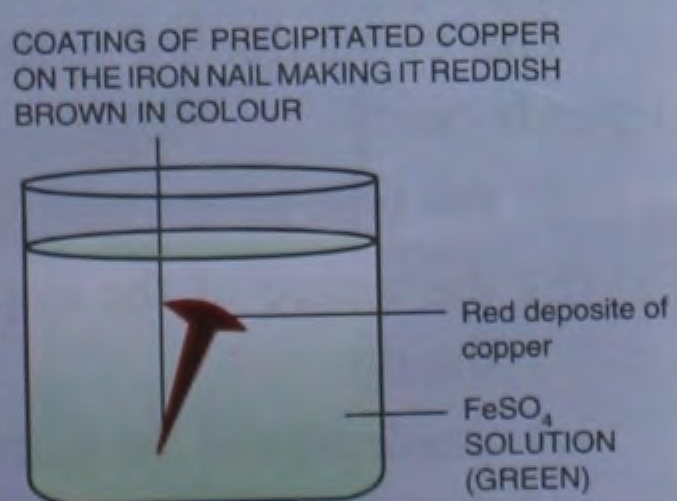
An iron nail is placed in blue coloured copper sulphate solution. After some time a reddish brown coating is seen on the iron nail even as the colour of the solution changes gradually from blue to light green. This is because iron, which is more reactive compared to copper, goes into the solution while copper is precipitated out.

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$$

(iron) (blue copper sulphate solution) (Green ferrous sulphate solution) (copper)



(a) Iron nail dipped in $CuSO_4$ solution



(b) The solution turns pale green due to the formation of $FeSO_4$

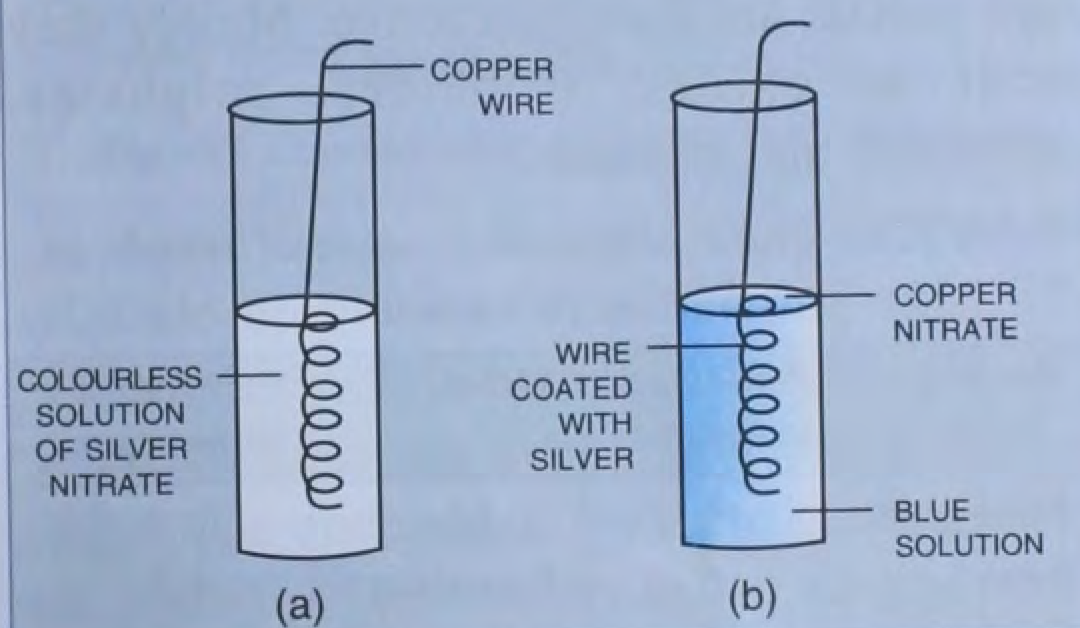
Activity 2

To show that copper is more reactive than silver.

A test tube is half filled with silver nitrate solution and a copper coil is dipped into it. After some time the copper coil gets coated with silver while the solution turns blue. This shows that copper is chemically more reactive than silver.

$$2AgNO_3 + Cu \longrightarrow 2Ag + Cu(NO_3)_2$$

(silver nitrate, colourless) (copper) (silver) (copper nitrate, blue)



Some more displacement reactions are as follows :

$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

[Zn is more reactive than Cu]

$Mg + FeSO_4 \rightarrow MgSO_4 + Fe$

[Mg is more reactive than Fe].

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

(dil.)

(Zn is more reactive than H_2)

Non-metals also show displacement reaction. Chlorine is more reactive than iodine

$$2KI + Cl_2 \rightarrow 2KCl + I_2$$

(Potassium iodide) (Chlorine) (Potassium chloride) (Iodine)

5.5 OCCURRENCE OF METALS

The knowledge of metals is very old. *Copper was perhaps the first metal to be used by man* for making utensils, weapons and other objects. Most metals have a significant role in our daily life. They constitute the mineral wealth of a country.

Metals occur in nature in both free (native) and combined states.

Native or free state : Gold and platinum are found exclusively in free state because they are not reactive elements. Also, due to their low reactivity, copper, mercury and silver occur in native or free state.

Combined state : Most metals occur in nature in combination with other substances, since metals are mostly reactive. Mainly they occur as oxides, sulphides, sulphates, carbonates and silicates.

Table 5.2 : The relative abundance of metals in the earth's crust

Metal	*Percentage proportion*	*Metal*	*Percentage proportion*
Aluminium	8	Sodium	2·5
Iron	6	Potassium	1·5
Calcium	5	Other metals	2
Magnesium	3		

5.6 TERMS RELATED TO METALS IN COMBINED STATE

Minerals : The naturally occurring compounds of metals mixed with earthly impurities like sand, clay, stone, *etc*., are called *minerals*. They are found beneath the earth's surface as the chemical ingredients of rocks.

Gangue : Earthly impurities like sand, clay and mud, when they are present in an ore, are called *gangue* or *matrix*.

Ores : An ore is a type of mineral from which elements or compounds can be extracted economically.

Mineral + Gangue = Ore

Table 5.3 : Common ores and the metals extracted from them

Type of ore	*Ore*	*Chemical formula*	*Metal extracted*
Oxide ores	Bauxite	$Al_2O_3{\cdot}2H_2O$	Al
	Haematite	Fe_2O_3	Fe
	Magnetite	Fe_3O_4	Fe
	Zincite	ZnO	Zn
	Cuprite	Cu_2O	Cu
Sulphide ores	Galena	PbS	Pb
	Copper glance	CuS	Cu
	Iron pyrite	FeS_2	Fe
	Zinc blende	ZnS	Zn
	Cinnabar	HgS	Hg
Carbonate ores	Marble	$CaCO_3$	Ca
	Magnesite	$MgCO_3$	Mg
	Siderite	$FeCO_3$	Fe
	Malachite	$Cu(OH)_2{\cdot}CuCO_3$	Cu
	Chalk	$CaCO_3$	Ca
Sulphate ores	Epsom salt	$MgSO_4{\cdot}7H_2O$	Mg
	Gypsum	$CaSO_4{\cdot}2H_2O$	Ca
Halide ores	Rock salt	$NaCl$	Na
	Horn silver	$AgCl$	Ag
	Fluorspar	CaF_2	Ca
	Cryolite	Na_3AlF_6	Al

5.7 METALLURGY

The scientific principles and the physical and chemical processes that are applied to obtain pure metals from their ores are known as metallurgy.

The extraction of a metal from its ore depends on :

(a) the type of ore being used

(b) the nature of the impurities present in the ore

(c) the degree of the reactivity of the metal that is to be extracted.

Usually the following consecutive steps are involved in metallurgical processes.

1. Ore dressing, *i.e.* concentration of ore.
2. Conversion of concentrated ore into metal oxide.
3. Reduction of metal oxide to impure metal.
4. Refining of impure metal.

1. Ore dressing or concentration of ore

The process of removing gangue (earthly impurities) from an ore is known as *concentration* or *dressing of ore*. The purified ore is called *concentrate*. Concentration is done to increase the proportion of metal in ore. It begins with the crushing of the ore so as to obtain powdered ore. Some common methods of concentration are :

(i) Hydraulic washing (gravity separation)

(ii) Froth flotation

(iii) Magnetic separation

(i) *Hydraulic washing* : This method depends upon the difference in the density of the ore and the density of gangue. Therefore it is also known as the gravity separation method. The powdered ore is washed with a strong current of water. The denser ore particles settle down while the lighter gangue particles are carried away by water. The ores of tin and lead are concentrated by this method.

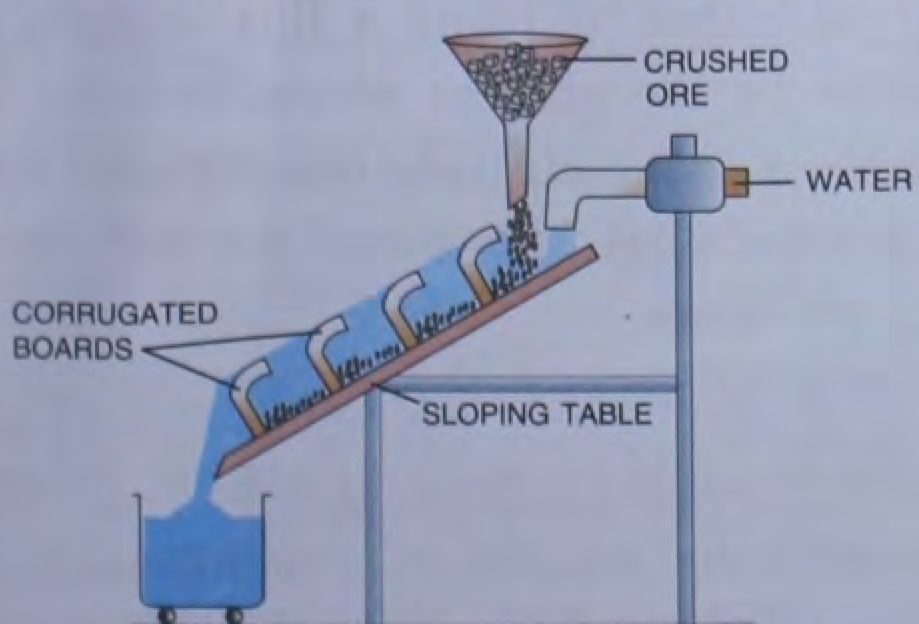


Fig. 5.2 Hydraulic washing of crushed ore.

(ii) *Froth flotation* : This process is based on the difference in the wettability when ore and gangue are wetted with certain liquids. Mainly oil and water are used for this purpose.

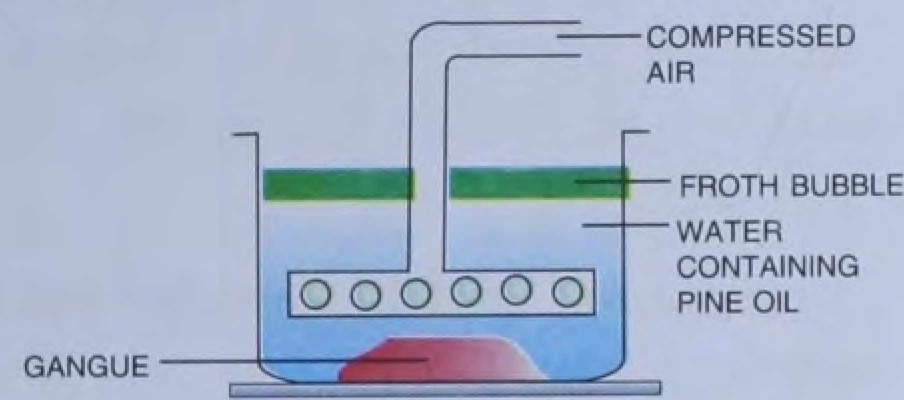


Fig. 5.3 Concentration of ore by froth flotation.

Froth flotation is used to concentrate the sulphide ores of copper, lead and zinc. The powdered ore is taken in a tank containing water to which a small amount of pine oil is added. Air under high pressure is blown into the mixture. This results in the formation of froth (or foam). The ore particles get wetted by the oil and remain in the froth while the impurities are left behind in the tank. The froth is now taken out from the tank and allowed to settle down. The concentrated ore then gets separated from both water and oil.

(iii) *Magnetic separation* : This method depends upon the difference in the respective magnetic properties of ore and gangue.

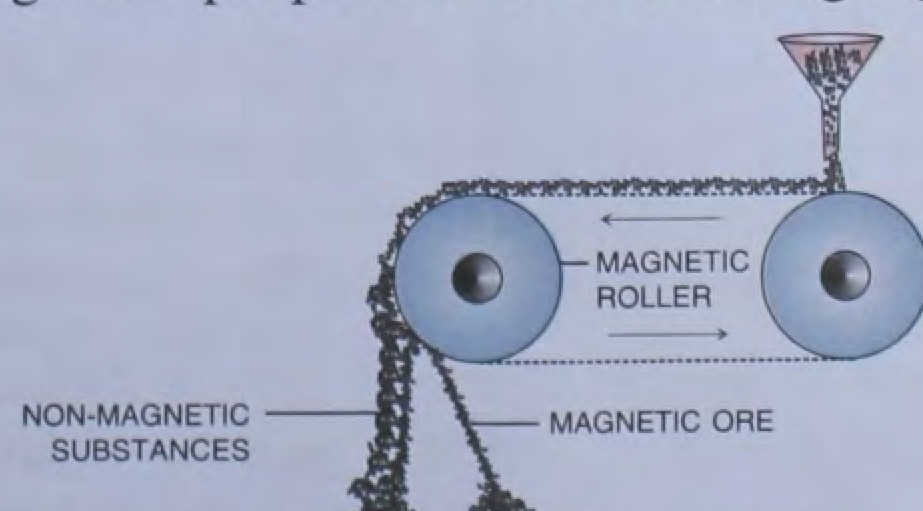


Fig. 5.4 Magnetic separation of ore.

Impurities of iron ore are removed by this process since, iron has magnetic properties.

A magnetic separator consists of a brass or a leather belt moving on two rollers of which one is magnetic. The powdered ore is placed over the belt from one end. The magnetic particles are attracted towards the magnetic roller and they fall separately away from the non-magnetic particles. Nickel and manganese too are separated using this method from their ores.

2. Conversion of the concentrated ore into metallic oxide

Concentrated ore is converted into metal oxide by either :

(i) Roasting or (ii) Calcination

The choice of method depends upon the physical and the chemical nature of the ore.

(i) *Roasting* : The process of heating concentrated ore to a high temperature in excess air is known as *roasting*. Roasting is most commonly carried out on sulphide ores. Roasting :

- removes water from concentrated ore.
- removes volatile impurities like arsenic and phosphorus from ores.
- converts ore into oxide.
- makes ores porous.

Examples

(a) $2CuS + 3O_2 \xrightarrow{\text{roasting}} 2CuO + 2SO_2$
(copper sulphide) (air) (copper oxide) (sulphur dioxide)

(b) $2PbS + 3O_2 \xrightarrow{\text{roasting}} 2PbO + 2SO_2$
(lead sulphide) (air) (lead monoxide) (sulphur dioxide)

(c) $2ZnS + 3O_2 \xrightarrow{\text{roasting}} 2ZnO + 2SO_2$
(zinc sulphide) (air) (zinc oxide) (sulphur dioxide)

(d) $4FeS + 7O_2 \xrightarrow{\text{roasting}} 2Fe_2O_3 + 4SO_2$
(ferrous sulphide) (air) (ferric oxide) (sulphur dioxide)

(ii) *Calcination* : The process of strongly heating a concentrated ore in the absence of air to a temperature that is insufficient to melt the ore is known as *calcination*. Calcination :

- removes moisture and volatile impurities like CO_2 from ores.
- converts carbonate ores into metallic oxides.
- makes ores porous.

Examples

(a) $CuCO_3 \xrightarrow{\text{calcination}} CuO + CO_2$
(copper carbonate) (copper oxide) (carbon dioxide)

(b) $PbCO_3 \xrightarrow{\text{calcination}} PbO + CO_2$
(lead carbonate) (lead oxide) (carbon dioxide)

(c) $ZnCO_3 \xrightarrow{\text{calcination}} ZnO + CO_2$
(zinc carbonate) (zinc oxide) (carbon dioxide)

3. Reduction of metal oxide to metal (smelting)

The process of removing oxygen from a metallic oxide so as to convert it (the metallic oxide) into a metal is known as **reduction** (or **smelting**). A metallic oxide obtained by roasting or calcination still contains about 5% earthly impurities. This impurity too gets removed either by using a flux, a reducing agent or by the process of electrolysis. The method of reduction selected depends upon the position of the metal in the metal reactivity series.

(i) *Reduction by electrolysis* : Highly reactive metals like potassium, sodium, calcium, magnesium and aluminium are extracted by the process of electrolysis, since they do not get reduced by conventional reducing agents.

***Example :* Extraction of aluminium**

- The ore used is Bauxite *i.e.* hydrated aluminium oxide [$Al_2O_3 \cdot 2H_2O$].

When electric current is passed through the concentrated ore the reaction takes place as follows :

$$\underset{\text{Molten}}{Al_2O_3} \rightleftharpoons 2Al^{3+} + 3O^{2-}$$

At cathode : $Al^{3+} + 3e^- \rightarrow Al \text{ (metal)}$

At anode : $2O^{2-} - 4e^- \rightarrow O_2 \text{ (gas)}$

In this way the metal is obtained.

(ii) *Reduction by conventional reducing agents* : In this process the metallic oxide is reduced to metal by using reducing agents like carbon (coke or charcoal), carbon monoxide, hydrogen, *etc*. Mostly metals like zinc, lead, iron and copper are extracted from their corresponding oxides this way.

Examples

(a) $\underset{\text{(zinc oxide)}}{ZnO} + \underset{\text{(coke)}}{C} \xrightarrow{\text{heat}} \underset{\text{(zinc)}}{Zn} + \underset{\text{(carbon monoxide)}}{CO}$

(b) $\underset{\text{(lead monoxide)}}{PbO} + \underset{\text{(coke)}}{C} \xrightarrow{\text{heat}} \underset{\text{(lead)}}{Pb} + \underset{\text{(carbon monoxide)}}{CO}$

(c) $\underset{\text{(ferric oxide)}}{Fe_2O_3} + \underset{\text{(carbon monoxide)}}{3CO} \xrightarrow{\text{heat}} \underset{\text{(iron)}}{2Fe} + \underset{\text{(carbon dioxide)}}{3CO_2}$

(d) $\underset{\text{(copper oxide)}}{CuO} + \underset{\text{(carbon monoxide)}}{CO} \xrightarrow{\text{heat}} \underset{\text{(copper)}}{Cu} + \underset{\text{(carbon dioxide)}}{CO_2}$

Flux : The substance added to the ore to remove its impurities during the reduction of oxidised ore from primary ore is called *flux*.

Slag : The substance formed by the chemical combination of flux and ore-based impurities is called *slag*. Since slag is a fusible compound it gets separated from the ore easily.

In the extraction of iron from its iron ore, haematite which contains silica as an impurity, limestone ($CaCO_3$) is used as a source of flux in order to remove it.

$$CaCO_3 \xrightarrow[\text{heat}]{1000°C} \underset{\text{flux}}{CaO} + CO_2$$

$$CaO + \underset{\text{silica}}{SiO_2} \longrightarrow \underset{\text{slag}}{CaSiO_3}$$

Note : Silica is the chemical name of sand.

(iii) *Reduction by thermal decomposition* : Oxides of metals like mercury and silver get reduced to their corresponding metals on heating above 300°C. They do not require a reducing agent or electrolytic reduction for this purpose.

$$\underset{\text{mercuricoxide}}{2HgO} \xrightarrow{\Delta} \underset{\text{mercury}}{2Hg} + \underset{\text{oxygen}}{O_2}$$

4. Refining of impure metals

The refining of impure metals is the process of removing impurities still present in the metal after extraction. The impurities are:

(i) other metals in pure or impure form

(ii) non-metals

(iii) dissolved gases

Some common methods of refining impure metals are distillation, liquefaction, oxidation, electro-refining, etc. However the best method is electro-refining, since it gives a highly pure (99%–99·9%) metal.

Electro-refining of impure metals (Refining by electrolysis) is the most widely used process for the purification of impure metals. Most commonly, the pure forms of copper, zinc, tin, aluminium, nickel, chromium, silver and gold are obtained by this process.

For electro-refining thick rod of impure metal is taken as anode and thin rod of pure metal as cathode. The two electrodes are dipped in the electrolyte which contains the ions of the metal that is to be refined. When electric current is passed through the electrolyte, it dissociates into free metal ions and thus pure metal gets deposited at the negative electrode *i.e.*, cathode. The mass of impurities that settles down in the solution below the anode is known as *anode mud*.

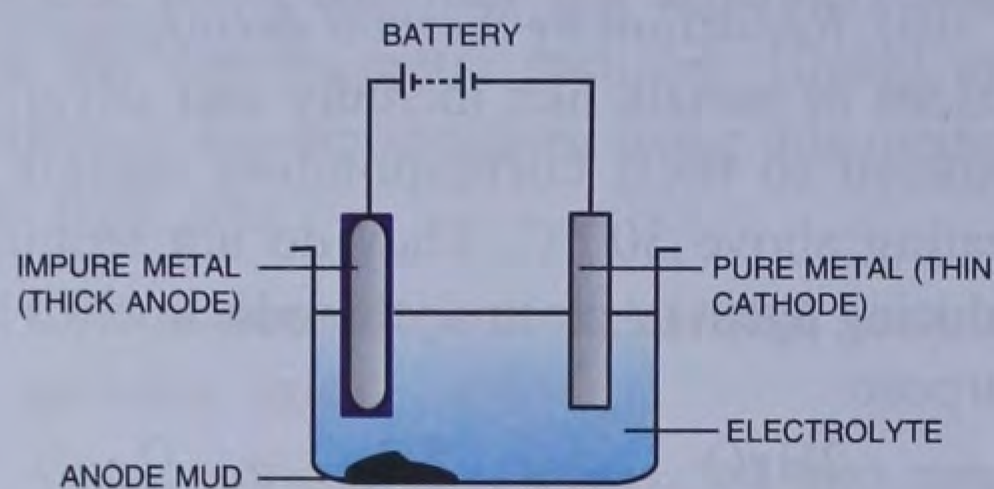


Fig. 5.5 Electrolytic refining

5.8 USES OF SOME COMMON METALS

Copper : Copper was among the first metals discovered by man along with gold and silver. It is reddish brown in colour. It is highly ductile, *i.e.* capable of being drawn into wires, and also a very good conductor of heat and electricity. It is used in making :

(i) electric wires and cables, utensils and semi-precious ornaments.

(ii) coins and statues (in the form of its two alloys, brass and bronze).

(iii) electronic devices.

(iv) several electroplating operations.

The use of copper in the electrical goods industry has declined due to the increasing use of aluminium as its substitute. Also copper is costly. But the most important reason for its decline is its scarcity.

Iron : Iron is definitely the most useful of all metals. It is among the most ancient metals known to man. There are three different varieties of manufactured iron, depending mainly on the proportion of carbon present in it. These are :

(a) pig iron (or cast iron)

(b) wrought iron

(c) steel

Wrought iron is the purest form of iron, since it has the least proportion of carbon present in it, while pig iron is the most impure form of iron, since it has the highest proportion of carbon present in it. Steel is the most widely used form of impure iron, to the extent of being the very basis of modern life.

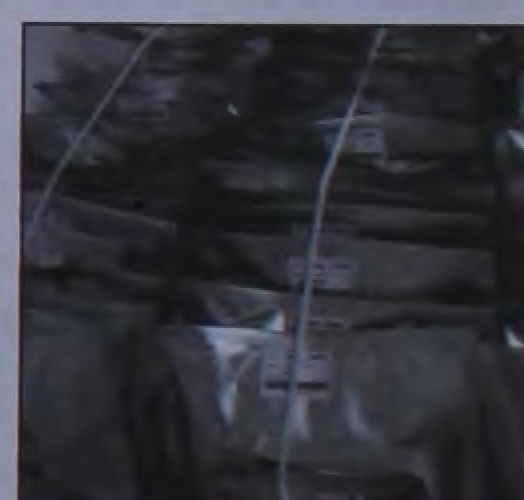
Iron is used in the manufacture of :

(i) radiators, railings, manhole lids and drain pipes [in the form of pig iron].

(ii) tanks, cylinders, smaller pipes, agricultural tools, nails and bolts, furniture, gates, *etc*. [in the form of wrought iron].

(iii) bridges, ships, machine parts, automobiles, buildings and utensils [in the form of steel].

(iv) power transmission towers.



Aluminium : Aluminium is definitely the second most useful metal today, after iron. It is silvery white in colour, malleable, ductile, light and strong, and it is a very good conductor of heat and electricity as well. Also it is resistant to corrosion. Therefore aluminium finds wide-ranging applications. It is used :

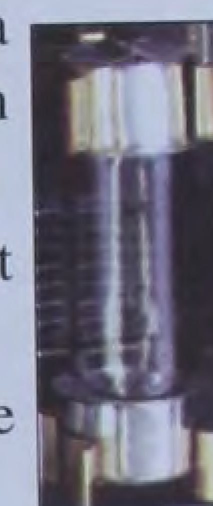
(i) to make utensils, cans for drinks, furniture, window frames, *etc*.
(ii) in making electric wires.
(iii) for packaging of foodstuffs (in the form of aluminium foil).
(iv) as a paint ingredient (in the form of its powder mixed with linseed oil, which protects against rusting when applied to the surface of iron).
(v) to make the bodies of aircraft and automobiles, and as machine parts and tools. This is because, in the form of its alloys, duralumin and magnalium, it is light and very strong.
(vi) in making mirrors (as reflector material).

Zinc : Zinc is a bluish white metal. It is neither malleable nor ductile, rather it is brittle. It is a good conductor of electricity. Zinc is used:

(i) to make dry cells and electrodes.
(ii) to make alloys like brass and bronze that are used to make utensils, statues, decoration pieces, etc.
(iii) to coat (galvanization) iron sheets so as to prevent them from rusting.
(iv) in the extraction of silver and gold from their ores.

Lead : Lead is a heavy, silver grey metal. It stays unaffected by impure water, steam and dilute acids. It has a low melting point. It is used for :

(i) making pipes and other sanitary fittings, bullet tips and tin roofs.
(ii) covering underground electric and telephone cables.
(iii) making **solder** and **type metal**.
(iv) the preparation of compounds like lead sulphate, red lead and litharge, which are used in paint and emulsion products.
(v) making screens that protect against X-rays and other radioactive radiations.



Magnesium : Magnesium is a silvery white metal. It is available in the shape of ribbons. It is used :

(i) in preparing fireworks, since it burns with a dazzling light.
(ii) in the preparation of alloys like duralumin & magnalium.
(iii) for making fuse wire.
(iv) in nuclear reactors for the absorption of neutrons.

Tin : Tin is a silvery white metal. It is highly malleable and ductile. It does not rust. It is used :

(i) to make cans for the storage of foodstuffs.
(ii) for the coating of utensils made of other metals so as to prevent them from corroding.

Calcium : Calcium is a white lustrous metal that slowly dulls down on exposure to air. It rarely occurs in free state, but in combined state it is found in the earth's crust as phosphates, sulphates, carbonates, *etc*. The sulphate and the chloride salts of calcium are present in hard water.

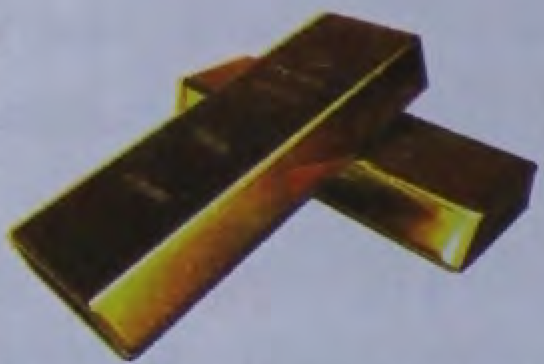
In its various combined states calcium has wide applications :

(i) Calcium chloride is used as a drying agent, *i.e.* for physical removal of water.

(ii) Calcium carbonate is used in the manufacture of glass, cement, lime, washing soda, etc.

(iii) Marble, a non-crystalline form of calcium carbonate, is used for building and laboratory purposes. It is used also to make statues.

(iv) Chalk, another form of calcium carbonate, is used for distempering of walls, in toothpastes and talcum powder, and in medicines for indigestion, *etc*.



Gold : Gold is a shiny yellow metal. It is extremely precious owing to its beauty, scarcity and chemical and physical stability. Gold is highly malleable and it is resistant to corrosion. It is a very good conductor of heat and electricity as well. Therefore it is used in :

(i) the manufacture of electronic devices like telephones, computers, etc.

(ii) making ornaments and coins.

(iii) dentistry to fill into teeth cavities (in the form of amalgam, an alloy made of gold, silver and mercury.

Silver : Silver is an off white, lustrous metal. It is the most ductile metal known to man. It is also the best known of all metallic conductors of electricity. It is used :

(i) for making jewellery, since it is fairly scarce and therefore semi-precious.

(ii) for filling into teeth cavities (in the form of amalgam, an alloy made of gold, silver and mercury).

(iii) as a water purifier.

(iv) for making electrodes and in several electroplating operations.

(v) in photography (in the form of silver nitrate and silver bromide).

(vi) in the form of silver iodide to seed clouds in order to create "artificial rain".

Though silver is the best known metallic conductor of electricity and the most ductile metal, it is not used for making electric wires. This is because it is rather costly and not as chemically stable as is required for transmission of electricity.

Mercury : Mercury is a silvery white, liquid metal. It does not moisten glass and it expands a lot on heating. Therefore it is used in :

(i) thermometers (as thermometric liquid).

(ii) barometers and other scientific apparatus.

(iii) dentistry, for filling into teeth cavities in the form of alloys known as silver amalgam and gold amalgam.

Platinum : Platinum is a lustrous and a very precious metal. It is not reactive, just as is gold. Platinum is an excellent catalyst. It is used :

(i) for making electrodes and electrolytic cells.

(ii) for making expensive ornaments and watches.

Do You Know ?

Metals in small amount are needed for the healthy growth of our body.

Calcium is needed to build strong bones and teeth.

Iron is an important part of haemoglobin in our blood.

Potassium makes our muscles and nervous system strong.

Zinc increases our immune system.

5.9 USES OF SOME COMMON NON-METALS

Non-metals too play a vital role in everyday life. Proteins, carbohydrates and fats are made mostly of non-metals — carbon, hydrogen, oxygen and nitrogen. We need oxygen to breathe and plants need carbon dioxide for photosynthesis. Non-metals are also important for the manufacture of a number of industrial substances. The uses of some commonly known non-metals are discussed below :

Oxygen : Oxygen is a life-supporting gaseous non-metal. No living thing can survive without oxygen. About 21% of air by volume and 23% by weight is oxygen. By weight 88·8% of pure water is oxygen. In combined state it is present in the earth's crust as oxides, carbonates, sulphates, *etc*. Oxygen is used :

(i) for respiration and combustion.

(ii) for artificial respiration for patients suffering from breathing problems (in the form of *carbogen*, a mixture of 95% oxygen and 5% carbon dioxide).

(iii) for artificial respiration by people in special occupations. Deep sea divers, mountaineers, astronauts, miners and firemen carry oxygen cylinders with them.

(iv) to weld and cut metals.

(v) for the extraction of iron and manufacture of steel. Oxygen reacts with the impurities of the crude iron ores to form ferrous oxides.

(vi) for the manufacture of sulphuric and nitric acids.

(vii) for blasting of rocks in the mining industry; carbon dust (carbon mixed with liquid oxygen) is used as an explosive, a substitute for dynamite.

(viii) as a propellant for spacecraft; liquid oxygen (**Lox**) helps to burn hydrogen. Oxygen is carried in containers attached to spaceships since, in space, there is no oxygen.

Nitrogen : Nitrogen constitutes about 78% of air by volume. It is a colourless, odourless, tasteless gas. It is slightly lighter than air. It is neither combustible nor a supporter of combustion. Nitrogen is an important component of human food nutrients.

(i) Nitrogen plays an important role in controlling the rate of combustion. It dilutes the oxygen present in the air that we breathe, otherwise pure oxygen would burn our lungs.

(ii) It is an important constituent of proteins, which are necessary for the growth of animals, plants and human beings. Plants convert nitrogen into proteins.

(iii) It is used in the manufacture of compounds like ammonia and nitric acid.

(iv) It is used to make fertilizers like ammonium salts, urea, potassium nitrate, *etc*.

(v) It is used to prepare explosives like T.N.T. (Trinitrotoluene)

(vi) Because of its inert nature nitrogen is used for the preservation of food. The containers used for storing foodstuffs are flushed with nitrogen (to remove oxygen) before they are packed and sealed. The absence of oxygen does not allow for bacterial growth. Thus food remains fresh for a long time.

During a thunderstorm, when lightning occurs, nitrogen and oxygen in the atmosphere combine to form oxides of nitrogen, which are washed away with rain (in the form of nitric acid) into the soil.

Chlorine : It is a greenish yellow gas, with a pungent, suffocating smell. It is fairly soluble in water, forming a pale yellow solution called *chlorine water*. Chlorine is used :

(i) as a bleaching agent for rough and hard fibres like jute and cotton.

(ii) as a disinfectant for sterilizing both drinking water and swimming pool water.

(iii) in the manufacture of mineral acids like hydrogen chloride.

(iv) in the manufacture of chemicals like D.D.T. (Dichloro diphenyl trichloroethane), B.H.C (Benzene hexachloride). and bleaching powder ($CaOCl_2$), which are used as an insecticide, a pesticide and a disinfectant, respectively.

Sulphur : Sulphur is a yellow solid. It is brittle in nature. In free state it occurs in volcanic regions, while in combined state it occurs as sulphates, sulphides, *etc*. Substances like garlic, onion, eggs, hair and wool contain sulphur. Sulphur in small amounts is a vital ingredient for the human body.

Sulphur has wide applications :

(i) It is used in the chemical industry for the manufacture of sulphuric acid, sodium thiosulphate (used in photography), gunpowder, dyes, matches and fireworks.

(ii) It is used in the medical industry :
- to prepare skin ointments, since it has excellent fungicidal properties.
- to fumigate disease-infected areas (in the form of sulphur vapour).
- to purify blood (in the form of a colloidal solution).
- to prepare *homeopathic* and *ayurvedic* medicines.
- to prepare a range of other medicinal drugs.

(iii) Sulphur powder is used as an insecticide and as a fungicide.

(iv) In the form of sulphur dioxide it is used for the fumigation of factories, godowns and cold storages.

Phosphorus : Phosphorus is found in red, yellow, white, black and scarlet colours. It does not occur in free state, since it readily combines with oxygen. In combined state phosphorus occurs as phosphates. It is present in the brain, the bones and the teeth of animals [in the form of calcium phosphate [$Ca_3(PO_4)_2$] and in plant cells.

(i) White phosphorus is used as rat poison. It is used also in fireworks because of its inflammable nature.

(ii) Phosphorus is used in the manufacture of fertilizers, detergents and fine chinaware.

(iii) Phosphorus sulphide is used on the sides of safety match boxes.

Silicon : Silicon is one of the most useful elements available to modern man. It does not occur free in nature. In combined state however it ranks next only to oxygen in abundance, as sand. [The chemical name of sand is silica (SiO_2)].

(i) Highly purified silicon is used in making microchips for computers, transistors, solar cells, rectifiers and other solid state devices that are used extensively in the electronics and space age industries.

(ii) Silicon is used in the manufacture of "silicone", a waterproof material.

(iii) It is used also to prepare silicon carbide, which is the hardest substance prepared by man. It is used as the grinding agent in various kinds of grinding tools.

(iv) Silicon is used in the form of sand to prepare concrete, bricks and cement. Sand is the principal ingredient of glass.

(v) In the form of silicates silicon is used in enamel, pottery, *etc.*, and for preserving eggs.

(vi) Silicon is an important ingredient in steel, an alloy of iron.

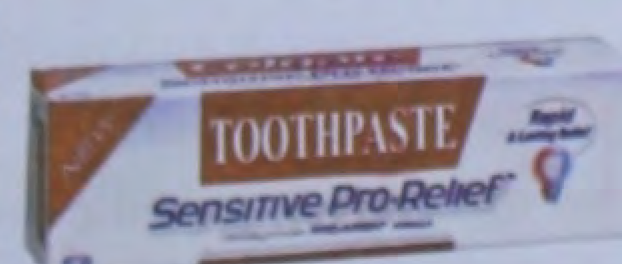
Iodine : Iodine is a dark grey, crystalline solid, with a metallic lustre. It is insoluble in water but soluble in both alcohol and potassium iodide solutions. It is used :

(i) in the form of iodized salt for the healthy growth of the human body. Iodine deficiency causes goitre and other thyroid based diseases.

(ii) in photographic films (in the form of potassium iodide).

(iii) to make tincture of iodine and *iodex*, which are used as disinfectant and pain reliever respectively.

Fluorine : Pure fluorine is a greenish yellow gas with a suffocating odour.



(i) Fluorine is used mainly in the production of fluorides and fluorocarbon compounds.

(ii) In the form of stannous fluoride it is used in toothpastes to prevent dental decay, especially in children.

(iii) Fluorine is used to prepare a type of plastic known as **teflon***. Teflon is thermally stable and **chemically resistant.** Therefore it is widely used as an insulator and as a lubricant.

(iv) Fluorine is potentially a rocket fuel, though it is rarely used for this purpose.

5.10 ALLOYS

The word 'alloy' comes from the French word "aloyer", meaning 'to bind'. *An alloy is a solid homogeneus mixture of usually two or more metals or metals and non metal.* The properties of an alloy are different from the properties of the metals of which it is made.

Purpose of making alloys

1. To prevent corrosion.
2. To acquire metallic substances of attractive colours.
3. To acquire metallic substances that have a desirable melting point.
4. To harden or strengthen or lighten the metal. Pure gold is so soft that it cannot be used for making ornaments. When mixed with copper or brass, however, gold is hardened enough for use as ornament material.

Amalgam : An amalgam is an alloy in which one of the component metals is mercury.

Dental Alloy

You may have an alloy in your teeth. An amalgam *i.e.* an alloy of mercury, silver, tin, zinc and copper is used to fill cavities of teeth.

Note : The science and the art of making alloys was known to the ancient Indians. *Ashtadhatu* and *panchdhatu* are two alloys mentioned in historical books.

5.11 THE NEED TO RECYCLE AND CONSERVE METALS

Learning the art of isolating metals from their corresponding minerals was a big step forward for human civilization. Metals find application in almost every field. They are used in utensils, buildings, factories, agricultural equipments, medical equipments, automobiles, locomotives, navigation, aviation and warfare machinery, space programmes, and in many other fields. However, it has been observed that metal objects become dull with the passage of time. Iron articles get covered with a brown coating, called rust. Aluminium vessels become a dull grey. Copperware lose their shine and acquire a green coating, and silver ornaments turn black. This causes economic

* *Teflon coated blades are more durable, sharper and safer compared to ordinary blades.*

loss because metals that lose their properties are rendered unfit for further use.

The wasting away of a metal layer by layer is called corrosion. The damage of metals by corrosion causes heavy economic loss. Therefore it becomes necessary to protect the metals from corrosion and thus conserve them.

Metals are prevented from being corroded by applying one or more of the following methods.

1. **Painting :** This is the most common method employed to protect metals. Steel, furniture, iron bridges, railway coaches, machines and the bodies of buses and trucks are coated with paints (made usually from lead or zinc). The layer of paint acts as a shield against corrosion.
2. **Greasing or oiling :** Greasing or oiling of metal articles protects them from corrosion by shielding them from direct contact with air and moisture.
3. **Galvanization :** The process of coating iron articles with a thin layer of zinc is known as galvanization. Zinc subsequently changes to zinc oxide, which prevents the contact of iron with air and moisture.
4. **Electroplating :** In this process the surface of metal to be protected is coated with a layer of another metal by electrolysis. In the case of gold the process is known as **gilding** or **gold plating**.

The metallic resources of the earth are being used at such a rapid rate that they cannot last forever.

Even in our country we do not have enough metallic deposits to meet our future industrial and domestic demands. Therefore, it becomes necessary to use the available metals with utmost care without their wastage. This can help in the conservation of metals.

Another way to meet our present demand is to recycle the metals. Metal articles that have become completely useless can be retreated with chemical reagent to regain them in their pure and usable forms. The method of reusing the metals is called **recycling of metals**.

Recycling includes separating, collecting, processing, marketing and ultimately using the metals that would have been thrown away. Recycling of metals is taking place to an ever increasing extent.

At present metals such as aluminium, tin, copper, silver, iron, gold, lead *etc*. are being recycled.

Scrap collectors are playing an important role in conservation and recycling of metals. These scrap metals come from homes, shops, manufacturers, industries *etc*. in the form of cans, pipes, automobiles, computer components, pans, furniture, wire, *etc*.

Recycling of metals saves an expensive extraction process.

- It also prevents pollution caused by the debris.
- Some metals like lead, mercury *etc*. are poisonous. If they will be not recycled they can cause hazards to the environment.

Thus, conservation and recycling of metals are very important and useful.

Table 5.4 : Alloys, their compositions, properties and uses

Alloys of copper	Composition	Properties	Uses
1. Brass	Cu – 60 – 70% Zn – 30 – 40%	Lustrous, more malleable and ductile than copper; much harder than copper; can be easily cast; resists corrosion.	For making statues, screws and handles, utensils, machine parts and decorative articles.
2. Bronze	Cu – 80% Zn – 2% Sn – 18%	Hard and brittle; resistant to corrosion; takes up a high polish.	For making coins and medals, utensils and statues.
3. Bell metal	Cu – 80% Sn – 20%	Sonorous (produces a sound); hard and brittle.	For making bells and gongs, statues, *etc*.
4. German silver	Cu – 50% Zn – 30% Ni – 20%	White and bright like silver; malleable and ductile; high electrical resistance.	For making ornaments, decorative articles, heaters and rheostats, *etc*.
5. Gun metal	Cu – 88% Sn – 10% Zn – 1% Pb – 1%	Hard and brittle and can be easily cast.	For making gun barrels and cannons, gears and motor brushes
Alloys of aluminium			
1. Duralumin	Al – 95% Cu – 4% Mg – 0·5% Mn – 0·5%	Light but as strong as steel; hard and resistant to corrosion; highly ductile.	For making aircraft bodies, light tools, pressure cookers.
2. Magnalium	Al – 90 – 95% Mg – 8 – 10%	Very light and hard; resistant to corrosion.	For making light tools, beam balances and machine parts.
Alloys of lead			
1. Solder	Pb – 50% Sn – 50%	Low melting point	For soldering of joints and fusing of metal objects.
2. Type metal	Pb – 75% Sb – 20% Sn – 5%	Low melting point; expands and can be cast easily.	In the printing industry
Alloys of steel			
1. Steel	Fe – 98 – 99% C – 0·1–1·5%	Hard and brittle.	For making rails, bridges, ships, tanks, *etc*.
2. Stainless steel	Fe – 75% Cr – 15% Ni – 8–9·95% C – 0·05–1%	Lustrous, hard and tenacious; resistant to corrosion by acids and alkalis.	For making utensils, surgical instruments, cutlery, decorative articles, *etc*.
3. Nickel steel	Fe – 95 – 98% Ni – 2·5%	Hard, elastic and resistant to corrosion.	For making electric cables, automobile parts, *etc*.

EXERCISE

1. Fill in the blanks :
   (a) Gold and silver are found in .... state.
   (b) The formula of haematite is ....
   (c) The more reactive metals are extracted by ....
   (d) .... is a homogeneous mixture of metals.
   (e) Bronze is an alloy of .... and ....
   (f) Metals are generally .... and ductile.
   (g) Metals form .... ions by losing electrons from their valence shells.
   (h) Non-metals have .... electrons in their valence shells.
   (i) Mercury is a liquid ....
   (j) The oxides of non-metals are .... or .... in nature.

2. Choose the correct alternative :
   (a) Magnetite is an ore of
       (i) copper (ii) zinc
       (iii) iron (iv) aluminium
   (b) Sulphur ores are concentrated by
       (i) roasting (ii) froth flotation
       (iii) calcination (iv) smelting
   (c) The method used to convert the carbonate ore of copper into its oxide in the absence of air is
       (i) roasting (ii) calcination
       (iii) concentration (iv) reduction
   (d) During electro-refining, impure metal acts as
       (i) cathode (ii) anode
       (iii) electrolyte (iv) none of the above
   (e) The alloy used in the manufacture of aircraft bodies is
       (i) duralumin (ii) gun metal
       (iii) brass (iv) german silver

3. Write ***true*** or ***false*** and correct the false statements by changing the underlined words :
   (a) Aluminium foils are used for <u>decorating sweets</u>.
   (b) <u>Oxygen gas</u> is used for hydrogenation of vegetable oils.
   (c) <u>Silicon</u> is used for making microchips.
   (d) <u>Cast iron</u> is the purest form of iron.
   (e) S^{2-} is the symbol of sulphide ion since <u>it loses</u> two electrons from its valence shell.
   (f) Gallium is a <u>liquid metal at room temperature</u>.
   (g) Water is an <u>acidic oxide</u>.
   (h) Alkalis are <u>soluble bases</u>.

4. Name the following :
   (a) The process by which iron ore is concentrated.
   (b) An alloy of iron used for making surgical instruments.
   (c) Two alloys of copper used for making statues.
   (d) A liquid metal and a non-metal.
   (e) Two neutral oxides.
   (f) Two reducing agents.
   (g) The gas evolved when a reactive metal combines chemically with dilute sulphuric acid.
   (h) The products formed when an acidic oxide reacts with a base.
   (i) Two most reactive metals in the metal reactivity series.

5. Complete and balance the following reactions :
   (a) $Na + O_2 \rightarrow$ (b) $K + H_2O \rightarrow$
   (c) $Zn + HCl \rightarrow$ (d) $Fe + CuSO_4 \rightarrow$
   (e) $CO_2 + NaOH \rightarrow$

6. Give the chemical names and chemical formulae of the following ores :
   (a) Bauxite (b) Haematite (c) Galena
   (d) Cinnabar (e) Marble

7. Give *two* important uses of the following metals and non-metals :
   (a) Gold (b) Silicon (c) Iron
   (d) Copper (e) Sulphur

8. Define the following terms :
   (a) Metallurgy (b) Gangue
   (c) Ore (d) Roasting
   (e) Calcination (f) Slag
   (g) Flux (h) Electrolysis
   (i) Smelting (j) Indicators

9. What are alloys ? Name one alloy for each of the following metals and give two uses for each.
   (a) Iron (b) Aluminium (c) Zinc
10. Compare the physical properties of the metals and the non-metals with respect to :
   (a) lustre (b) malleability
   (c) conductivity (d) ductility
   (e) solubility
11. What is meant by the metal reactivity series ? What are its important features ?
12. Differentiate between :
   (a) ore and mineral
   (b) calcination and roasting
   (c) cation and anion
13. How is electro-refining done ?
14. Name
   (a) The processes involved in concentration and refining of ores.
   (b) An oxide of a metal reduced by coke only.
   (c) Two important ores of iron. Also give their composition.
15. Why is it necessary to conserve and recycle metals? Explain.

RECAPITULATION

- Elements are broadly divided into metals and non-metals.
- Metals are hard, lustrous, crystalline solids. They are malleable, ductile and good conductors of heat and electricity, and they have high melting and boiling points, high tensile strength and sonorous quality. Some common metals are copper, iron, aluminium, tin, lead, gold, silver, zinc, calcium and sodium. [Mercury is a liquid metal].
- Non-metals are generally gases or dull brittle solids. They are neither malleable nor ductile nor tensile. They are bad conductors of heat and electricity, have low melting and boiling points, and they do not produce a sound when struck. Some common non-metals are oxygen, nitrogen, hydrogen, chlorine, carbon, sulphur, phosphorus, iodine, etc. [Bromine is a liquid non-metal].
- Metals react with oxygen to form basic oxides. A basic oxide is a compound that reacts with water to produce a metallic hydroxide. A basic oxide reacts with acids to produce salt and water.
  Soluble bases are called *alkalis,* which turn red litmus paper blue. All alkalis are bases but all bases are not alkalis, since all bases are not soluble in water.
- Non-metals react with oxygen to form acidic oxides or neutral oxides (water, nitricoxide, etc.). Acidic oxides dissolve in water to produce acids. These oxides react with bases to produce salt and water.
- A salt is a compound that contains a basic radical other than hydrogen and an acid radical other than a hydroxyl ion. *For example*, sodium chloride (NaCl) is a salt containing the ions Na^+ and Cl^-.
- The list in which metals are arranged in the decreasing order of chemical reactivity is called the Metal Activity Series.
- Metals occur mostly in combined state, such as in the form of carbonates, sulphides, sulphates, halides, oxides, etc.
- Most metals are present in the earth's crust in the form of *minerals.* A mineral is a naturally occurring chemical deposit that contains elements and compounds in a mixed state with earthly impurities. The minerals from which metals are extracted profitably are called metallic ores.
- Metallurgy is the process by which metals are extracted from their corresponding ores. The various steps involved in metallurgy are : (i) concentration of ore, (ii) roasting or calcination, (iii) reduction (smelting) of metallic oxides, and (iv) refining of impure metals to gain pure ones.
- Metals find application in almost every field. They are used in utensils, buildings, factories, agricultural equipment, medical equipment, automobiles, locomotives, navigation and aviation and warfare, and in space programmes, etc.
- Alloys are homogeneous mixtures of metals. They usually enhance the qualities of their parent metals. They too find application in various fields.
- The metallic resources of a nation are of great importance. Therefore their conservation and recycling is necessary to meet the demands of future.

GLOSSARY

Allotropes : Different forms of an element in the same physical state with identical chemical properties but different physical properties.

Allotropy : A phenomenon due to which an element exists in two or more forms in the same physical state.

Alloys : A homogeneous solid mixture of two or more metals or metals and non metal

Amorphous : The solid in which particles are not arranged in regular geometrical pattern.

Atom : The building block of matter, may or may not have independent existence.

Atomic number : The number of protons present in an atom.

Biogas : A mixture of gases obtained by degradation and decomposition of animal and plant matter.

Calcination : Heating concentrated ore in the absence of air.

Calorific value : The amount of heat energy liberated when one gram of fuel is completely burnt.

Carbonization : The process of slow conversion of vegetable matter into carbon rich substances.

Catalyst : Substance which changes the rate of a chemical reaction.

Catalytic hydrogenation : A process in which hydrogen gas is passed through oil in the presence of a catalyst to change into solid (ghee).

Chemical bond : The force which holds the atoms together in a molecule.

Chemical change : A change in which new substances are formed.

Combination reaction : A reaction in which two or more substances combine chemically to produce a single product.

Combustible : Substances that burn easily in air.

Combustion : Burning of a substance in air to produce heat, light and sound energy.

C.N.G. : Compressed Natural Gas (methane is the main gas).

Concentration of ore : Process to remove impurities.

Covalent bond : A bond formed between the atoms by sharing of electrons.

Crystalline : The solid in which particles are arranged in a regular geometrical pattern.

Decomposition reaction : A process in which a substance decomposes to produce two or more new substances.

Destructive distillation : Heating of a substance in the absence of air or oxygen to form carbon rich residue.

Displacement reaction : A process in which a more reactive element displaces a less active element from its compound.

Distillation : The process of converting a liquid into its vapour by boiling and then condensing the vapour into the liquid state on cooling.

Double decomposition reaction : A process in which two compounds exchange their radicals to produce two new compounds in solution.

Electrodes : The solid conductor through which electric current enters and leaves the electrolyte.

Electrolysis : The process in which electricity is passed through a substance in aqueous or molten state to bring about some chemical change.

Electrolyte : The substance in molten or aqueous solution state through which electricity passes during electrolysis.

Electrometallurgy : The process in which metal is extracted from its ore by electrolysis.

Electronic configuration : Arrangement of electrons in different shells/orbits of an atom surrounding the nucleus.

Electrons : The negatively charged subatomic particle with negligible mass which revolve round the nucleus of an atom.

Endothermic reaction : In which the energy is absorbed from the surroundings.

Enzymes : Complex organic compounds acting as catalysts in biochemical reactions.

Exothermic reaction : In which energy is given out to the surrounding in the form of heat and light.

Fire extinguisher : A device used to extinguish fire.

Flame : A zone of combustion of gaseous substances.

Fractional distillation : A process of distillation employed to separate the components of a homogeneous liquid mixture on the basis of different boiling points of the components.

Fuel : A substance used to produce usable heat energy.

Fullerene : The third crystalline form of carbon.

Ignition temperature : The temperature at which a substance begins to burn.

Inflammable : A substance that burns with a flame and has low ignition temperature.

Ions : Charged particles formed due to loss or gain of electrons from atoms.

Isotopes : Atoms with same atomic number but different mass number.

L.P.G. : Liquefied petroleum gas.

Mass number : Sum of protons and neutrons present in air atom.

Metal activity series : A series of metals in which they are arranged in the descending order of their reactivity.

Metallurgy : The process of extracting metals from their ores.

Molecules : The smallest particle of matter with independent existence.

Neutrons : The subatomic particles present in the nucleus of an atom with unit mass but no charge.

Non-combustible : A substance that does not burn in air or oxygen.

Non-electrolyte : A substance that does not conduct electricity in liquid state.

Nuclear fission : A radio-active phenomenon in which a heavy nucleus breaks into smaller nuclei.

Nuclear fusion : A radio-active phenomenon in which lighter nuclei fuse to form a bigger nucleus.

Nuclear reactor : A power plant based on nuclear energy to produce electricity.

Nucleons : The particles present in the nucleus of an atom.

Nucleus : The central, dense part of an atom containing protons and neutrons which is responsible for the total mass of an atom.

Ore : A mineral mixed with earthly impurities from which a metal is extracted profitably.

Oxidation : The process in which a substance combines with oxygen.

Oxidising agent : A substance which helps in oxidation.

Petroleum : A dark coloured, viscous mixture of hydrocarbons.

Physical change : A change in which no new substance is formed.

Precipitate : Insoluble solid formed due to chemical combination of two solutions.

Protons : Positively charged particles with unit mass present in the nucleus of an atom.

Radicals : A single atom or group of atoms which is charged and behaves as a single unit.

Radio-activity : A phenomenon in which highly energetic rays are emitted from the nucleus of a heavy atom.

Redox reaction : A reaction in which reduction and oxidation take place simultaneously.

Reducing agent : A substance which helps in reduction.

Reduction : The process in which a substance combines with hydrogen.

Roasting : Strong heating of an ore in the presence of air.

Shells/Orbits : The fixed circular path along which electrons revolve round the nucleus of an atom.

Smelting : The process of reducing concentrated and roasted ore to obtain metal by using reducing agents.

Valence electrons : The number of electrons present in the outermost shell of an atom.

Valency : It is the combining capacity of an element. It is equal to the number of electrons lost, gained or shared by atoms during chemical combinations.