6 Metals and Nonmetals

As you know, elements can be broadly classified into metals and nonmetals.

Metals are	Nonmetals are
• lustrous, • crystalline solids of high tensile strength, • malleable and ductile, and • good conductors of heat and electricity.	• nonlustrous (i.e., dull looking), • brittle, if solid, • nonmalleable and nonductile, and • bad conductors of heat and electricity.
Examples K, Ca, Na, Mg, Al, Zn, Fe, Sn, Pb, Cu, Ag, Au	*Examples* H, C, N, O, P, S, Cl

Of the 114 elements known today, 90 are metals and the remaining 24 are nonmetals.

Physical Properties of Metals and Nonmetals

Metals differ widely from nonmetals in their physical properties. This is evident from the following comparison.

Property	Metals	Nonmetals
1. State	Except mercury, metals are solids under ordinary conditions.	Under ordinary conditions, some nonmetals are solids, one is a liquid and some are gases. Of the 24 nonmetals, 12 (e.g., carbon, sulphur, phosphorus) are solids, 1 (bromine) is a liquid, and 11 (e.g., nitrogen, oxygen, chlorine) are gases.
2. Lustre	Metals have a lustre, called metallic lustre. They can be polished. For example, iron, aluminium, zinc, tin, copper, silver and gold are all lustrous, and can be polished.	Nonmetals are usually lustreless (dull-looking). They cannot be polished. *Exceptions* Graphite (carbon) and iodine are lustrous.
3. Density	Metals generally have a high density. *Metal* — *Density* (g/cm^3) Zinc — 7.1 Tin — 7.28 Iron — 7.9 Copper — 8.9 Silver — 10.5 Lead — 11.3 Mercury — 13.6 Gold — 19.3 Platinum — 21.45 *Exceptions* Potassium, sodium, magnesium and aluminium have comparatively low densities, and are light.	Nonmetals usually have a low density. *Nonmetal* — *Density* (g/cm^3) Phosphorus (white) — 1.82 Sulphur — 2.07 Graphite (carbon) — 2.25 Diamond (carbon) — 3.51 *Exception* Bromine has a high density ($8.13\ g/cm^3$).

Property	Metals	Nonmetals
	Metal — *Density* (g/cm^3) Potassium 0.86 Sodium 0.97 Magnesium 1.74 Aluminium 2.7	
4. Tensile strength	In general, metals are hard solids with high tensile strength, i.e., they can withstand high pressure without breaking. A metal wire or rope can take big loads, and thus can be used in ropeways. It is the tensile strength of iron that makes a bridge or a skyscraper able to withstand high pressures. *Exceptions* Sodium and potassium are soft metals that can be cut with a knife.	In general, solid nonmetals are soft, and have low tensile strength. They are brittle. For example, sulphur and phosphorus are brittle. *Exception* Diamond is very hard—the hardest solid known.
5. Malleability	Metals are malleable, i.e., they can be hammered or pressed into sheets or foils. Iron, aluminium, tin, copper, silver, gold, etc., are all malleable. Aluminium is pressed into foils that are used for covering or wrapping food. A blacksmith hammers red-hot steel to make tools, and a piece of copper or brass to make utensils.	Nonmetals are not malleable.
6. Ductility	Metals are ductile, i.e., they can be bent and drawn into wires.	Nonmetals are not ductile.
7. Sonority	Metals are sonorous, i.e., they produce a characteristic sound, called a metallic sound or metallic clink, when hit by a hard object.	Nonmetals are not sonorous. They do not produce a characteristic sound when hit by a hard object.
8. Melting point (m.p.) and boiling point (b.p.)	Metals generally melt and boil at high temperatures. *Metal* — m.p. (°C) — b.p. (°C) Zinc 419 920 Aluminium 660 2467 Iron 1539 2800 Copper 1083 2450 Potassium, sodium, tin and lead have comparatively low melting points, but quite high boiling points. *Metal* — m.p. (°C) — b.p. (°C) Potassium 63 766 Sodium 98 881 Tin 232 2260 Lead 327 1620 *Exception* The liquid metal, mercury, freezes at –39°C and boils at 357°C.	Nonmetals generally melt and boil at low temperatures. *Nonmetal* — m.p.(°C) — b.p.(°C) Phosphorus 44 281 Sulphur 114 445 Iodine 114 185 The boiling as well as the melting points of nonmetals are much lower than ordinary temperature. Bromine, the only liquid nonmetal, boils at 60°C. Nonmetal — m.p.(°C) — b.p.(°C) Bromine – 7 60 Hydrogen –259 –253 Oxygen –229 –183 Nitrogen –210 –196 Chlorine –101 – 34 *Exception* Carbon melts at a very high temperature (~4000°C).
9. Conduction of heat	Metals are good conductors of heat.	Nonmetals are bad conductors of heat.
10. Conduction of electricity	Metals are good conductors of electricity. They are, therefore, used for transmitting electricity	Nonmetals are bad conductors of electricity. *Exception* Graphite is a good conductor of

Fig. 6.1 Metals are lustrous and can be pressed into sheets or foils and drawn into wires.

Fig. 6.2 Metals have high tensile strength. Steel cables carry heavy loads such as that of cable cars.

Fig. 6.3 Metals are sonorous.

Activity Using an electrical circuit of the type shown in Figure 6.4, you can easily test whether or not something conducts electricity. The test material conducts electricity if the bulb glows when the test material is in circuit.

You will find that a metal key conducts electricity (the bulb glows), but a block of sulphur does not.

Test something else now. Sharpen a small pencil at both ends, and connect the two naked

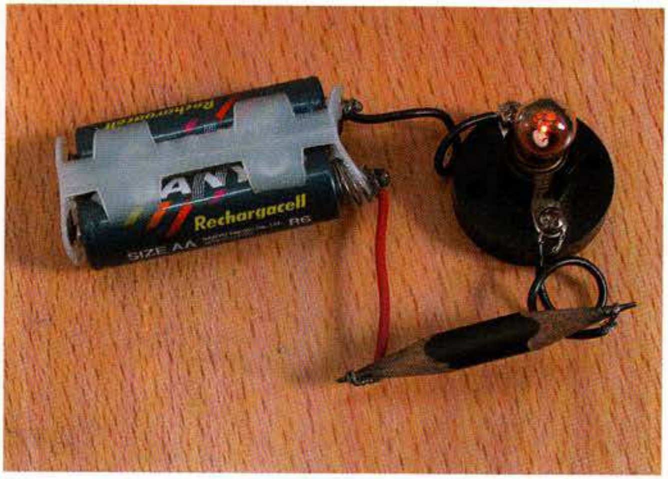


Fig. 6.5 Graphite conducts electricity.

ends of the 'lead' to the circuit. The bulb will glow, showing that graphite conducts electricity.

Chemical Properties of Metals and Nonmetals

In chemical properties too, metals differ from nonmetals to a great extent.

The activity series helps in grading the chemical reactivities of metals (along with hydrogen). We find that the higher the position of the metal in the series, the greater is its reactivity. Sodium and potassium occupy high positions in the series, and are very active. Silver, gold and platinum are placed very low in the series, and are unreactive. They are called noble metals.

Action of Air or Oxygen

Action on metals

Metals generally react with oxygen to form oxides. The vigour with which a metal reacts with oxygen decreases as we go down the activity series. Potassium and sodium react with air or oxygen even at ordinary temperatures. That is why they are preserved in kerosene. Magnesium burns in air with a dazzling white light only when ignited. Zinc, iron and copper react with air only when

$$4Na + O_2 \xrightarrow[\text{temperature}]{\text{ordinary}} 2Na_2O$$

$$2Mg + O_2 \xrightarrow{\text{ignition}} 2MgO$$

$$2Zn + O_2 \xrightarrow[\text{heating}]{\text{strong}} 2ZnO$$

$$3Fe + 2O_2 \xrightarrow[\text{heating}]{\text{strong}} Fe_3O_4$$

$$2Cu + O_2 \xrightarrow[\text{heating}]{\text{strong}} 2CuO$$

Metals which occupy a very low position in the activity series either react to a very small extent (e.g., silver) with air or oxygen or do not react at all (e.g., gold and platinum).

Corrosion The freshly cut surfaces of metals shine. But, on being exposed to air, these surfaces usually get tarnished (discoloured). This happens because a thin film of the metal oxide is generally formed over them. Sometimes, the hydrogen sulphide gas present in polluted air causes the formation of the metal sulphide too. For example, silver gets tarnished in polluted air by the formation of silver sulphide (Ag_2S, which is black). In many cases (e.g., silver and gold), tarnishing protects the rest of the metallic mass from the chemical action of air.

In the other cases, when the chemical action of air is prolonged beyond tarnishing, the compounds formed slowly eat away the metal. We then say that the metal is corroded.

> The slow destruction of a metal or alloy by chemical action is called corrosion.

The rusting (of iron) is a common example of corrosion. Other metals, like magnesium, aluminium, zinc, tin and copper, also corrode. However, the action of air on a highly active metal, like potassium or sodium, is not called

Fig. 6.6 The iron pillar at Delhi has not rusted for centuries.

Factors that aid corrosion The following factors hasten the corrosion of metals.

1. **The presence of impurities in the metal** Pure metals kept in isolation do not corrode. The iron pillar at Delhi, standing in the open air, has not corroded for centuries because it is made of pure iron.
2. **The presence of moisture**
3. **The presence of acid-forming gases** Gases like carbon dioxide, sulphur dioxide and hydrogen sulphide form acids upon reacting with moisture, leading to chemical action on the metal.
4. **The presence of salts** Salts facilitate corrosion.

   This is evident from the fact that

   - the metals used in ships corrode easily, and
   - corrosion is observed to a much greater degree in coastal areas than in places far away from the sea.

Activity You can see for yourself how salty water hastens corrosion. Place a few pieces of bright copper wire in two glasses containing distilled water. Add a few crystals of common salt to one of them. Allow the glasses to stand for a day or two. You will find that the metal pieces in the distilled water remain shining, whereas those in the salty water become grey or black.

Preventing corrosion Corrosion is highly destructive. It

- eats away the metal, and
- destroys the strength of the metal by making it crack.

When metal is corroded, it has to be replaced. In terms of money, the loss caused by corrosion runs into huge amounts every year.

Corrosion can be prevented by the following methods.

1. **Painting** Applying a paint—preferably acid-resistant—protects the metal from the chemical action of air or a solution.
2. **Greasing** Applying grease over the metal surface also protects the metal from chemical action.
3. **Galvanising** A metal object is dipped in molten zinc so that a layer of zinc forms on the surface of the object. Then the object is said to be **galvanised.** Galvanising protects a metal (like iron), which is lower

Fig. 6.7 Corrosion in the body of a washing machine

than zinc in the activity series, from corrosion. Being more active than the metal, it is zinc that reacts with air.

4. Electroplating As you know, depositing a thin, uniform layer of one metal over another by electrolysis is known as electroplating.

   Electroplating a metal with tin, nickel, chromium or copper is quite a common method of preventing corrosion.

5. Alloying Alloying a metal with other(s) not only increases the strength of the metal, but protects it from corrosion too. Thus, stainless steel (Fe + Cr + Ni + Mn + C), brass (Cu + Zn), bronze (Cu + Sn) and magnalium (Al + Mg + Cu) are all corrosion-resistant.

Action on nonmetals

Except white phosphorus, nonmetals generally react with oxygen or air only at high temperatures. White phosphorus burns in air or oxygen at room temperature.

When carbon is heated in a limited supply of air (or oxygen), it forms carbon monoxide. When the supply of air is sufficient, it forms carbon dioxide.

$$2C + O_2 \xrightarrow{\text{heat}} 2CO\uparrow \quad \text{(limited air)}$$

$$C + O_2 \xrightarrow{\text{heat}} CO_2\uparrow \quad \text{(sufficient air)}$$

$$2CO + O_2 \xrightarrow{\text{heat}} 2CO_2\uparrow \quad \text{(sufficient air)}$$

When heated in air (or oxygen), phosphorus forms phosphorus(III) oxide (P_4O_6) and phosphorus(V) oxide (P_4O_{10}), both of which are solids.

$$P_4 + 3O_2 \xrightarrow{\text{heat}} P_4O_6 \quad \text{(limited air)}$$

$$P_4 + 5O_2 \xrightarrow{\text{heat}} P_4O_{10} \quad \text{(sufficient air)}$$

(P_4O_6 and P_4O_{10} are often represented as P_2O_3 and P_2O_5 respectively.)

When burnt in air (or oxygen), sulphur forms sulphur dioxide. Sulphur dioxide can be converted into sulphur trioxide by catalytic oxidation.

$$S + O_2 \longrightarrow SO_2\uparrow$$

$$2SO_2 + O_2 \xrightarrow[\text{platinum catalyst}]{\text{heat}} 2SO_3\uparrow$$

Nitrogen is quite inactive and reacts with oxygen to form nitric oxide only under the influence of an electric spark. This is how nitric oxide is formed during lightning. Once formed, nitric oxide easily reacts with oxygen, forming nitrogen dioxide.

$$N_2 + O_2 \xrightarrow[\text{spark}]{\text{electric}} \underset{\text{nitric oxide}}{2NO\uparrow}$$

$$2NO + O_2 \longrightarrow \underset{\text{nitrogen dioxide}}{2NO_2\uparrow}$$

Other oxides of nitrogen (N_2O, N_2O_3, N_2O_4 and N_2O_5) are also known, but they are formed by other reactions.

The Acid–Base Nature of Oxides

The oxides of metals

Oxides of metals are generally basic. They react with acids to form salts and water. The oxides of potassium, calcium, sodium, magnesium, aluminium, zinc, iron, tin, copper, etc., are basic.

Base		*Acid*		*Salt*		*Water*
K_2O	+	2HCl	→	2KCl	+	H_2O
CaO	+	2HCl	→	$CaCl_2$	+	H_2O
MgO	+	H_2SO_4	→	$MgSO_4$	+	H_2O
FeO	+	H_2SO_4	→	$FeSO_4$	+	H_2O
CuO	+	H_2SO_4	→	$CuSO_4$	+	H_2O

The oxides of potassium, calcium and sodium dissolve in water to form the hydroxides of the metals. Being soluble bases, these hydroxides are alkalis.

Soluble bases are called alkalis.

$$K_2O + H_2O \rightarrow 2KOH$$

$$Na_2O + H_2O \rightarrow 2NaOH$$

$$CaO + H_2O \rightarrow Ca(OH)_2$$

The hydroxides of metals like magnesium, aluminium, zinc, iron, tin, copper and silver are not soluble in water. So, they are not alkalis.

Some metals form basic oxides as well as acidic oxides. For example, chromium forms chromium(III) oxide (Cr_2O_3), which is basic, and chromium(VI) oxide (CrO_3), which is acidic.

Acid		*Base*		*Salt*		*Water*
$6HCl$	+	Cr_2O_3	$\rightarrow$	$2CrCl_3$	+	$3H_2O$
CrO_3	+	$2NaOH$	$\rightarrow$	Na_2CrO_4	+	H_2O

If a metal forms two or more oxides, the lower-valent oxide is basic.

Every metal must form at least one basic oxide.

The oxides of nonmetals

Except water (H_2O), carbon monoxide (CO), nitrous oxide (N_2O) and nitric oxide (NO), which are neutral, the oxides of nonmetals are acidic. They show the following properties.

1. They dissolve in water to form acids. So, they are also called acid anhydrides.

$$CO_2 + H_2O \rightarrow \underset{\text{carbonic acid}}{H_2CO_3}$$

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$SO_3 + H_2O \rightarrow \underset{\text{sulphuric acid}}{H_2SO_4}$$

$$P_4O_{10} + 6H_2O \rightarrow \underset{\text{phosphoric acid}}{4H_3PO_4}$$

$$N_2O_5 + H_2O \rightarrow \underset{\text{nitric acid}}{2HNO_3}$$

2. They react with bases to form salts.

$$CO_2 + Na_2O \rightarrow \underset{\text{sodium carbonate}}{Na_2CO_3}$$

$$SO_2 + 2NaOH \rightarrow \underset{\text{sodium sulphite}}{Na_2SO_3} + H_2O$$

$$SO_3 + 2NaOH \rightarrow \underset{\text{sodium sulphate}}{Na_2SO_4} + H_2O$$

Note that the anion, i.e., the negative radical, of the salt formed is the same as that of the acid formed by the dissolution of the oxide in water. For example, SO_4^{2-} is the negative radical of Na_2SO_4. And SO_4^{2-} is the anion of the acid H_2SO_4, which is formed when SO_3 dissolves in water.

EXAMPLE 1 *Give the balanced chemical equation for the reaction between* N_2O_5 *and* Na_2O.

Solution Na_2O is a base and N_2O_5 is the acid anhydride of nitric acid (HNO_3). So, the reaction between the two will give the salt $NaNO_3$ (sodium nitrate). The balanced chemical equation can be expressed as follows.

$$N_2O_5 + Na_2O \rightarrow 2NaNO_3$$

Action of Water

Action on metals

Metals higher than hydrogen in the activity series, except lead, displace hydrogen from water. As we go down the series, the vigour of the reaction decreases. Thus, potassium, sodium and calcium react vigorously even with cold water. So much heat is evolved in these reactions that the liberated hydrogen catches fire. Magnesium displaces hydrogen from water on being heated, and iron does so when steam is passed over the red-hot metal. Copper, silver and gold do not react with water.

$$\left.\begin{array}{l} 2K + 2H_2O \rightarrow 2KOH + H_2\uparrow \\ 2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow \\ Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2\uparrow \end{array}\right\}\text{cold conditions}$$

$$Mg + H_2O \xrightarrow{\text{heat}} MgO + H_2\uparrow$$

$$\underset{\text{red hot}}{3Fe} + \underset{\text{steam}}{4H_2O} \longrightarrow Fe_3O_4 + 4H_2\uparrow$$

Note that, when the reaction takes place in cold conditions, the corresponding metal hydroxide is formed. And when the reaction takes place in hot conditions, the metal oxide is formed.

Action on nonmetals

Except carbon, nonmetals do not displace hydrogen from water. A mixture of carbon monoxide and hydrogen, called water gas, is formed when steam is passed over red-hot coke.

$$\underset{\text{red hot}}{C} + \underset{\text{steam}}{H_2O} \rightarrow \underbrace{CO + H_2}_{\text{water gas}}$$

Action of Acids

You have learnt earlier that hydrochloric acid and dilute sulphuric acid behave mainly as acids, whereas concentrated sulphuric acid and nitric acid (dilute or concentrated) behave as oxidising agents too. Here, we will discuss the action of dilute hydrochloric and sulphuric acids on metals and nonmetals.

Action on metals

Metals higher than hydrogen in the activity series displace hydrogen from dilute hydrochloric and sulphuric acids. And the vigour of the reaction decreases down the series.

Thus, potassium, sodium and calcium react violently, whereas magnesium, aluminium, zinc and iron react slowly with these acids.

$$2K + 2HCl \rightarrow 2KCl + H_2\uparrow$$

$$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2\uparrow$$

$$Ca + 2HCl \rightarrow CaCl_2 + H_2\uparrow$$

$$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2\uparrow$$

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$$

$$Fe + 2HCl \rightarrow FeCl_2 + H_2\uparrow$$

Decreasing vigour

Metals like copper, mercury, silver and gold, which are lower than hydrogen in the activity series, do not displace hydrogen from dilute acids.

Exception Lead, though higher than hydrogen in the activity series, does not displace hydrogen from dilute hydrochloric or sulphuric acid. This is because lead forms an insoluble film of lead chloride or lead sulphate on the surface of the metal. The film does not allow the metal to come in contact with the acid.

Action on nonmetals

Nonmetals do not react with dilute hydrochloric or sulphuric acid.

Displacement of Metals and Nonmetals

Displacement of metals

You already know that a more active metal displaces a less active metal from its compounds. Thus, magnesium displacess iron from a solution of iron(II) sulphate, and zinc or iron displaces copper from a solution of copper(II) sulphate. Similarly, zinc displaces silver from a solution of silver nitrate.

$$\underset{\text{silvery white}}{Mg} + \underset{\text{green solution}}{FeSO_4} \rightarrow \underset{\text{colourless solution}}{MgSO_4} + \underset{\text{grey solid}}{Fe\downarrow}$$

$$\underset{\text{white}}{Zn} + \underset{\text{blue solution}}{CuSO_4} \rightarrow \underset{\text{colourless solution}}{ZnSO_4} + \underset{\text{brown-red solid}}{Cu\downarrow}$$

$$\underset{\text{white}}{Zn} + \underset{\text{colourless solution}}{2AgNO_3} \rightarrow \underset{\text{colourless solution}}{Zn(NO_3)_2} + \underset{\text{grey solid}}{2Ag\downarrow}$$

However, a less active metal does not displace a more active metal from its solution. Thus, iron does not displace magnesium from its compounds, and copper does not displace zinc or iron from its compounds.

Displacement of nonmetals

Just like metals, a more active nonmetal displaces a less active nonmetal from its compounds. This can be easily observed in the halogen family, in which the order of activity is F > Cl > Br > I. We have already discussed the relevant displacement reactions in Chapter 5.

Sources of Metals

Being active, most metals are found in the combined state, in minerals. And, as you know, minerals are formed naturally in rocks.

However, an inactive metal like gold is found in the free or native state. Gold is found as very small particles in alluvial sands. It is also found trapped in quartz.

The less active metals, e.g., copper and silver, are found in the combined as well as in the native state.

Minerals and Ores

A mineral may contain a metal. But the question is whether or not the metal can be extracted, i.e., obtained, *profitably* from the mineral. If it can be, the mineral is said to be an ore of the metal. For example, the metal aluminium is found in bauxite ($Al_2O_3 \cdot 2H_2O$) as well as in clay ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$). But extracting aluminium from bauxite is profitable, whereas doing so from clay is not. So, bauxite is an ore of aluminium, but clay is not. Similarly, haematite (Fe_2O_3) is an ore of iron, but the iron-containing mineral, copper pyrites ($CuFeS_2$), is an ore of copper, not iron.

Ores are minerals from which metals or certain other elements can be obtained profitably.

Minerals other than those used as ores are also of great use to us in various ways. Some common ores and minerals other than ores are mentioned in Tables 6.1 and 6.2 respectively.

Table 6.1 Some common ores of different metals

Metal	Ore	Composition
Magnesium	Magnesite	$MgCO_3$
	Carnallite	$KCl \cdot MgCl_2 \cdot 6H_2O$
Aluminium	Bauxite	$Al_2O_3 \cdot 2H_2O$
Zinc	Zinc blende	ZnS
	Calamine	$ZnCO_3$
Iron	Haematite	Fe_2O_3
	Limonite	$Fe_2O_3 \cdot 3H_2O$
	Magnetite	Fe_3O_4
Tin	Tinstone (or cassiterite)	SnO_2
Lead	Galena	PbS
Copper	Copper glance	Cu_2S
	Chalcopyrite (or copper pyrites)	$CuFeS_2$
	Cuprite	Cu_2O
	Malachite	$CuCO_3 \cdot Cu(OH)_2$
Mercury	Cinnabar	HgS
Silver	Argentite (or silver glance)	Ag_2S
	Horn silver	$AgCl$

Table 6.2 Some common minerals other than ores

Mineral	Content	Use
Rock salt	$NaCl$	For flavouring food
Saltpetre (or nitre)	KNO_3	1. As a fertiliser 2. For making gunpowder and matches
Chile saltpetre	$NaNO_3$	1. As a fertiliser 2. For manufacturing potassium nitrate and nitric acid
Limestone	$CaCO_3$	1. For manufacturing quicklime, cement and glass 2. As a flux (we will discuss flux later) in the extraction of metals
Dolomite	$MgCO_3 \cdot CaCO_3$	For making refractory materials (i.e., materials that can stand high temperatures), including furnace lining
Gypsum	$CaSO_4 \cdot 2H_2O$	1. For making plaster of Paris ($CaSO_4 \cdot \frac{1}{2} H_2O$) 2. In the manufacture of cement
China clay (or kaolin)	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	1. For making crockery 2. As a medicine
Mica	Silicate of K and Al	As electrical insulation
Talc	Hydrated silicate of Mg	In cosmetics
Asbestos	Silicate of Ca and Mg	1. In high-temperature experiments (asbestos fibres stand high temperatures) 2. For making building materials, e.g., asbestos sheets for roofing
Apatite (or phosphate rock)	Calcium phosphate + calcium chloride/fluoride	For making superphosphate of lime, a fertiliser

Extracting Metals from Ores

Metals are generally extracted from their ores in three steps.

1. Concentration of the ore, i.e., removal of impurities
2. Production of the crude metal
3. Refining the crude metal

Concentration of the Ore

The ore is concentrated by one or more of the following methods.

Hand-picking

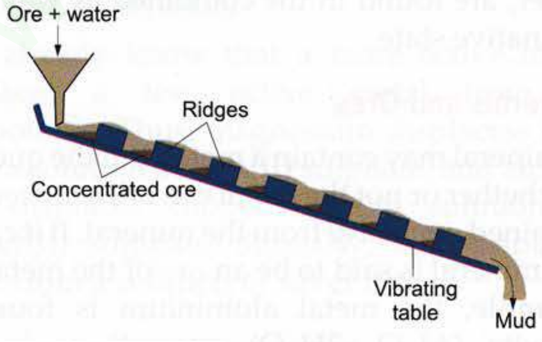
If the ore particles are distinct from the impurities—in size or colour—they can be separated by hand-picking. We have discussed hand-picking in Class 6, while studying the

Gravity separation, or washing

When mixed with water,

- the ore particles, being heavy, sink, and
- most impurities, being lighter than water, float.

The ore can be concentrated by repeated washing with water. As the particles of the ore sink due to gravity, the process is known as gravity separation.



A mixture of the ore and water is passed over the table, which is made to vibrate. The heavy ore particles are caught in the ridges and the muddy impurities are washed away.

Froth floatation

Froth floatation is used for concentrating sulphide ores, e.g., zinc blende (ZnS) and copper pyrites ($CuFeS_2$).

A mixture of the sulphide ore, water and a suitable oil is taken in a tank. Air is passed, under pressure, through the mixture. A froth is then formed in the layer of oil. The sulphide particles adhere to the oil, and the muddy impurities remain in the water. So, the sulphide particles rise up with the froth. The froth is collected and the oil is squeezed out to isolate the sulphide particles.

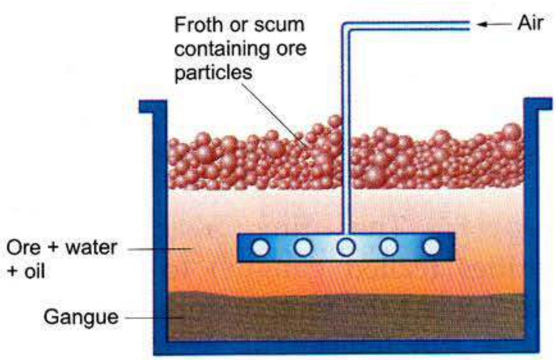


Fig. 6.9 Froth floatation

Magnetic separation

Magnetic separation is used when one of the two—either the ore or the impurity—is magnetic. The crushed ore is placed over a conveyor belt running on magnetic wheels. While falling from the conveyor belt, the magnetic particles are attracted inwards and the nonmagnetic particles are thrown outwards. Thus, separate heaps of the magnetic and nonmagnetic particles are formed.

This method is used to separate the magnetic ore magnetite (Fe_3O_4) from its

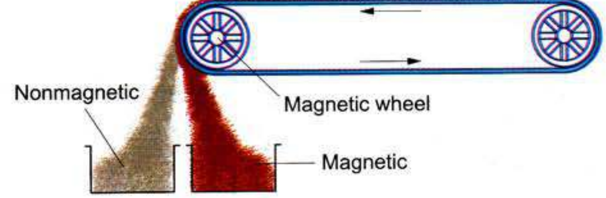


Fig. 6.10 Magnetic separation

separating the nonmagnetic ore tinstone from its magnetic impurities.

Production of the Crude Metal

Depending on the metal, one of the following methods is used for obtaining a metal from the concentrated ore.

Electrolytic method

This method is used for obtaining the highly active metals, down to aluminium, in the activity series. A salt or the oxide of the metal is electrolysed in the molten state. The metal is then obtained at the cathode.

K
Na
Ca
Mg
Al

Pyrometallurgy

Pyrometallurgy is used for obtaining metals less active than aluminium but more active than the noble metals. This method is cheaper than other methods and gives us the metals we require in large amounts.

Zn
Fe
Sn
Pb
Cu
Hg

In this method,

- the concentrated ore is first converted into the oxide of the metal, and
- the oxide of the metal is then generally reduced by carbon to the metal.

Converting the ore to the metal oxide Depending upon the composition of the ore, the concentrated ore is converted into the metal oxide by *either* calcination *or* roasting.

In **calcination,** the ore is strongly heated to drive off any volatile (low-boiling) material

> Heating an ore below its fusion point in order to remove any volatile matter is known as calcination.

The method is used for obtaining the oxides of metals from their carbonates, hydrated oxides or hydroxides.

$$\underset{\text{cerussite}}{PbCO_3} \xrightarrow{\text{calcination}} PbO + CO_2\uparrow$$

$$\underset{\text{calamine}}{ZnCO_3} \xrightarrow{\text{calcination}} ZnO + CO_2\uparrow$$

$$\underset{\text{limonite}}{Fe_2O_3 \cdot 3H_2O} \xrightarrow{\text{calcination}} Fe_2O_3 + 3H_2O\uparrow$$

$$\underset{\text{malachite}}{CuCO_3 \cdot Cu(OH)_2} \xrightarrow{\text{calcination}} 2CuO + H_2O\uparrow + CO_2\uparrow$$

Roasting is done mainly to convert a metal sulphide to the metal oxide. Obviously, a sufficient amount of air or oxygen is required.

> Heating an ore below its fusion point in a regular supply of air or oxygen in order to convert the metal into its oxide is known as roasting.

$$\underset{\text{zinc blende}}{2ZnS} + 3O_2 \xrightarrow{\text{roasting}} 2ZnO + 2SO_2\uparrow$$

$$\underset{\text{copper glance}}{2Cu_2S} + 3O_2 \xrightarrow{\text{roasting}} 2Cu_2O + 2SO_2\uparrow$$

Reducing the metal oxide—smelting The metal oxide is heated with coke and a substance, known as flux, in a furnace. The oxide is reduced by carbon to the metal. At the temperature of the furnace, the metal is obtained in the molten state. The process is called smelting.

$$ZnO + C \xrightarrow{\text{heat}} Zn + CO\uparrow$$

$$Fe_2O_3 + 3C \xrightarrow{\text{heat}} 2Fe + 3CO\uparrow$$

In smelting, carbon acts in two ways. It

- produces heat by burning (i.e., acts as a fuel), and
- reduces the metal oxide (i.e., acts as a reducing agent).

In some cases, however, carbon acts only as a fuel, and the metal is obtained by some other reaction. Here are a couple of examples.

1. During the roasting of copper(I) sulphide, copper(I) oxide is formed first. The oxide then reacts with the unreacted sulphide to form the metal.

$$Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2$$

   This is called self-reduction.

2. When the sulphide ore of mercury is roasted, the oxide of mercury is formed. Not being very stable, the oxide of mercury decomposes to give the metal at the high temperature of the furnace.

$$2HgO \rightarrow 2Hg + O_2$$

   This is called thermal decomposition.

The role of flux The flux reacts with the impurities (called gangue) to form what is called slag. At the temperature of the furnace, the slag also melts. The molten slag, being lighter than the metal, forms a separate layer above the molten metal. Thus, the molten metal and the slag can be tapped separately. Slag formation may be represented as follows.

$$\text{Flux} + \text{Gangue} \longrightarrow \text{Slag}$$

Example:
$$\underset{\text{lime}}{CaO} + \underset{\text{silica}}{SiO_2} \longrightarrow \underset{\text{calcium silicate}}{CaSiO_3}$$
$$\underset{\text{limestone}}{CaCO_3} \xrightarrow[-CO_2]{\text{heat}} CaO$$

Hydrometallurgy

This method is used for extracting noble metals, like silver and gold. We will study it in higher classes.

Ag
Au

Refining the Metal

Metals can be refined by several methods. Let us discuss a few of them.

Liquation

Metals with low melting points (e.g., tin and lead) may be separated from those with high melting points by liquation. The crude metal is heated on a slanting platform. The low-melting metal melts out and gets separated from the high-melting impurities.

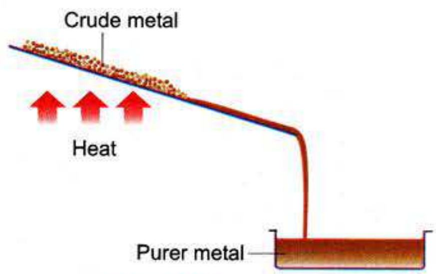


Fig. 6.11 Liquation

Distillation

Metals like zinc and mercury do not have very high boiling points. Hence, they can be refined by repeated distillation.

Electrolytic refining (or Electrorefining)

This process gives a very pure metal.

In electrorefining, a salt of the metal is electrolysed between the anode, made of impure metal, and the cathode, made of pure metal. For metals down to aluminium in the activity series, the electrolyte should be in the molten state. For metals below aluminium, the electrolyte should be in solution.

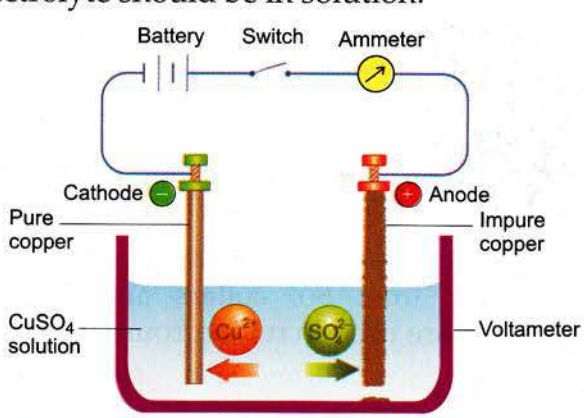


Fig. 6.12 The electrolysis of an aqueous solution of $CuSO_4$, using copper electrodes

For example, copper is refined by electrolysing copper(II) sulphate solution (acidified with sulphuric acid) between the anode, made of impure copper, and the cathode, made of pure copper.

The copper ions are discharged at the cathode, and pure copper is deposited there. The sulphate ions attack the anode and dissolve out copper from it. Slowly, the anode gets thinner and the cathode gets thicker.

Conserving Metals

The Need to Conserve Metals

There are mainly two reasons why we must conserve metals.

1. **Mineral resources are nonrenewable.** Metals are obtained from minerals, which occur in rocks. And you know that it takes millions of years for rocks to form. Thus, mineral resources are nonrenewable and the stock of minerals is limited. The need for metals is increasing every day and so we are mining ores indiscriminately. A day will, therefore, come when minerals will be scarce.
2. **If we do not conserve metals, the environment will be badly polluted.** We throw away used metal objects, e.g., cans, bottle stoppers, wire meshes, air conditioners, air coolers, tools, machines, and abandon vehicles that are beyond repair. The debris causes pollution. Some metals, e.g., mercury, lead, antimony and bismuth, are poisonous too.

Recycling Metals

The best way of conserving metals is by recycling them. You can understand recycling from the following examples.

1. Suppose we have a huge stock of scrap iron. (Iron becomes scrap due to rusting, i.e., the formation of its oxide.) This stock can be directly used for smelting.
2. Aluminium is obtained by the electrolytic

process and is also refined by the same process. Bottle stoppers made of aluminium can be directly used for electrolytic refining. This cuts the cost of electricity because the process by which the metal is obtained from the ore is done away with.

In general, when we recycle a metal, we do not incur any cost in concentrating the ore and producing the metal oxide (involving calcination or roasting).

Benefits of recycling

The following are the benefits of recycling metals.

- The amount of the ore that would have been otherwise used for the production of the metal is reduced.
- The cost of production of the metal is lowered.
- Recycling prevents the pollution that would have been otherwise caused by metal debris.

Uses of Metals and Alloys

Uses of Metals

The history of metals dates back to more than 5000 years. Man learnt the use of copper first, as it was available in the free state. Gold was also available in the free state, but its scarcity, sheen and unreactiveness made it a valuable substance. Then man learnt how to extract iron from its ores, and iron came in use. Other metals like silver, tin, mercury and lead have also been known since ancient times. Aluminium, the most abundant metal in the earth's crust, was discovered as late as in 1824.

A method of extracting aluminium profitably from its ore was found in 1886, and so the metal came into common use only after that.

We will now briefly discuss the uses of some common metals.

Iron

Iron is tough, strong and cheap.

It is used in the construction of buildings and for making pipes, cylinders, machines, agricultural tools, mechanical tools, wire meshes, railings, furniture, etc.

To prevent rusting of iron, it is galvanised. Galvanised iron (GI) is used to make pipes and sheets.

Iron coated with tin is used in making cars. Nonstick utensils are made of iron coated with a polymer that can withstand high temperatures.

Copper

Copper is a very good conductor of electricity—next only to silver. So it is used in electrical wiring, cables and gadgets.

Being a very good conductor of heat too, it is used for making cooking vessels. You may have seen the copper bottom in a utensil—the copper distributes heat fast.

Aluminium

Aluminium is a good conductor of electricity, but poorer than copper. However, it is so light that, for a given mass of the metal, the wires made of aluminium are much longer than those made of copper. Thus, aluminium is much cheaper than copper for the transmission of electricity.

Being a good conductor of heat, it is used for making utensils.

Its lightness and malleability make it especially useful for making foils for packaging food and medicines.

Being light, it is used in aircraft too.

Aluminium paint is used on iron objects to prevent rusting.

Magnesium

Magnesium burns with a dazzling white light. So it is used in fireworks and flash bulbs.

Magnesium prevents rusting when it is coated over iron. So, collars and caps of magnesium are used in underground pipes.

Zinc

Zinc is used to galvanise iron and also to make dry cells.

Mercury

Mercury is the only metal found in the liquid state under ordinary conditions. Being a metal, it is a good conductor of heat, and, being a liquid, it expands or contracts more than a solid on being heated or cooled. Moreover, it does not stick to glass. So, it is used in making thermometers.

Because it is not sticky, reactive and volatile, it is used in making barometers.

Large quantities of mercury are required in the manufacture of the alkalis sodium hydroxide and potassium hydroxide.

It is also used in making amalgams, i.e., alloys of mercury.

Silver

Silver—the shining white metal—is used (i) in jewellery, (ii) for silvering mirrors, and (iii) for electroplating. It is also used in Ayurvedic and Yunani medicines. Silver foils are used for decorating sweets.

Gold

Known for its yellow sheen and nobility, gold is a precious metal and is mainly used in jewellery.

It is also used in Ayurvedic and Yunani medicines.

It is used for electroplating silver or bronze jewellery.

Platinum

Platinum is a shining white metal, nobler and costlier than even gold. So, it is used mainly in jewellery.

It is also used in many scientific experiments.

Uses of Alloys

You know what an alloy is.

> A solid solution, i.e., a homogeneous mixture, of a metal with other metal(s) or nonmetal(s) is called an alloy.

You also know that alloying generally makes a metal stronger and corrosion-resistant.

Brass and bronze are alloys known from ancient times. Brass was made by smelting the ores of copper with those of zinc. Similarly, bronze was made by smelting the ores of copper and tin.

Some common alloys and their constituents, properties and uses are mentioned in Table 6.3.

Gold alloys

Pure gold, being soft, is not suitable for making jewellery. It is made harder and stronger by alloying it with silver or copper or both.

The purity of gold is expressed in carats. 24-carat gold is pure gold. Jewellery is usually made of 22-carat gold, 24 parts of which contain 22 parts of pure gold and 2 parts of the alloying metal.

Table 6.3 Some common alloys

Alloy	Constituents	Properties	Uses
Steel	Iron with very small amounts of carbon (0.1–1.5%) and manganese	Hard and strong	For making railway tracks, coaches, locomotives, ships, bridges, buildings, etc.
Stainless steel	Steel containing chromium (~18%) and nickel (~8%)	Hard, strong and rustproof	For making utensils, cutlery, valves, etc.
Manganese steel	Steel containing manganese (>10%)	Hard and strong	For making railway tracks, grinding machines, safes, etc.
Chrome–vanadium steel	Steel with chromium (1–10%) and vanadium (0.15%)	High tensile strength	For making axles and other parts of automobiles

Alloy	Constituents	Properties	Uses
Brass	Copper with zinc (up to 40%)	Tough and corrosion-resistant	For making utensils, bullets, and reeds and strings for musical instruments
Bronze	Copper with tin (~10%)	Hard and corrosion-resistant	For making statues, medals, etc.
Bell metal	Copper with tin (~22%)	Strong and highly sonorous	For making bells
German silver	Copper with zinc (~20%) and nickel (~20%)	Hard and shining	For making utensils, cutlery, ornaments, etc.
Solder	Tin (50%) and lead (50%)	Low-melting and noncorrosive	For soldering wires, electronic components, etc.
Duralumin	Aluminium with some copper (~4%), a little manganese and magnesium	Light and tough	For making light-weight instruments and aircraft bodies
Magnalium	Aluminium with magnesium and copper	Light and tough	For making aircraft

Uses of Nonmetals

Nonmetals are very useful elements. Life would not have been possible on earth without some of them, e.g., carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur. The uses of some nonmetals are summarised in Table 6.4.

Semimetals

From the nonmetals, we sometimes carve out a class of elements known as semimetals or metalloids. The properties of semimetals are between those of metals and nonmetals. Some common examples of semimetals are boron, silicon, germanium, arsenic and antimony.

Semiconductors

A semiconductor is an element, whose ability to conduct electricity lies between those of conductors and nonconductors (or insulators). Silicon and germanium are examples of semiconductors. They conduct electricity at higher temperatures though to a smaller extent than conductors do. They have brought about a revolution in electronics and are used in TVs, computers, etc.

Table 6.4 The uses of some nonmetals

Nonmetal	Uses	
Hydrogen	(A constituent of water and all organic compounds)	
	In the oxyhydrogen torch	
	For the hydrogenation of vegetable oils	
Carbon	(A constituent of all organic matter)	
	Coal:	As a fuel
		For the production of coke
	Coke:	In metallurgy (as a reducing agent)
		For manufacturing water gas
	Graphite:	As electrodes
		As a lubricant for high-speed tools
		For manufacturing pencils
	Diamond:	As a gem
		For cutting glass and rocks

Nonmetal	Uses
Oxygen	(An important constituent of air and the most abundant element in the earth's crust)
	In all combustion processes
	For respiration
	Given to patients suffering from respiratory problems
	For the respiration of deep-sea divers (as a mixture of oxygen and helium)
	In oxyhydrogen and oxyacetylene torches
	In the iron and steel industry
	For manufacturing sulphuric and nitric acids
	For burning rocket fuel
Nitrogen	(An important constituent of air, it is an inactive gas.)
	For manufacturing proteins in plants
	In the liquid state, for preserving blood, corneas and other donated organs
	For filling food packages (food does not go bad in an inert medium)
	For manufacturing ammonia and urea
Sulphur	For vulcanisation—a treatment of rubber with sulphur, which makes rubber harder and more useful
	For making medicines
	In the match industry
	For making gunpowder
	For manufacturing sulphuric acid
Phosphorus	(An essential element for all living things)
	In phosphatic fertilisers (as compounds)
	In the match industry
Silicon	(The second-most abundant element in the earth's crust)
	In transistors, TVs and computers
	As silica, for manufacturing glass, cement and polymers
Chlorine	For disinfecting water
	As a bleach for household purposes, and for the paper and textile industries
	For manufacturing
	(i) the polymer PVC (polyvinyl chloride)
	(ii) hydrochloric acid
	(iii) pesticides like Gammexene
	(iv) bleaching powder
Iodine	As an antiseptic (as tincture iodine—a solution in ethyl alcohol—or as an ointment)
	As an ointment with petroleum jelly (gives relief from muscular pain)
	For treating thyroid disorders
	For making iodised salt (in the form of sodium iodate)
Helium	(A noble gas; the second-lightest element)
	For filling balloons (safer than hydrogen as it does not catch fire)
	As a diluent of oxygen for the respiration of divers
	For illuminating advertisement signs
Neon	(A noble gas)
	For illuminating advertisement signs
Argon	(A noble gas)
	For illuminating advertisement signs

Points to Remember

- *Comparison of the physical properties of metals and nonmetals*

Property	Metals	Nonmetals
1. State	Solid *Exception* Mercury, which is a liquid	12 solids, 1 liquid and 11 gases
2. Lustre	Lustrous	Lustreless (dull-looking) *Exceptions* Graphite and iodine
3. Density	Usually high	Usually low
4. Tensile strength	High *Exceptions* Sodium and potassium	Low *Exception* Diamond
5. Malleability	Malleable	Nonmalleable
6. Ductility	Ductile	Nonductile
7. Sonority	Sonorous	Not sonorous
8. Melting and boiling points	Generally high *Exception* Mercury	Generally low *Exception* Carbon
9. Conduction of heat	Good conductors	Bad conductors
10. Conduction of electricity	Good conductors	Bad conductors *Exception* Graphite

- Metals react with oxygen to form oxides. The vigour of the reaction decreases down the activity series.
- Every metal forms at least one basic oxide.
- The slow destruction of a metal or alloy by chemical action is called *corrosion*.
- The presence of impurities (in the metal), moisture, salts or acid-forming gases hastens corrosion.
- Painting, greasing, galvanising or electroplating prevents corrosion.
- Alloying makes a metal stronger and corrosion-resistant.
- Nonmetals form acidic oxides (except H_2O, CO, N_2O and NO, which are neutral).
- Metals above hydrogen in the activity series displace hydrogen from water, and also from dilute hydrochloric and sulphuric acids. The vigour of the reaction decreases down the series.
- Carbon displaces hydrogen from water, forming water gas, when steam is passed over red-hot coke. Other nonmetals do not displace hydrogen from water.
- Nonmetals do not displace hydrogen from dilute hydrochloric and sulphuric acids.
- A more active metal or nonmetal displaces a less active metal or nonmetal from its compounds.
- Ores are minerals from which metals or certain other elements can be extracted profitably.
- Metals are generally extracted from their ores in three steps—(i) concentration of the ore, (ii) production of the crude metal, and (iii) refining of the crude metal.
- Ores are concentrated by hand-picking, gravity separation, froth floatation and magnetic separation.
- The oxide of a metal is produced by *calcining* or *roasting* the concentrated ore.

  Calcination Heating an ore below its fusion point in order to drive off any volatile matter

  Roasting Heating an ore below its fusion point in a regular supply of air or oxygen in order to convert the metal into its oxide
- In *pyrometallurgy*, the oxide of the metal is reduced by heating it with carbon in a furnace. The process is called *smelting*.

- During smelting, a *flux* is used to remove the impurities (called *gangue*) as a *slag*.
- Metals are refined by *liquation*, *distillation* and the *electrolytic process*.
- There is a need to conserve metals, as the minerals from which they are extracted are a nonrenewable resource. Recycling metals is the best way of conserving them.

Exercise

Short-Answer Questions

1. Give one word for each of the following.
   (a) The slow destruction of a metal or alloy by chemical action
   (b) Making a thin uniform deposit of one metal over another by the electrolytic method
   (c) Soluble bases
   (d) A mineral from which a metal can be extracted profitably
2. Name any three factors that hasten corrosion.
3. Give an example of a nonmetal that forms two oxides. Name the oxides and give their formulae.
4. What is the chemical reaction that occurs between nitrogen and oxygen during lightning?
5. Give one reaction in each case that shows the acid–base behaviour of copper(II) oxide (CuO) and sulphur dioxide (SO_2).
6. What kind of an oxide—acidic, basic or neutral—is water?
7. Give the names and formulae of the anhydrides of sulphurous acid and sulphuric acid.
8. Write balanced chemical equations for the reactions between the following pairs of substances.
   (a) Calcium and cold water
   (b) Steam and red-hot iron
   (c) Steam and red-hot coke
   (d) Aluminium and dilute hydrochloric acid
   (e) Zinc and copper(II) sulphate solution
9. Will copper, mercury or silver displace hydrogen from dilute hydrochloric acid? Give reasons.
10. Name a method by which magnetite can be separated from its nonmagnetic impurities.
11. Name three metals for which pyrometallurgy is suitable.
12. Define roasting.
13. Give equations for the reduction of the oxides of zinc, iron and lead during smelting.
14. Will environmental pollution decrease or increase if we recycle metals?
15. What is a semiconductor? Give an example.

Long-Answer Questions

1. Describe gravity separation.
2. Describe the froth-floatation process.
3. Write a note on the use of flux in smelting.
4. Describe the electrorefining of metals, with reference to copper.

Objective Questions

Choose the correct option.

1. Which of the following elements is preserved in kerosene?
   (a) Mercury (b) Sodium (c) Magnesium (d) Sulphur

2. Which of the following metals is not attacked by air?
   (a) Gold (b) Calcium (c) Potassium (d) Sodium
3. Which of the following prevents corrosion?
   (a) Calcining (b) Roasting (c) Smelting (d) Galvanising
4. Which of the following makes a metal stronger as well as corrosion-resistant?
   (a) Electroplating (b) Refining (c) Alloying (d) None of these
5. Which of the following compounds is an alkali?
   (a) $Cu(OH)_2$ (b) $Al(OH)_3$ (c) NaOH (d) $Fe(OH)_3$
6. Which of the following metals will be displaced from its compounds, in solution, by iron?
   (a) Copper (b) Magnesium (c) Calcium (d) Aluminium
7. Which of the following metals can be purified by liquation?
   (a) Aluminium (b) Iron (c) Copper (d) Lead
8. Which of the following metals can be purified by distillation?
   (a) Aluminium (b) Iron (c) Mercury (d) Copper

Fill in the blanks.

1. Sodium and potassium are _______ than water. (lighter/heavier)
2. Sodium and potassium are _______ metals. (hard/soft)
3. Sulphur is _______ . (sonorous/not sonorous)
4. On being burnt in air, magnesium forms magnesium _______ . (oxide/hydroxide)
5. Heating an ore _______ its fusion point in order to remove any volatile matter is known as _______ . (below/above/calcination/roasting)
6. $ZnCO_3 \xrightarrow{\_\_\_\_\_\_\_} ZnO + CO_2\uparrow$ (calcination/roasting)
   $2ZnS + 3O_2 \xrightarrow{\_\_\_\_\_\_\_} 2ZnO + 2SO_2\uparrow$ (calcination/roasting)
7. Mineral resources are _______ . (renewable/nonrenewable)
8. By recycling a metal, its cost of production is _______ . (lowered/raised)
9. Solder is a _______ melting alloy. (low-/high-)

Match the columns.

1. Match the following elements with their characteristics.

Element	**Characteristic**
(a) Mercury	(i) Malleable and ductile
(b) Aluminium	(ii) A shining nonmetal
(c) Bromine	(iii) A liquid metal
(d) Graphite (carbon)	(iv) A liquid nonmetal

2. Match the following oxides with their behaviour.

Oxide	**Behaviour**
(a) CO	(i) Basic
(b) CaO	(ii) Acidic
(c) P_4O_{10}	(iii) Neutral

3. Match the following ores with the metals that are extracted from them.

Ore	**Metal**
(a) Bauxite	(i) Copper
(b) Haematite	(ii) Silver
(c) Galena	(iii) Aluminium

(d) Chalcopyrite	(iv) Lead
(e) Argentite	(v) Iron

4. Match the following minerals with their uses.

Mineral	**Use**
(a) Gypsum	(i) As a flux in metallurgy
(b) Limestone	(ii) For making crockery
(c) China clay	(iii) For making building material
(d) Talc	(iv) For making plaster of Paris
(e) Asbestos	(v) In cosmetics

5. Match the following metals and alloys with their uses.

Metal or alloy	**Use**
(a) Copper	(i) Construction of buildings
(b) Magnesium	(ii) Statues
(c) Aluminium	(iii) Foils for food packaging
(d) Mercury	(iv) Fireworks
(e) Steel	(v) Thermometers
(f) Bronze	(vi) Electric wiring

6. Match the following nonmetals with their uses.

Nonmetal	**Use**
(a) Graphite	(i) In computers
(b) Oxygen	(ii) For disinfecting water
(c) Nitrogen	(iii) For treating thyroid disorders
(d) Phosphorus	(iv) As a diluent of oxygen for the respiration of divers
(e) Silicon	(v) As electrodes
(f) Chlorine	(vi) For respiration
(g) Iodine	vii) For filling food packages
(h) Helium	(viii) In the match industry

Indicate which of the following statements are true and which are false.

1. Platinum has a low density.
2. Iodine is lustrous and is, therefore, a metal.
3. Being the oxide of a nonmetal, nitric oxide is acidic.
4. All metals are extracted by pyrometallurgy.
5. All minerals are ores.
6. Phosphorus is essential for life.

You Can Prepare Your Own Activity Series

You have learnt how the activity series helps us in the study of chemical reactions. Scientists must have worked hard to find the relative chemical activities of metals and hydrogen. You can also do it on a smaller scale.

Suppose you want to have an activity series consisting of Al, Fe and Cu. You can prepare it by studying their displacement reactions.

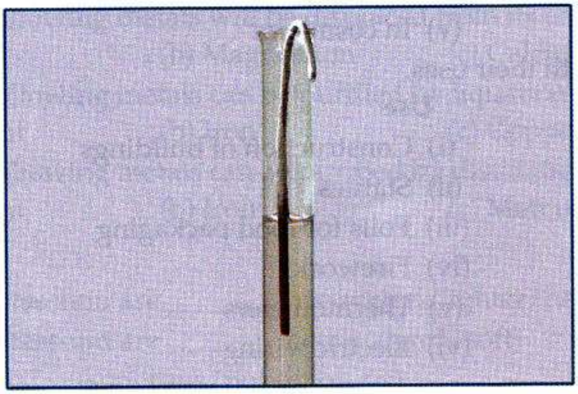
Materials required

(iii) blue vitriol—$CuSO_4 \cdot 5H_2O$.

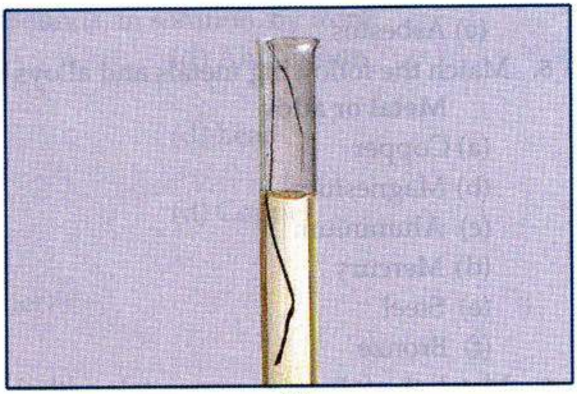
The solutions may be prepared by dissolving the crystals (available in stores) in water.

3. A few glasses/test tubes

Activity 1 Dip a length of aluminium wire into a solution of green vitriol, i.e., iron(II) sulphate, and another into that of blue vitriol, i.e., copper(II) sulphate.



(a)



(b)

Fig. 6.13 (a) Aluminium wire dipped in $CuSO_4$ solution (b) Aluminium wire dipped in $FeSO_4$ solution. The colour of both the solutions will change.

Action of Al on $FeSO_4$ There will be a dark grey coating on the aluminium wire.

$$2Al + 3FeSO_4 \longrightarrow 3Fe\downarrow + Al_2(SO_4)_3$$

Action of Al on $CuSO_4$ There will be a red-brown coating of copper on the aluminium wire.

$$2Al + 3CuSO_4 \longrightarrow 3Cu\downarrow + Al_2(SO_4)_3$$

Inference Al is more active than Fe and Cu.

Activity 2 Drop an iron nail into a solution of alum and another into that of blue vitriol.

Action of Fe on alum There is no reaction.

$$Fe + K_2SO_4 + Al_2(SO_4)_3 \longrightarrow \text{No action}$$

Action of Fe on $CuSO_4$ There will be a brown-red deposit on the nail, and the colour of the solution will slowly change to green.

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

Inference Fe is less active than Al, but more active than Cu.

Activity 3 Drop a few pieces of copper wire into the solution of alum and a few into that of green vitriol.

Action of Cu on alum There is no reaction.

Action of Cu on green vitriol There is no reaction.

Inference Cu is less active than Al as well as Fe.

Conclusion The activity series consisting of Al, Fe and Cu is as shown alongside.

Al
Fe
Cu