we observe that among these metals, *sodium is the most reactive metal while copper is the least reactive metal.* The order of reactivity of these metals with oxygen is :

Na > Mg > Al > Zn > Fe > Cu

Reactivity with oxygen decreases

It may be noted that metals like **silver and gold do not react with oxygen even at high temperatures.**

At ordinary temperature, the surfaces of metals such as magnesium, aluminium, zinc, lead, etc. are covered with a thin layer of oxide. This protective layer of oxide prevents the metal from further oxidation.

DO YOU KNOW?

Aluminium is known to be a self protecting metal because a thin coating of oxide layer is formed on its surface when exposed to air. This coating of oxide layer protects it from corrosion. The resistance of aluminium from corrosion can be improved further by making the oxide layer thicker. This process of forming a thick layer of oxide on the surface of a metal is called **anodising**. This can be done by electrolysis. During the process, clean aluminium article is made the anode and is electrolysed with dilute sulphuric acid. The oxygen gas evolved at the anode reacts with aluminium to form a thick protective oxide layer. This oxide layer can be easily dyed to give an attractive finish to aluminium articles.

The reactivity of the metal to react with oxygen depends on the ease with which it can lose its valence electrons. It is explained later on (activity series).

As already learnt, the metal oxides are **basic** in nature. Most metal oxides are insoluble in water but some of these dissolve in water to give an alkaline solution. Some metal oxides react with acids to form salt and water. For example,

Sodium and potassium oxide react with water to form alkaline solutions which turn red litmus to blue.

$$\underset{\text{Sodium oxide}}{Na_2O\,(s)} + H_2O\,(l) \longrightarrow \underset{\text{Sodium hydroxide}}{2NaOH(aq)}$$

$$\underset{\text{Potassium oxide}}{K_2O\,(s)} + H_2O\,(l) \longrightarrow \underset{\text{Potassium hydroxide}}{2KOH(aq)}$$

Magnesium also dissolves in water partially to form magnesium hydroxide which is basic in nature.

$$\underset{\text{Magnesium oxide}}{MgO\,(s)} + H_2O\,(l) \longrightarrow \underset{\text{Magnesium hydroxide}}{Mg(OH)_2(aq)}$$

Magnesium oxide and copper oxide react with acids and therefore, behave as bases.

$$\underset{\text{Magnesium oxide}}{MgO} + H_2SO_4 \longrightarrow \underset{\text{Magnesium sulphate}}{MgSO_4} + H_2O$$

$$\underset{\text{Copper oxide}}{CuO} + H_2SO_4 \longrightarrow \underset{\text{Copper sulphate}}{CuSO_4} + H_2O$$

However, some metal oxides such as aluminium oxide (Al_2O_3), zinc oxide (ZnO), etc. show both acidic and basic behaviour. Such metal oxides are called **amphoteric oxides.** As already learnt in Unit 2, such oxides react with both acids as well as bases to produce salt and water. For example, aluminium oxide reacts with acids and bases as :

$$\underset{\text{Aluminium oxide}}{Al_2O_3} + 6HCl \longrightarrow \underset{\text{Aluminium chloride}}{2AlCl_3} + 3H_2O$$

In this reaction, aluminium oxide reacts with an acid and therefore, behaves as a base.

$$\underset{\text{Aluminium oxide}}{Al_2O_3} + 2NaOH \longrightarrow \underset{\text{Sodium aluminate}}{2NaAlO_2} + H_2O$$

In this reaction, aluminium oxide reacts with a base and therefore, behaves as an acid.

Similarly, zinc oxide is an amphoteric oxide which reacts with acids and bases to form salt and water as given below:

(*i*) **ZnO as a base**

$$\underset{\text{Zinc oxide}}{ZnO(s)} + H_2SO_4(aq) \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + H_2O(l)$$

(*ii*) **ZnO as an acid**

$$\underset{\text{Zinc oxide}}{ZnO} + 2NaOH(aq) \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2(aq)} + H_2O(l)$$

2. Reaction of metals with water

Metals react with water to form *metal oxide* or *metal hydroxide* and *hydrogen*.

$$\text{Metal} + \text{Water} \longrightarrow \text{Metal oxide} + \text{Hydrogen}$$

$$\text{Metal oxide} + \text{Water} \longrightarrow \text{Metal hydroxide}$$

The reactivity of metals towards water depends upon the nature of the metals. Some metals react even with cold water, some react with water only on heating while there are some metals which do not react even with steam. We can demonstrate the reactivity of different metals with water by the activity given below.

Activity 4

❑ **To study the reactivity of metals with water**

Collect the samples of common metals such as copper, iron, calcium, lead, magnesium, zinc, aluminium, sodium, potassium, etc.

Put small pieces of samples separately in beakers half filled with cold water.

What do you observe ?

(*i*) Which metals reacted with cold water ? Arrange them in the decreasing order of their reactivity with cold water.

(*ii*) Did any metal produce fire with water ?

(*iii*) Does any metal start floating after sometime ?

You will observe that calcium, sodium and potassium react with cold water, sodium and potassium react violently with cold water, making a hissing sound. The reaction with sodium and potassium is so violent and exothermic that the evolved hydrogen gas catches fire and the reaction leads to little explosion. Calcium reacts less violently and the piece of calcium starts floating in water because the bubbles of hydrogen gas formed stick to the surface of the metal.

Other metals copper, iron, lead, magnesium, zinc and aluminium do not react with cold water.

Now, put the metals which did not react with cold water in beakers half filled with hot water.

What do you observe ?

Magnesium, as seen above does not react with cold water but it reacts rapidly with hot water. It also starts floating due to the bubbles of hydrogen sticking to its surface.

Metals like zinc, aluminium, copper, lead and iron donot react even with hot water. To study its reactivity with steam, set up the experiment as shown in Fig. 4. A lump of glass wool soaked in water is placed at the bottom of a boiling tube. The water present in the glass wool will form steam on heating. The metal sample (to be reacted with steam) is placed in the middle of the horizontally kept boiling tube.

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The hydrogen gas is collected in a jar as shown in the figure 3.

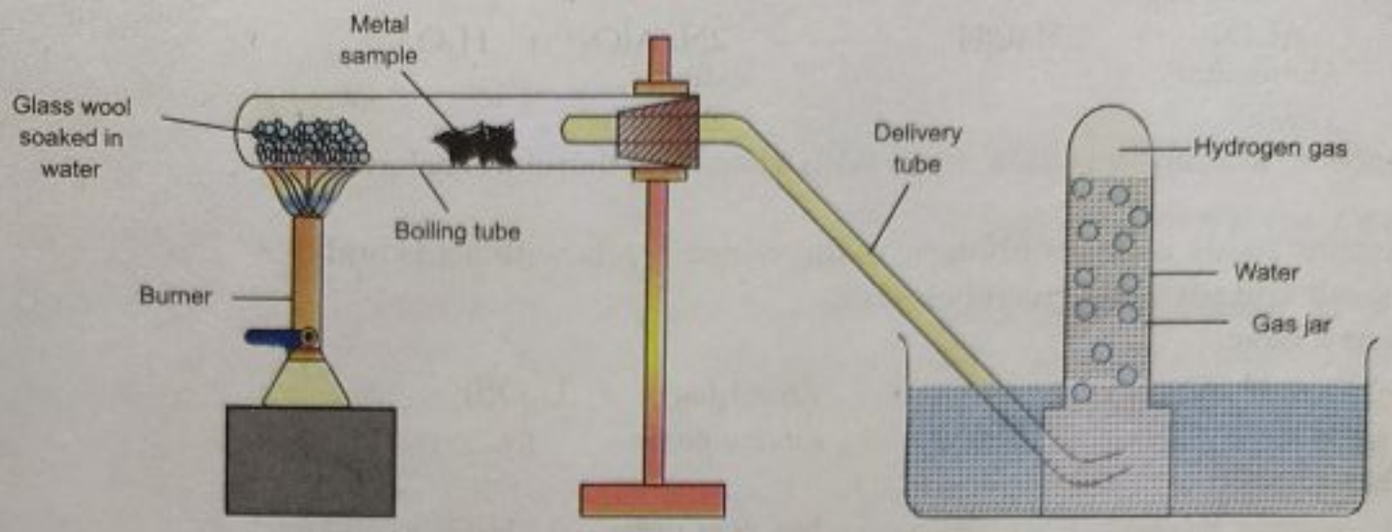

Fig. 3. Experiment to demonstrate the reaction of metals with steam.

Now, place the metals one by one in the middle of the horizontal tube and heat with the help of a glass wool by using burner. The water present in glass wool forms steam on heating. This steam then passes over the metal. The metal reacts with steam to form corresponding metal oxide and hydrogen gas is liberated. The hydrogen gas comes out of the boiling tube and it is collected over water as shown in Fig. 4.

? What do you observe ?

You will observe that metals aluminium and zinc react with steam. Iron does not react under ordinary conditions but it reacts only when steam is passed over hot iron.
Metals such as lead and copper donot react with water at all.
Thus, this activity helps us to understand the reactivity of different metals with water.

CAUTION : The activity must be performed only in the presence of teacher.

Thus, from the above activity, we can conclude :

(*i*) *Sodium and potassium metals react* **vigorously** *with cold water to form sodium hydroxide and hydrogen gas is liberated.*

$$\underset{\text{Sodium}}{2Na(s)} + \underset{\text{Cold water}}{2H_2O(l)} \longrightarrow \underset{\substack{\text{Sodium}\\\text{hydroxide}}}{2NaOH\,(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

$$\underset{\text{Potassium}}{2K(s)} + 2H_2O(l) \longrightarrow \underset{\substack{\text{Potassium}\\\text{hydroxide}}}{2KOH\,(aq)} + H_2(g)$$

This reaction is so violent and exothermic that the hydrogen gas evolved catches fire.

(*ii*) *Calcium reacts with cold water to form calcium hydroxide and hydrogen gas. The reaction is less violent.*

$$Ca(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + H_2(g)$$

Calcium starts floating because the bubbles of hydrogen gas formed stick to the surface of the metal.

(*iii*) *Magnesium does not react with cold water but reacts with hot water forming magnesium hydroxide and hydrogen.*

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\substack{\text{Boiling}\\\text{water}}}{2H_2O(l)} \longrightarrow \underset{\substack{\text{Magnesium}\\\text{hydroxide}}}{Mg(OH)_2} + H_2(g)$$

It also starts floating in water due to the bubbles of hydrogen gas sticking to its surface.

(*iv*) *Metals like zinc and aluminium donot react either with cold or hot water. But they react only with steam to form metal oxide and hydrogen.*

$$\underset{\text{Zinc}}{Zn\,(s)} + \underset{\text{Steam}}{H_2O(g)} \longrightarrow \underset{\text{Zinc oxide}}{ZnO\,(s)} + H_2\,(g)$$

$$\underset{\text{Aluminium}}{2Al\,(s)} + 3H_2O(g) \longrightarrow \underset{\text{Aluminium oxide}}{Al_2O_3\,(s)} + 3H_2\,(g)$$

(*v*) *Iron metal does not react with water under ordinary conditions.* The reaction occurs only when steam is passed over red hot iron and the products are iron (II, III) oxide and hydrogen.

$$\underset{\substack{\text{Iron}\\\text{(Red hot)}}}{3Fe(s)} + \underset{\text{Steam}}{4H_2O(g)} \longrightarrow \underset{\substack{\text{Iron (II, III)}\\\text{oxide}}}{Fe_3O_4(s)} + 4H_2(g)$$

(*vi*) **Metals like copper, silver and gold *do not react with water even under strong conditions*.**

The above reactions indicate that metals react with water to form oxides or hydroxides and hydrogen gas is evolved. Out of sodium, magnesium, zinc, iron and copper, ***sodium is the most reactive while copper is the least reactive towards water.*** The order of reactivities of these metals with water is :

$$Na > Mg > Al > Zn > Fe > Cu$$

Reactivity with water decreases

Explanation of reaction of metals with water on the basis of electron transfer.

Water (H_2O) is slightly ionized to give hydrogen ions (H^+) and hydroxide ions (OH^-).

$$\underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Hydrogen ion}}{H^+} + \underset{\text{Hydroxide ion}}{OH^-}$$

When a metal combines with water, it loses its electron readily :

$$\underset{\text{Metal}}{M} \longrightarrow M^+ + \underset{\text{Electron}}{e^-}$$

The electrons are accepted by H^+ ions to form hydrogen atoms (H). The hydrogen atoms, then combine and form hydrogen gas.

$$H^+ + e^- \longrightarrow H$$

$$H + H \longrightarrow H_2\,(gas)$$

Thus, the reactivity of metal depends upon the ease with which it can lose electrons. Reactive metals can easily lose electrons and therefore, react with water readily. Less reactive metals lose electrons with difficulty and therefore, react with water slowly. The metals like copper do not lose electrons easily so they do not react with water or displace hydrogen from water.

3. Reaction of metals with dilute acids

Many metals react with dilute acids and **liberate hydrogen gas**.

$$\text{Metal} + \text{dil.acid} \longrightarrow \text{Metal salt} + \text{Hydrogen}$$

Only less reactive metals such as copper, silver, gold, etc. do not liberate hydrogen from dilute acids. These metals are labelled as **less reactive** (these are regarded as less reactive than hydrogen discussed in electrochemical series). The reactions of metals with dilute hydrochloric acid (HCl) and dilute sulphuric acid (H_2SO_4) are similar. With dil. HCl, they give metal chlorides and hydrogen whereas with dil. H_2SO_4, they give metal sulphates and hydrogen.

The reactivity of different metals is different with the same acid. For example :

(*i*) *Sodium, magnesium and calcium react violently with dilute hydrochloric acid (HCl) or dilute sulphuric acid (H_2SO_4) liberating hydrogen gas and corresponding metal salt.*

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KEY NOTE

It may be noted that hydrogen gas is not evolved when a metal reacts with dil. nitric acid (HNO_3). This is because nitric acid is a strong oxidising agent. It oxidises the hydrogen produced to water and itself gets reduced to oxides of nitrogen (such as NO, N_2O, NO_2). However, magnesium (Mg) reacts with dilute HNO_3 to evolve H_2 gas.

$$2Na(s) + 2HCl(aq) \longrightarrow \underset{\text{Sodium chloride}}{2NaCl\,(aq)} + H_2(g)$$
Sodium

$$2Na(s) + H_2SO_4 \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4\,(aq)} + H_2(g)$$
Sodium

Similarly,

$$2Mg(s) + 2HCl(aq) \longrightarrow \underset{\text{Magnesium chloride}}{MgCl_2\,(aq)} + H_2(g)$$
Magnesium

$$Mg(s) + H_2SO_4(aq) \longrightarrow \underset{\text{Magnesium sulphate}}{MgCl_4\,(aq)} + H_2(g)$$
Magnesium

Though both sodium and magnesium react violently with dil. acids, the reaction with magnesium is less violent than that of sodium. Therefore, *sodium is more reactive than magnesium.*

(ii) Metals like zinc and aluminium react with dil. HCl or dil. H_2SO_4 but the reaction is less rapid than that of magnesium.

$$Zn(s) + 2HCl(aq) \longrightarrow \underset{\text{Zinc chloride}}{ZnCl_2(aq)} + H_2(g)$$
Zinc

$$Zn(s) + 2H_2SO_4(aq) \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + 2H_2(g)$$
Zinc

Similarly,

$$2Al(s) + 6HCl(aq) \longrightarrow \underset{\text{Aluminium chloride}}{2AlCl_3(aq)} + 3H_2(g)$$
Aluminium

$$2Al(s) + 3H_2SO_4(aq) \longrightarrow \underset{\text{Aluminium sulphate}}{Al_2(SO_4)_3(aq)} + 3H_2(g)$$
Aluminium

(iii) Iron reacts **slowly** *with dilute HCl or dil. H_2SO_4 and therefore, it is less reactive than zinc and aluminium.*

$$Fe(s) + 2HCl(aq) \longrightarrow \underset{\text{Ferrous chloride}}{FeCl_2(aq)} + H_2(g)$$

$$Fe(s) + H_2SO_4(aq) \longrightarrow \underset{\text{Ferrous sulphate}}{FeSO_4(aq)} + H_2(g)$$

Let us perform the following activity :

(iv) Copper does not react with dil. HCl or dil. H_2SO_4 at all.

$$Cu(s) + HCl(aq) \longrightarrow \text{No reaction}$$

$$Cu(s) + H_2SO_4(aq) \longrightarrow \text{No reaction}$$

Therefore, copper is even less reactive than iron.

From the above reactions, we conclude that metals react with dil. HCl or dil. H_2SO_4 liberating hydrogen gas. Among the metals, sodium, magnesium, zinc, aluminium, iron and copper, **sodium is most reactive metal, while copper is least reactive metal.** The order of reactivity of metals with dilute acids is :

Na > Mg > Al ≈ Zn > Fe > Cu

Reactivity with dilute acids decreases

The reactivity of metals with dil. acids (HCl or H_2SO_4) can be easily demonstrated by a simple experiment.