electrons. Therefore, these are also called **electronegative elements.** For example, chlorine is a non-metal and can readily accept electron to form negatively charged (Cl^-) ion.

$$\underset{\text{Chlorine atom}}{Cl} + e^- \longrightarrow \underset{\text{Chloride ion}}{Cl^-}$$

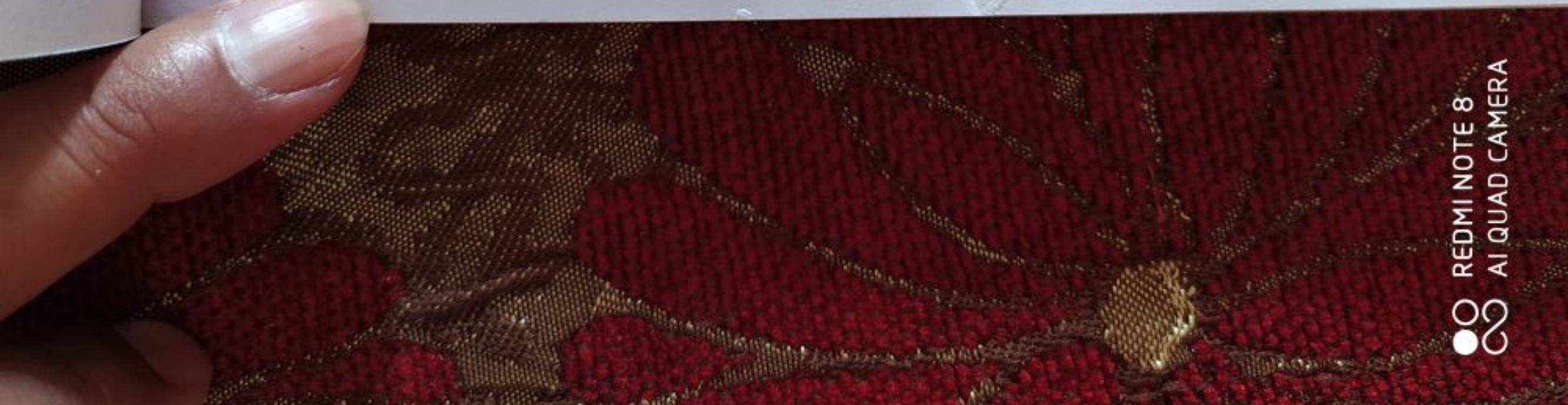
Similarly, oxygen is a non-metal and can accept two electrons to form negatively charged oxide (O^{2-}) ion.

$$\underset{\text{Oxygen atom}}{O} + 2e^- \longrightarrow \underset{\text{Oxide ion}}{O^{2-}}$$

Thus, non-metals may also be defined as **the elements which can form negative ions by gaining electrons.**

PHYSICAL PROPERTIES OF NON-METALS

In your previous class, you have learnt that non-metals are very few in number as compared to metals. Among the 118 elements known there are only 22 non-metals. Some common examples of non-metals are carbon, sulphur, iodine, oxygen, hydrogen, phosphorus, chlorine, etc. These are



either solids or gases except bromine which is a liquid. Though non-metals are small in number yet they represent an extremely important class of elements.

Non-metals display many properties opposite to those of metals. We can collect common non-metals such as carbon (coal or graphite), sulphur or iodine and study all the properties as studied for metals. These studies conclude the following general properties of non-metals.

The important physical properties of non-metals are discussed below :

1. Non-metals may be solid, liquid or gases at room temperature.

The non-metals exist in all the three states. For example :

Gaseous non-metals	Hydrogen (H_2), oxygen (O_2), nitrogen (N_2), fluorine (F_2), chlorine (Cl_2), helium (He), neon (Ne), argon (Ar), etc.
Liquid non-metal	Bromine
Solid non-metals	Carbon (C), Phosphorus (P_4), Sulphur (S_8), Iodine (I)

2. Non-metals are non-lustrous and cannot be polished

Most of the non-metals are non-lustrous and dull and these cannot be polished. Only graphite and iodine are lustrous non-metals.

3. Non-metals are generally soft

Most of the non-metals are soft, except diamond (allotropic form of carbon). Diamond is the hardest known substance.

The physical properties of non-metals can be demonstrated by taking graphite, sulphur and iodine and performing activities 1 and 2.

4. Non-metals are brittle

Non-metals are brittle and these break into pieces when hammered or stretched. For example, sulphur and phosphorus are brittle non-metals. Since non-metals are not malleable, they cannot be beaten into sheets.

5. Non-metals are not ductile

Non-metals are not ductile and, therefore, these cannot be drawn into thin wires.

6. Non-metals are bad conductors of heat and electricity

Non-metals are generally bad conductors of heat and electricity. This is due to fact that the non-metals do not have free electrons. There is one exception. The allotropic form of carbon, graphite is a good conductor of heat and electricity like metals. Therefore, graphite is used for making electrodes.

7. Non-metals have low densities

Most of the non-metals are light. For example, the density of sulphur is 2 g cm^{-3}.

8. Non-metals have generally low melting and boiling points

Most of the non-metals have low melting and boiling points except graphite which has high melting point.

9. Non-metals are not sonorous

Non-metals donot produce any sound when struck on hard surfaces. Therefore, non-metals are not sonorous.

SOME EXCEPTIONS TO GENERAL TRENDS

A comparison of physical properties of metals and not-metals shows that we cannot group elements according to their physical properties alone. There are many exceptions to the general properties. Some of the exceptions are given below :

1. All metals except mercury are solids at room temperature.
2. Metals in general have very high melting and boiling points. However, gallium and cesium have very low melting points. Gallium has such a low melting point that it melts on our palm.
3. Metals are generally hard, but sodium and potassium are the examples of metals which are very soft. Therefore, unlike metals, these can be easily cut with a knife. They have low densities and low melting points.
4. Non-metals do not have shiny lustre but iodine is a non-metal and has lustre.
5. Non-metals are generally soft. But carbon is a non-metal which can exist in different forms called **allotropes**. Diamond is an allotrope of carbon and is very hard. It is the hardest natural substance known and has very high melting and boiling points.

Another allotrope of carbon is graphite. It is good conductor of electiricity unlike other non-metals.

Elements can be more clearly classified as metals and non-metals on the basis of chemical properties as discussed below :

CHEMICAL PROPERTIES OF METALS

Metals and non-metals react differently with other substances and form different products.

Before we discuss the chemical properties of metals and non-metals, let us perform an activity to show how these react differently. We can take common metals such as magnesium and a common non-metal such as sulphur. Perform the following activity carefully.

Activity 3

To show that metals and non-metals react differently

Take a small piece of magnesium ribbon.
Hold the magnesium ribbon with a pair of tongs and burn it over the flame of burner.

What do you observe?

You will observe that magnesium ribbon burns with brilliant light and gets into a white solid residue (called ash).
Collect the ash in a beaker.
Add water to the ash and dissolve by stirring. Test the resulting solution with both blue and red litmus paper.

What do you observe?

You will observe that in solution formed by burning magnesium ribbon blue litmus paper remains unaffected while red litmus paper becomes blue.

This shows that the solution is **basic or alkaline**. This may be represented as

$$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$$
$$MgO(s) + H_2O(l) \longrightarrow Mg(OH)_2(aq)$$
$$Mg(OH)_2(aq) + \underset{\text{Alkaline}}{\text{Red litmus}} \longrightarrow \text{Blue}$$

Now, take powdered sulphur on a spatula and heat it on a flame.

? What do you observe?

The sulphur first melts and then begins to burn.
Place a test tube over the burning sulphur to collect the fumes produced.
Add some water to the above test tube and shake the contents. Test this solution with blue and red litmus paper.

? What do you observe?

In the case of solution formed by burning sulphur, red litmus paper remains unaffected but the blue litmus paper changes to red. This shows that solution formed is **acidic in nature**. This may be represented as :

$$S(s) + O_2(g) \longrightarrow SO_2(g)$$
$$SO_2(g) + H_2O\ (l) \longrightarrow H_2SO_3\ (aq)$$
$$H_2SO_3(aq) + \text{Blue litmus} \longrightarrow \text{Red}$$
acidic

➡ Thus, **it may be concluded that metal oxides are basic while non-metal oxides are acidic.**

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

Thus, **most metals form basic oxides when dissolved in water.** On the other hand, **non-metals form acidic oxides when dissolved in water.**

We shall learn more about these by studying the chemical properties of metals and non-metals as discussed below :

1. Reaction of metals with oxygen

We have learnt in the Activity 3 that magnesium burns in air with a brilliant white flame.

We can repeat the experiment by taking samples of other metals such as aluminium, copper, iron, lead, magnesium, zinc and sodium. Hold each metal sample with a pair of tongs and try to burn it over a flame. Collect the products formed in each case.

You can note the following observations :

(*i*) Which metals burn easily ?
(*ii*) How does the metal surface appear after burning ?
(*iii*) What flame colour did you observe when the metal is burnt ?
(*iv*) Are the products of reaction soluble in water or not ?

You will observe that metals react with air or oxygen to form oxides.

Metal + Oxygen ⟶ Metal oxide

For example, when magnesium is heated in air, it combines with oxygen to form magnesium oxide (white powder) (see Activity 3).

$$\underset{\text{Magnesium}}{2Mg} + O_2 \longrightarrow \underset{\text{Magnesium oxide}}{2MgO}$$

Similarly, copper reacts with oxygen, when heated in air to form copper (II) oxide, a black oxide.

$$\underset{\text{Copper}}{Cu} + O_2 \longrightarrow \underset{\text{Copper (II) oxide}}{2CuO}$$

Aluminium forms aluminium oxide

$$\underset{\text{Aluminium}}{4Al} + 3O_2 \longrightarrow \underset{\text{Aluminium oxide}}{2Al_2O_3}$$

These oxides are **basic** in nature. When these oxides are dissolved in water, they give alkaline solutions. For example, sodium metal reacts with oxygen of the air and forms sodium oxide.

$$4Na\ (s) + O_2(g) \longrightarrow \underset{\text{Sodium oxide}}{2Na_2O\ (s)}$$

Sodium oxide reacts with water to form an alkali called sodium hydroxide. Therefore, sodium oxide is a basic oxide.

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

Due to the formation of sodium hydroxide (which is an alkali), the solution of sodium oxide in water turns red litmus blue (common property of all alkaline solutions).

Similarly, potassium oxide dissolves in water to produce alkalies as :

$$4K\,(s) + O_2\,(g) \longrightarrow 2K_2O\,(s)$$
$$K_2O\,(s) + H_2O\,(l) \longrightarrow 2KOH\,(aq)$$

You will observe an interesting observation. It will be observed that some metals give characteristic colour to the flame. For example, **sodium burns with a golden yellow colour and copper burns with bluish green colour.**

Reactivity of metals with oxygen

All metals do not react with oxygen with equal ease. The reactivity of oxygen depends upon the nature of the metal. Some metals react with oxygen even at room temperature, some react on heating while still others react only on strong heating. For example,

(i) Metals like sodium, potassium and calcium, react with oxygen even at room temperature to form their oxides.

$$\underset{\text{Sodium}}{4Na} + O_2 \longrightarrow \underset{\text{Sodium oxide}}{2Na_2O}$$
$$\underset{\text{Potassium}}{4K} + O_2 \longrightarrow \underset{\text{Potassium oxide}}{2K_2O}$$
$$\underset{\text{Calcium}}{4Ca} + O_2 \longrightarrow \underset{\text{Calcium oxide}}{2CaO}$$

Sodium and potassium metals are so reactive with oxygen (of air) that they react vigorously. They catch fire and start burning even if they are kept in the air. Therefore, to protect them and to prevent accidental fires sodium and potassium metals are stored under kerosene to prevent their reaction with oxygen, moisture and carbon dioxide of the air. Therefore, **sodium and potassium are very reactive metals.**

(ii) Metals like magnesium, aluminium and zinc do not react with oxygen at room temperature. They burn in air only on strong heating to form corresponding oxides.

$$\underset{\text{Magnesium}}{2Mg} + O_2 \longrightarrow \underset{\text{Magnesium oxide}}{2MgO}$$
$$\underset{\text{Aluminium}}{4Al} + 3O_2 \longrightarrow \underset{\text{Aluminium oxide}}{2Al_2O_3}$$
$$\underset{\text{Zinc}}{2Zn} + O_2 \longrightarrow \underset{\text{Zinc oxide}}{2ZnO}$$

(iii) Metals like iron and copper do not burn in air even on strong heating. However, they react with oxygen only on **prolonged heating.** Iron filings burn vigorously when sprinkled in the flame of the burner.

$$\underset{\text{Sodium}}{3Fe} + 2O_2 \xrightarrow{\text{Heat}} \underset{\text{Iron (II, III) oxide}}{Fe_3O_4}$$

It may be noted that Fe_3O_4 is a mixture of iron (II) oxide or ferrous oxide (FeO) and iron (III) oxide or ferric oxide (Fe_2O_3). Therefore, it is written as iron (II,III) oxide.

$$2Cu + O_2 \xrightarrow{\text{Heat}} \underset{\text{Copper (II) oxide}}{2Na_2O}$$

Copper has low reactivity with oxygen in comparison to iron. From the above reactions of sodium, magnesium, zinc, iron and copper with oxygen,

REMEMBER

Fe_3O_4 is a mixture of iron (II) oxide (or ferrous oxide), FeO and iron (III) oxide or (ferric oxide), Fe_2O_3 and is written as iron (II, III) oxide.