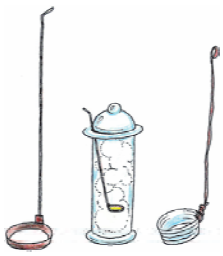
CHAPTER 11

# CHEMISTRY OF NON-METALS



In the chapters on periodic table and metals and metallurgy, we read that most of the elements are metals. If non-metals are so few in number why do we give them so much importance? To understand this, let us think about the following questions:

- Water is made of two elements. Are these elements metals or non-metals?
- Is the gas which is essential to maintain life on earth a metal or non-metal?

In this chapter, we will learn which elements are non-metals and the criteria for placing them in this category. We will also study in detail three non-metals - hydrogen, oxygen and nitrogen - which are important for sustaining life one earth.

## 11.1 Physical properties of non-metals

You are familiar with some non-metals like hydrogen, oxygen and nitrogen. Can you tell how you determined that these elements are non-metals, not metals?

We know that metals have certain defining characteristics, for example, under normal emperature and pressure most metals are solids. If an element is gas at normal temperature and pressure then we can easily say that it is not a metal and is a non-metal. But not all non-metals are gases. Different non-metals are found in different states, for example, bromine is the only non-metal found in the liquid state and non-metals like carbon, iodine, phosphorous, sulphur, selenium etc. are found in the solid state. In fact, the hardest element is diamond, which is one of the allotropes of carbon.

**Allotropy**

*You may be aware that both graphite and diamond are forms of carbon. Both are solely made of carbon atoms. Think - how is it possible that two substances that look so different are actually forms of same substance, carbon?*

*Not just carbon but many other elements are found in more than one form in the same state. This property of elements is known as allotropy and the different forms are known as allotropes. The bonding between atoms in different allotropes is different leading to difference in some physical properties.*

*Since the atoms of different allotropes of an element are identical therefore the chemical reactions shown by them are same. For example, both graphite and diamond give carbon dioxide on combustion. Oxygen, phosphorous and sulphur are some other non-metals that exhibit allotropy.*

It is possible to differentiate whether a solid element is metal or non-metal; this is because most non-metals are brittle. In other ways also solid metals and solid non-metals are different from each other. Non-metals do not display ductility or malleability nor do they produce a metallic sound. Further, apart from graphite which is an allotrope of carbon, all other non-metals are poor electrical conductors or insulators. Similarly, except diamond, all other non-metals are poor thermal conductors.

**Questions**

1. The physical properties of four different elements are shown in the given table. Can you tell:

| Element | State | Ductile | Conducts electricity |
|---|---|---|---|
| A | Solid | No | No |
| B | Solid | Yes | Yes |
| C | Gas | No | No |
| D | Solid | No | yes |

   (a) which of the elements are metals and which are non-metals

   (b) the criteria for deciding whether element 'D' is metal or non-metal?

2. Which of the following exhibit allotropy?

   C, $CO_2$, $SO_2$, S, $C_4H_{10}$, $CH_4$

## 11.2 Where do non-metals lie in the periodic table?

Can you tell whether an element is a metal or non-metal by looking at its position in the periodic table? We know that as we move from left to right in a periodic table, there is a decrease in metallic character, that is, as the group number increases the metallic character decreases. If we look at the elements of the first group then we find that all its elements except hydrogen are metals but we will not find a single metal in the elements of group 18. If we look at the elements in a particular group then there is an increase in the metallic character as we go down the group, for example, if we take group 15 then the first two elements (nitrogen, phosphorous) are non-metals. The fourth and fifth elements (arsenic, antimony respectively) of group 15 show some metallic character but are not completely metal. However, the last member (Bismuth) of the same group is a metal.

There are some properties that are exhibited only by metals while there are other properties that are shown only by non-metals. However, we also find some elements that show some properties of metals and others of non-metals, that is, their properties lie somewhere in the middle. In the periodic table, these elements are located between metals and non-metals. That is why we don't see a sudden change in metallic group as we move from one group to the next, the change is step-wise. This behavior is seen in elements situated along a zig-zag diagonal line in the periodic table. The elements are counted among metals but they are called metalloids or semi-metals. Metalloids include boron, silicon, germanium, arsenic, antimony, tellurium and polonium. Just like metals the metalloids are also found as solids. Boron and silicon are poor conductors of electricity but addition of impurities leads to electrical conductivity. All elements that do not belong to metals and metalloids groups are called non-metals.

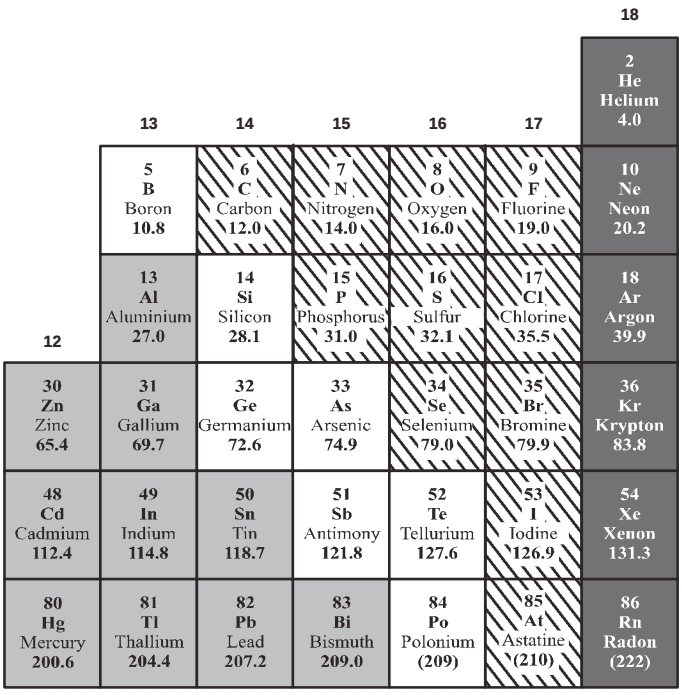



**Figure-1: Non-metals in the periodic table**

Non-metals include one member (carbon) of group 14, two members (nitrogen and phosphorous) of group 15 and three members (oxygen, sulphur and selenium) of group 16. Group 17 is known as the halogen group and five of its members - fluorine, chlorine, iodine, bromine and astatine - are non-metals. Since halogens require only one electron to complete their octet therefore they are very reactive. They are not found in the free-state in nature and were recognized only near the end of the 18th century. Group 18 consisting of noble gases is a big group of non-metals. It includes the colourless gases helium, neon, krypton, argon, xenon and radon. Since the outermost shells of noble gases have 8 electrons therefore they do not normally take part in chemical reactions. They are also known as inert gases due to this lack of reactivity. Since they are found in trace amounts in the atmosphere they are called rare gases as well.

Can you think of any element which is a non-metal but which has been placed on the left side in the periodic table? Before we study more about non-metals let us read a little bit about their history.

## 11.3 How and when were non-metals discovered?

Carbon and sulphur are two non-metals that were known even in ancient times. In fact, they were discovered so long ago that we don't know the exact dates or the names of the persons who discovered them.

In nature, carbon is found as diamond and graphite and these two forms have been mentioned in various ancient documents. However, at that time graphite and diamond were regarded as two separate substances. It was only with the development of modern chemistry that we understood that diamond, graphite etc. all are actually carbon which give carbon dioxide on burning. Lavoisier carried out combustion of carbon and diamond to prove that both are actually the element carbon. Thus, he called it carbon and gave it a place in his list of elements published in the year 1789. Similarly, sulphur was also known from ancient times and again it was Lavoisier who proved that sulphur is an element. Phosphorous was discovered in the middle-ages (1669) by Hennig Brand, a merchant from Hamburg, Germany.

Till the middle-ages very little was known about gaseous substances. Since most non-metals are found as gases in nature therefore they were discovered only after techniques to produce and collect gases had been refined. Before this, due to lack of knowledge about gaseous state, role of gases in chemical reactions and their formation as chemical products was not understood. Thus, it was long time before we could completely understand the nature of several chemical reactions, especially combustion.

In mid-eighteenth century, a device called pneumatic trough was developed by Hales. Pneumatic troughs made it possible to collect gases produced during combustion and other chemical reactions. With the help of this apparatus other scientists were able to separate and study many gases and it led to the discovery of gaseous non-metals.

With this, there was an increase in discovery of non-metals. Fluorine was discovered in 1771 and chlorine in 1774 by the Swedish chemist Scheele. Slowly, other non-metals were also discovered.

Inert gases are found in the free state in nature but only in trace amounts therefore, their discovery also took some time. In 1785, Cavendish carried out some experiments with air in which he separated nitrogen gas and oxygen gas from it. He was left with bubbles of some unknown gas, possibly argon, but he was unable to identify it. It was more than 100 years before these bubbles were identified as a new element. In 1894, two scientists called Ramsay and Raleigh found that the density of nitrogen gas obtained from air is more than that of pure nitrogen from which they concluded that another gas was present in air. They separated the gas and called it argon. Ramsay also included other inert gases like helium, neon, krypton and xenon. In this way, most of the non-metals had been discovered by the end of 19th century.

**Questions**

1. What are metalloids? Give any two examples.
2. Give reasons why gaseous elements were discovered quite late as compared to solid elements.
3. The elements of group 18 do not normally take part in chemical reactions, why?

## 11.4 Chemistry of non-metals

Non-metals, except hydrogen, are found between groups 14 to 18 in the periodic table which means that they have 4 to 8 electrons in their outermost shell. Since non-metals have a tendency to gain electrons therefore they are electronegative in nature. We know that non-metals are more electronegative than metals but the electronegativity of each non-metal is not same. The value of electronegativity for non-metals ranges from 2.01 to 4.1.

In the chapter on periodic table, we saw that electronegativity decreases on going down a group and increases on moving from left to right in a period. This means that the elements of group 17 are most electronegative. Fluorine has the highest electronegativity value and that for oxygen and chlorine is also quite close. The value of electronegativity determines how a non-metal will react with metals or other non-metals.

All non-metals, except those in group 18, form negative ions or covalent bonds during chemical reactions. Let us now study about some common chemical reactions shown by different non-metals.

### 11.4.1 Reaction between metal and non-metal

We have previously read about the reactions between metals and non-metals. Let us review some of them -

$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

$2Cu(s) + O_2(g) \longrightarrow 2CuO(s)$

$Fe(s) + S(s) \longrightarrow FeS(s)$

$3Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$

*Magnesium nitride*

$2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$

$6Ca(s) + P_4(s) \longrightarrow 2Ca_3P_2(s)$

*Calcium phosphide*

Metals and non-metals react with one-another to form ionic compounds. Here, the metal is oxidized and the non-metal is reduced.

### 11.4.2 Reactions between non-metals

We know that covalent bonds are formed when non-metals react with one another. Many covalent compounds can be formed but here we will concentrate on chlorides and oxides, that is, compounds of oxygen and chlorine.

(A) Reaction of non-metals with chlorine - non-metals react with chlorine to form chlorides.

$$C(s) + 2Cl_2(g) \longrightarrow CCl_4(l)$$

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$

$$P_4(s) + 6Cl_2(g) \longrightarrow 4PCl_3(l)$$

Phosphorous chloride

(B) Reaction of non-metals with oxygen - non-metals react with oxygen to form oxides.

$$C(s) + O_2(g) \longrightarrow CO_2(g)$$

$$S(s) + O_2(g) \longrightarrow SO_2(g)$$

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(s)$$

Remember that while writing the chemical formula of compounds keep the less electronegative element before the more electronegative element. Since the electronegativity of both oxygen and chlorine is more as compared to other elements therefore they are written last in chemical formulae of compounds.

### 11.4.3 Nature of oxides of non-metals

**Activity-1**

- Take some sulphur powder in a deflagrating spoon and heat it.
- When sulphur starts burning, put the spoon in a gas-jar or covered glass so that the gas being formed collects in it (Figure-2).
- After some time remove the spoon, add a little water to it and immediately cover it again.
- Now shake the jar and test the solution formed with blue and red litmus paper.

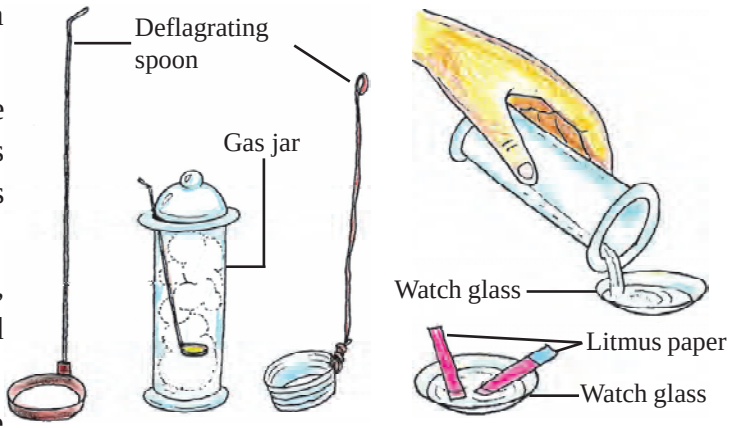



**Figure-2: Testing the nature of non-metal oxide**

- Did you observe any change in colour of litmus paper?

***Precaution:*** *Since sulphur dioxide gas being formed can harm us therefore carry out the experiment in a well-ventilated area.*

Sulphur reacts with oxygen to form sulphur dioxide. In activity-1, you may have observed that the solution of sulphur dioxide in water is acidic in nature.

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

In the same way, the solutions of most non-metal oxides in water are acidic, for example,

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

But, not all non-metal oxides are acidic. We know that water is an oxide of hydrogen but it is neutral.

**Questions**

1. Look up the names of different acids used in the laboratory and find out the non-metals that make them up.
2. Non-metals are electronegative, why?
3. You are given an element; how will you identify whether it is a metal or non-metal? Give three means.

**Some important non-metals**

Consider the names hydrogen, oxygen and nitrogen. Do you notice any similarities in the names? All of them end in -gen. Actually, the suffix -gen is derived from the Greek word genes which means 'one which produces'. For example, hydrogen is combination of hydro, which means water and -gen and thus, the word hydrogen means 'one which forms or produces water'. When oxygen was discovered it was believed that this element was needed to form acids (oxy-) and thus the name oxygen was given.

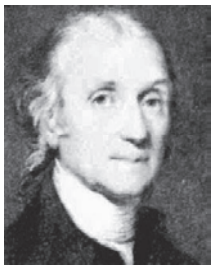
Nearly 70% of the earth's surface is water which is a compound of hydrogen and oxygen. The air around us is about 78% nitrogen and 21% oxygen. This is the reason why these three are also known as elements of air and water. Along with oxygen, these three non-metals form many compounds, such as protein, that are vital and fundamental to life.

## 11.5 Hydrogen

Usually, we say that an element has been discovered only when it has been isolated in the pure form and its physical and chemical properties have been studied. In 1671, the British scientist observed that a highly inflammable gas is produced in the reaction between iron and hydrochloric acid but he did not study it systematically or identify it as a new element. Other scientists also saw that many metals are soluble in acids producing an inflammable gas but it was Cavendish who in 1776 first proved that this gas was different from other gases. Therefore, he is credited with the discovery of hydrogen. He also produced water from hydrogen and oxygen and on the basis of this reaction Lavoisier named the new gas hydrogen.

93% of the universe is hydrogen. Hydrogen is present around us as diatomic molecule (H2). On earth we rarely find pure hydrogen molecules and it is usually found as a compound. Hydrogen is a colourless, odorless, tasteless gas which is extremely inflammable. In previous classes, you have read about isotopes. Hydrogen has three isotopes called protium, deuterium (heavy water) and tritium. The atomic number of hydrogen and the relative atomic weight is also 1.

**Henry Cavendish**



British physicist and chemist Henry Cavendish (1731-1810) obtained hydrogen by the reaction between hydrochloric acid and different metals like tin, zinc and iron. He characterized the properties of this gas and found that hydrogen was extremely light and had the lowest density among the known elements. After studying the gas, he named it flammable air. Along with discovery of hydrogen he studied atmospheric composition, properties of different gases, determined the composition of water and measured the density of earth based on different experiments. Cavendish is famous for rigour and accuracy in his experiments.

### 11.5.1 Laboratory preparation of hydrogen

1. In the laboratory, hydrogen gas (H2) is prepared by the reaction between hydrochloric acid and granulated zinc. In the chapter on acids and bases you read about the preparation of hydrogen using this method. Write the balanced chemical equation for this reaction.

**Activity-2**

- Take some granulated zinc in a Wolf bottle.
- Place a thistle funnel on one opening and a bent glass tube on the other opening of the bottle (figure-3).
- Attach a rubber tube to the other end of the glass tube and place the tube in a filled water-trough.
- To collect the gas produced, place a test-tube or gas jar filled with water over the rubber tube in the trough.

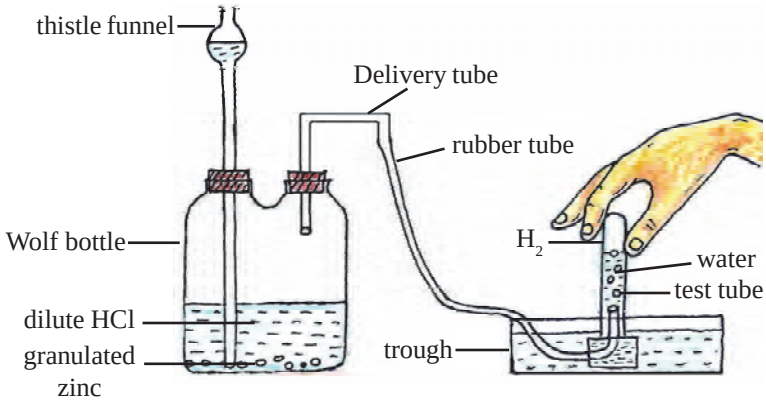



**Figure-3: Laboratory method for hydrogen preparation**

- Using the thistle funnel keep adding dilute hydrochloric acid to the bottle till the lower end of the funnel is submerged. After some time you should observe some bubbles in the water in the trough.
- How will you test that the gas collected by the displacement of water is hydrogen?

2. The reaction of granulated zinc with a base also produces hydrogen gas.

$$Zn(s) + 2NaOH(aq) \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2(aq)} + H_2\uparrow$$

***Precautions:*** *While collecting hydrogen gas, if it is contaminated by air then the mixture will explode as soon as it comes in contact with a flame. Therefore, collect the gas carefully and for testing the gas don't put the lighted matchstick inside the test-tube, merely take it close to the mouth of the test tube.*

### 11.5.2 Chemical properties of hydrogen

Hydrogen atom has one electron present in its K-shell. Hydrogen, similar to elements of group 1, can lose one electron to form $H^+$ ion (hydrogen ion). It is also possible for hydrogen to gain an electron and form negatively charged $H^-$ ion (hydride ion) and in this respect it is similar to the elements of halogen group. Thus, hydrogen can be placed either in group-1 or group-17 in the periodic table. Since, in the modern periodic table, elements have been placed in increasing order of their atomic number therefore hydrogen is palced in the first position in group-1.

1. Reaction with metals- the electronegativity of hydrogen as compared to hydrogen so hydrogen reacts with metals to give the corresponding hydride.

$$2Na + H_2 \longrightarrow 2NaH$$

$$Mg + H_2 \longrightarrow MgH_2$$

2. Reaction with halogens- halogen halides are obtained when hydrogen reacts with halogens.

$$H_2(g) + X_2(g) \longrightarrow 2HX(g) \quad \text{Where X = F, Cl, Br, I}$$

On this basis, complete the following equations and balance them-

$$H_2(\ \ ) + Br_2(\ \ ) \longrightarrow ?$$

$$H_2(\ \ ) + F_2(\ \ ) \longrightarrow ?$$

3. Reduction reaction- hydrogen reacts with hot metal oxides and reduces them to the corresponding metal.

$$CuO(s) + H_2(g) \xrightarrow{200°C} Cu(s) + H_2O(g)$$

$$Fe_3O_4(s) + 4H_2(g) \longrightarrow 3Fe(s) + 4H_2O(g)$$

The reduction of metal halides is also possible using hydrogen.

$$2AgCl + H_2 \longrightarrow 2Ag + 2HCl$$

### 11.5.3 Uses of hydrogen

1. In metallurgy, a stream of hot hydrogen gas is passed over metal oxides to get metals. Hydrogen is used in extracting tungsten and molybdenum metals.
2. Hydrogen is used in industrial preparation of ammonia, hydrochloric acid etc.
3. Hydrogen is also essential in manufacture of carbonic compounds. For example, hydrogen is used in large scale preparation of methanol.
4. Production of vegetable fat by hydrogenation of vegetable oils- Double bonds between carbon atoms are found in the carbonic compounds present in vegetable oils which react with hydrogen and are converted to single-bonded vegetable fats.
5. Dissociation of hydrogen molecules in fuel cells produces electrical energy and then heat is produced in the reaction between hydrogen and oxygen. It causes less pollution as compared to fossil fuels.

## 11.6 Nitrogen

The atomic number of nitrogen is 7 and its electronic configuration is 2,5. Under normal temperature and pressure conditions nitrogen is found in the gaseous state. It is the first element of group 15 in the periodic table.

Nitrogen is the most abundant element in the atmosphere. At one point of time in the past it was believed that air was an element. British scientist Black (1728-99) demonstrated through some experiments that when a candle is burnt in a closed jar or beaker it extinguishes after some time and we can conclude that the air left inside the beaker no longer supports combustion. When he removed the gas formed during combustion of candle from the beaker he found that there was another gas left behind in the beaker. This gas also did not support combustion. But he could not explain his observations. Ultimately, one of his students Daniel Rutherford (1749-1819) was able to characterize the properties of the gas and therefore he is credited with the discovery of nitrogen.

### 11.6.1 Laboratory method of nitrogen preparation

In the laboratory, nitrogen gas is obtained by heating a solution of ammonium chloride and sodium nitride.

$$NH_4Cl(aq) + NaNO_2(aq) \xrightarrow{\text{Heat}} NaCl(aq) + 2H_2O(l) + N_2(g)$$

**Activity-3**

- Take equal amounts (25 g) of ammonium chloride and sodium nitride in a round bottom flask.
- Add 100 mL water to the flask and shake it so that the ammonium chloride and sodium nitride dissolve in the water.
- Take a glass tube, boiling tube, water-trough and test tube and arrange it as shown in figure-4.
- Now heat the flask and use displacement of water to collect the gas formed.

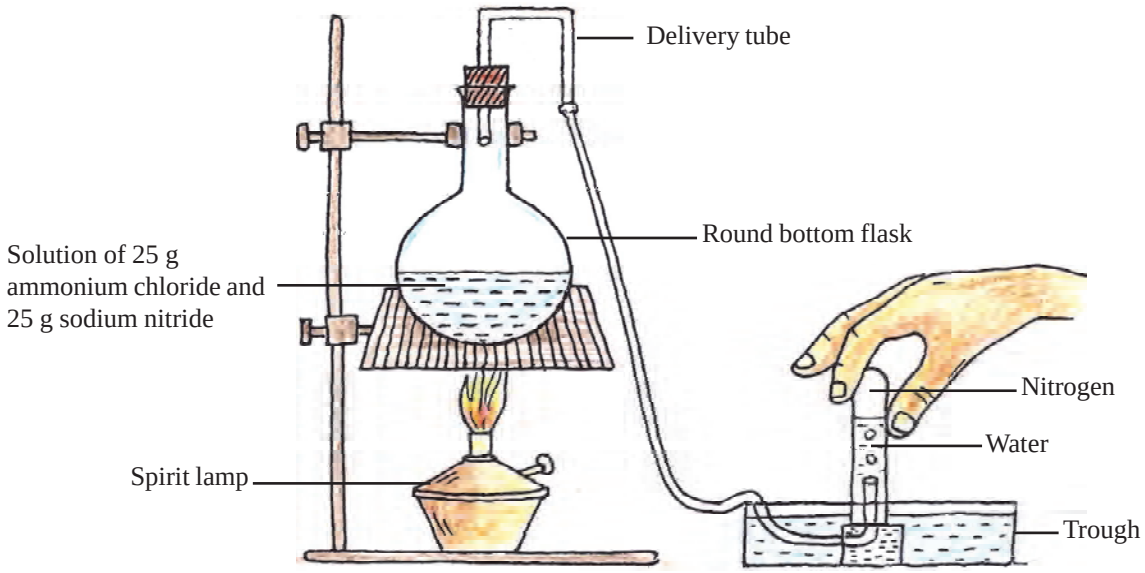



**Figure-4: Laboratory method of nitrogen preparation**

### 11.6.2 Chemical properties of nitrogen

We know that a molecule of nitrogen has two nitrogen atoms joined together by a triple bond. Therefore, nitrogen is a diatomic molecule and takes part in chemical reactions as $N_2$.

1. **Reaction with oxygen -** Nitrogen reacts with oxygen at extremely high temperatures (2000°C) to form nitric oxide.

$$N_2(g) + O_2(g) \xrightarrow{2000\ K} 2NO(g)$$

2. **Reaction with metals -** Nitrogen reacts with metals at high temperatures to form metal nitrides.

$$6Li + N_2 \xrightarrow{Heat} 2Li_3N$$

*Lithium nitride*

3. **Reaction with hydrogen -** At high temperature (450-500°C) and under high pressure (200 atm), in the presence of Fe catalyst and Mo promoter, nitrogen and hydrogen react with one another to form ammonia. (Catalysts increase the rate of reactions without taking part in it. Here, the catalyst Fe increases the rate of reaction and the promoter Mo increase the efficiency of the catalyst). This method of ammonia production is known as the Haber's process.

$$N_2(g) + 3H_2(g) \underset{200\ atm}{\overset{450\text{-}500°C}{\rightleftharpoons}} 2NH_3(g)$$

### 11.6.3 Uses of nitrogen

1. Proteins found in living organisms are compounds of nitrogen and some other elements (C,H,O,S).
2. It is used in the industrial manufacture of ammonia and nitric acid.
3. To create and inert atmosphere in packaged foods, chips' packets etc.
4. Manufacture of useful fertilizers like urea in agricultural field.
5. Liquid nitrogen rapidly absorbs heat therefore it is used to freeze and preserve tissue samples, blood samples etc.

## 11.7 Oxygen

Oxygen is the first element of group 16 in the periodic table. Oxygen is most abundant element in the earth's crust. It is second only to nitrogen in abundance in the atmosphere.

The atomic number of oxygen is 8 and its electronic configuration is 2,6. Two isotopes of oxygen, $O_2$ and $O_3$ are found in nature. Most of the oxygen around us is in the form of diatomic molecule, $O_2$.

### 11.7.1 Laboratory method of oxygen preparation

In the laboratory method, oxygen is prepared by heating potassium permanganate.

$$2KMnO_4 \xrightarrow{\triangle} K_2MnO_4 + MnO_2 + O_2\uparrow$$

*Potassium manganate*

**Activity-4**

- Take 2-3 g of potassium permanganate in a glass boiling tube and set-up your apparatus as shown in figure-5.
- Now heat the boiling tube and collect the gas formed in an upside down test tube or gas jar filled with water and kept in a trough.
- When the test tube is filled completely with the gas then place your thumb over its mouth and carefully remove it from water.

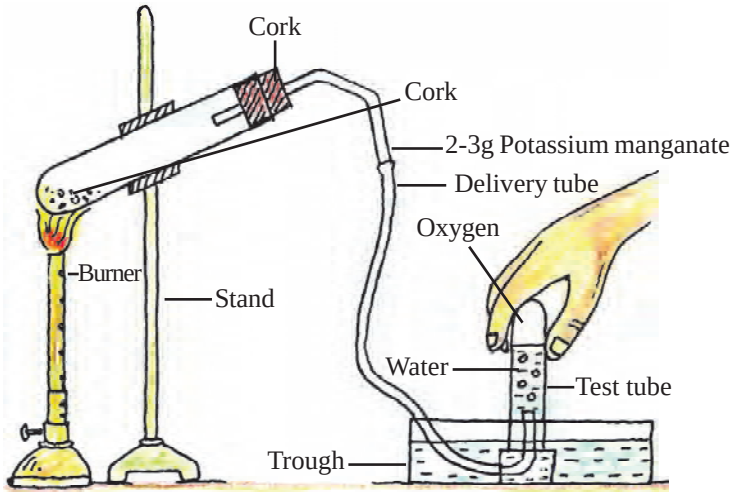



**Figure-5: Laboratory method of making oxygen gas**

- How will you test whether the collected gas is oxygen?

### 11.7.2 Chemical properties of oxygen

Although oxygen gas itself does not burn but it supports combustion. After fluorine, it is the most electronegative element.

1. Reaction of oxygen with metals and with non-metals - Oxygen reacts with metals and non-metals to form the respective oxides.

$$4Na + O_2 \longrightarrow 2Na_2O$$

$$N_2 + O_2 \longrightarrow 2NO\uparrow$$

2. Reaction with hydrogen - On passing an electric spark through a mixture of oxygen and hydrogen, water is obtained.

$$2H_2 + O_2 \xrightarrow{\text{Electric spark}} 2H_2O$$

3. Reaction with compounds - Oxygen reacts with ammonia to form water and nitrogen gas.

$$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O$$

4. Reaction with hydrogen chloride gas - In the presence of copper chloride catalyst, oxygen oxidizes hydrogen chloride gas into chlorine gas.

$$4HCl + O_2 \xrightarrow{\text{Catalyst } 400^\circ C} 2H_2O + 2Cl_2\uparrow$$

### 11.7.3 Uses of oxygen

1. Oxygen is necessary for essential processes like respiration and combustion. The energy produced during these reactions is used to sustain life and in daily processes.
2. Proteins, carbohydrate and fats which are fundamental molecules of life are also compounds of oxygen.

3. Oxygen is used in the industrial preparation of several chemicals like nitric acid, sulphuric acid, ozone etc.
4. Liquid oxygen is used as component of liquid fuel in rockets.
5. Oxy-hydrogen flames (which is produced as a result of combustion of a mixture of hydrogen and oxygen) and oxy-acetylene flames (which is produced as a result of combustion of a mixture of acetylene and oxygen) are used for cutting, joing and welding metals.

**Questions**

1. Write the balanced chemical equations for reactions of calcium, lithium and aluminium with hydrogen.
2. Which gas is used in packaged foods and why?
3. In laboratories, oxygen is collected in an upturned, water-filled test tube or gas jar, why?

## Keywords

Metalloid, catalyst, promoter, halogen, allotropy, electronegativity, noble gas, oxide, fluoride, nitride

## What we have learnt

- Elements can be classified as metals, non-metals and metalloids.
- Different Non-metals are found in all three states - solids, liquids and gaseous.
- The electronegativity of non-metals is more than that of metals.
- Different forms of the same element that exhibit different physical properties are known as allotropes. Thus, the occurrence of an element in a particular state in different forms is known as allotropy.
- Except graphite, which is an allotrope of carbon, all other non-metals are electrical insulators.
- Non-metals react with oxygen to give oxides which are mostly acidic in nature.
- Hydrogen, nitrogen and oxygen are found in nature as diatomic molecules.
- Ionic compounds are formed by reactions between metals and non-metals gives.
- Non-metals react with each-other to give covalent compounds.
- Hydrogen atom can lose one electron to form $H^+$ ion (similar to elements of the first group) and can gain one electron to form $H^-$ ion (similar to elements of group 17).
- Hydrogen reduces metal oxides to corresponding metals.
- At 450-500°C and under 200 atm, in the presence of iron catalyst and molybdenum promoter, nitrogen and hydrogen react with one another to form ammonia.

## Exercises

1. Choose the correct option -

   (i) The solution in water of which of the following will be acidic

   (a) $Na_2O$ (b) $CO_2$

   (c) MgO (d) $H_2O$

   (ii) Which of the following elements does not exhibit allotropy

   (a) Sodium (b) Oxygen

   (c) sulphur (d) phosphorus

   (iii) Which among the following is a metalloid

   (a) oxygen (b) helium

   (c) magnesium (d) arsenic

   (iv) Noble gases do not react with other elements because

   (a) They are monoatomic gases (b) Their atomic size is small

   (c) Their outermost shell is full (d) They are found in abundant amounts

   (v) The gas obtained on heating potassium permanganate is

   (a) nitrogen (b) oxygen

   (c) hydrogen (d) helium

2. Fill in the blanks

   (i) The most electronegative element is …….. (chlorine/ fluorine).

   (ii) Carbon is …… (more/less) reactive as compared to oxygen.

   (iii) Non-metals are found at the …….(right/ left) side of the periodic table.

   (iv) …….. (hydrogen/ nitrogen) gas is obtained when granulated zinc is reacted with dilute acid or alkali.

3. Compare the physical properties of metals and non-metals.

4. Write the balanced chemical equations for formation of chlorides and oxides of the following elements - hydrogen, phosphorous, sodium and magnesium.

5. Write the equation and corresponding conditions for reaction between nitrogen and hydrogen.

6. "Hydrogen can be placed either in group 1 or in group 17". Do you agree with this statement or disagree? Give reasons.

7. Why are helium, neon, krypton, argon, xenon and radon known as inert gases?

8. Explain the following industrial uses of hydrogen-
   (a) Heat production on combustion
   (b) Reaction with vegetable oils in the presence of a catalyst
9. What happens when potassium permanganate is heated? Explain giving balanced equation.
10. Gas 'A' is formed when granulated zinc reacts with dilute hydrochloric acid. It reacts with oxide 'B' and reduces it to copper metal. Write the names of 'A' and 'B' and also give the equations for the described reactions.
11. Sevati took sulphur powder in deflagrating spoon, heated it and collected the gas formed in a test tube. What will happen when moist red and blue litmus papers are taken near the mouth of the test tube and why? Write the chemical equations for the reactions taking place.
12. The processes described below are due to which property of hydrogen-

a. A hydrogen filled balloon floats in air.

b. A 'pop' sound is heard when a lighted matchstick is taken near the mouth of a hydrogen filled gas jar.

13. Compound X, which is used for drinking, has pH value 7. Electrolysis of an acidic solution of X gives gases Y and Z. The volume of Y is twice that of Z. Y burns rapidly while Z supports burning. Identify X, Y and Z and write the equations for the described reactions.