Changes in Matter

Chemistry
16

Objects made of iron rust when exposed to the air. Moth balls become smaller in size when kept exposed to the air. Ice melts and turns into liquid water. We have seen changes in matter like these. To study them further let us do the activity 16.1 given below.

Activity - 16.1

Requirements : A piece of magnesium (Mg) ribbon, about 50 ml of dilute sulfuric acid (H_2SO_4), a few pellets of sodium hydroxide (NaOH), two metal spoons, a moth ball (naphthalene), a box of matches, two 50 ml beakers, a Bunsen burner, a thermometer

Do the activities (i), (ii), (iii) and (iv) and record the observations.

i). Heat a metal spoon strongly in the Bunsen flame and take it away from the flame. Place a moth ball on it and observe. Close it with another spoon quickly. After some time observe the inner side of the spoon.

ii). Hold a piece of cleaned magnesium ribbon with a pair of tongs and burn it.

iii). Measure the initial temperature of a dilute sulfuric acid solution. Add a few pellets of sodium hydroxide to this solution, stir and measure the temperature again.

iv). Put a piece of magnesium ribbon to a beaker containing dilute sulfuric acid.

See whether the observations you obtained through the above activities conform to the following.

i). Moth ball melted and vaporized. A white powder deposited on the inner side of the spoon.

ii). Magnesium ribbon burned with a white bright flame leaving a white powder.

iii). Sodium hydroxide dissolved. The container became hot. The thermometer reading rose.

iv). Magnesium ribbon dissolved liberating gas bubbles. The beaker was heated.

In case (i) above solid naphthalene melted and then turned into a vapour. On the cold surface of the spoon the vapour solidified forming a thin solid layer of naphthalene. When solid naphthalene melted, liquid naphthalene vaporized and naphthalene vapour solidified again, and only the physical state (arrangement of particles) of the given substance changed without giving new substances. Such changes are called **physical changes.**

In the instances from (ii) to (iv), the given substances changed forming new substances. Such changes are known as **chemical changes** or chemical reactions.

Observations such as burning with a flame, evolution of heat, effervescence, change in colour and precipitation can be given as evidences for the occurrence of a chemical reaction.

To investigate physical and chemical changes further, let us study Table 16.1

Table 16.1

Physical changes and relevant observations	Chemical changes and relevant observations
The arrangement of particles which form the substance changes. No new substances are produced.	The existing substances change. New substances are produced.
Examples: 1.Crushing stone (lumps $\longrightarrow$ powder) 2.Melting of wax (solid $\longrightarrow$ liquid) 3.Vaporization of water (liquid $\longrightarrow$ gas) 4.Condensation of water vapour into droplets (gas $\longrightarrow$ liquid)	Examples: 1.Burning firewood (formation of ash, liberation of gases) 2. Heating limestone (formation of quicklime, evolution of gas) 3. Heating potassium permanganate (liberation of oxygen) 4. Rusting of iron (formation of rust)

16.1 Chemical Changes

One of the following can happen during a chemical reaction.

- Formation of new substances by the combination of two or more substances.
- Turning one substances into two or more substances.
- Reorganization of initial substances to form new substances.

The substances taking part in a chemical change are called the **reactants**. The new substances produced by a chemical changes are known as the **products**.

During a chemical reaction, reactants turn into products.

$$\text{Reactants} \longrightarrow \text{products}$$

To study the variety of chemical changes let us engage in activity 16.2.

Activity - 16.2

Requirements: magnesium ribbon, zinc granules, potassium permanganate, barium chloride, sodium sulphate, boiling tubes, test tubes, a Bunsen burner, an iron plate, a dry ekel , a box of matches, a pair of tongs.

i. Hold a magnesium ribbon in the Bunsen flame with the pair of tongs.
ii. Heat crystals of potassium permanganate in a boiling tube. Insert a glowing splint into the tube.
iii. Take some copper sulphate solution into a test tube and add a clean zinc granule into it.
iv. Take a little barium chloride solution into a test tube and add a little sodium sulphate solution into it.

Complete the Table 16.2 using the above chemical changes.

Table 16.2

Reaction	Nature of the reactants	Observation	Nature of the products
i. Burning magnesium in air	shiny, silvery white metal	Burns with a bright white flame	A white powder
ii.			
iii.			
iv.			

According to the nature of the chemical change, they can be classified into four types. They are as follows.

- Chemical combination reactions
- Chemical decomposition reactions
- Single displacement reactions
- Double displacement (Double decomposition) reactions

• Chemical Combination Reactions

Consider the first reaction of Activity 16.2. In it, magnesium reacts with oxygen in the air forming magnesium oxide.

magnesium + oxygen ⟶ magnesium oxide

$$2Mg + O_2 \longrightarrow 2MgO$$

Here, two elements have combined to form a new compound.

The formation of a new compound by the combination of elements with elements or elements with compounds or compounds with compounds is known as a chemical combination reaction.

A few other examples for chemical combinations are given below.

carbon + oxygen $\longrightarrow$ carbon dioxide

$C + O_2 \longrightarrow CO_2$

carbon dioxide + carbon $\longrightarrow$ carbon monoxide

$CO_2 + C \longrightarrow 2\,CO$

calcium oxide + water $\longrightarrow$ calcium hydroxide

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

hydrogen + chlorine $\longrightarrow$ hydrogen chloride

$H_2 + Cl_2 \longrightarrow 2HCl$

The common reaction for chemical combinations is as follows.

$$A + B \longrightarrow C$$

• Chemical Decomposition Reactions

Reflect on the second reaction in Activity 16.2. In that reaction potassium permanganate decomposes under the influence of heat to form other compounds and elements.

potassium permanganate $\xrightarrow{\Delta}$ potassium manganate + manganese dioxide + oxygen

$2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2$

The decomposition of a compound giving other simpler compounds or elements is known as a chemical decomposition reaction.

Some examples for chemical decomposition reactions are given below.

calcium carbonate $\xrightarrow{\Delta}$ calcium oxide + carbon dioxide

$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$

hydrogen peroxide $\xrightarrow{\Delta}$ water + oxygen

$2H_2O_2 \xrightarrow{\Delta} 2\,H_2O + O_2$

silver oxide $\xrightarrow{\Delta}$ silver + oxygen

$$2Ag_2O \xrightarrow{\Delta} 4Ag + O_2$$

The common reaction for chemical decompositions is as follows.

$$A \longrightarrow B + C$$

• Single Displacement Reactions

Focus your attention on the third reaction of Activity 16.2. In that reaction zinc metal reacts with copper sulphate freeing copper metal and forming zinc sulphate.

zinc + copper sulphate ⟶ zinc sulphate + copper

$$zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$$

The reactions in which an element displaces another element in a compound occupying its place and forming another compound are referred to as single displacement reactions.

Given below are some examples for single displacement reactions.

magnesium + copper sulphate ⟶ magnesium sulphate + copper

$$Mg + CuSO_4 \longrightarrow MgSO_4 + Cu$$

magnesium + hydrogen chloride ⟶ magnesium chloride + hydrogen

$$2Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

potassium bromide + chlorine ⟶ potassium chloride + bromine

$$2KBr + Cl_2 \longrightarrow 2KCl + Br_2$$

The common reaction for the single displacement reactions is as follows.

$$A + BC \longrightarrow AC + B$$

• Double Displacement Reactions

Consider the reaction (iv) of the Activity 16.2. In that reaction barium chloride and sodium sulphate react giving barium sulphate and sodium chloride.

barium chloride + sodium sulphate ⟶ barium sulphate + sodium chloride

$$BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$$

A reaction in which an element or a radical contained in a compound is exchanged with an element or a radical in another compound is called a double displacement reaction.

A few other examples for double displacement reactions are given below.

ferrous sulphate + sodium hydroxide ⟶ ferrous hydroxide + sodium sulphate

$$FeSO_4 + 2NaOH \longrightarrow Fe(OH)_2 + Na_2SO_4$$

calcium chloride + sodium carbonate ⟶ calcium carbonate + sodium chloride

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$$

The common reaction representing double displacement reactions is as follows.

$$AB + CD \longrightarrow AD + CB$$

16.2 Chemical Equations

A chemical equation is the symbolic representation of a chemical reaction using chemical formulae. When writing chemical equations in the standard form, reactants are written on the left hand side and the products on the right hand side. An arrow indicates the direction of a reaction. For a reaction, there may be several reactants as well as several products.

Reactants + Reactants ⟶ Products + Products

In such instances placing (+) mark between them is the accepted way. Moreover, the reacting substances as well as the substances produced are indicated by their chemical symbols and formulae. To write a chemical equation correctly, one should know chemical symbols and formulae well.

Now let us try to write the reaction between magnesium and oxygen in the form of an equation.

magnesium + oxygen ⟶ magnesium oxide

$$Mg + O_2 \longrightarrow MgO$$

According to the law of conservation of mass you have learnt, atoms are neither created nor destroyed during a reaction, so the number of atoms of the respective elements in the reactants should be equal to their number of atoms in the products. Equating the number of atoms of reactants with those of the products is known as balancing the equation.

$$Mg + O_2 \longrightarrow MgO$$

Follow the following steps to balance the above equation.

There are two oxygen atoms in the reactants. Products contain one oxygen atom. To balance oxygen, magnesium oxide cannot be written as MgO_2 because the formula of magnesium oxide produced by the above reaction is MgO. Therefore, 2 is written in front of MgO.

$$Mg + O_2 \longrightarrow 2MgO$$

When writing '2 MgO', two magnesium atoms are present in the products. But there is only one magnesium atom on the reactant side. So, '2' should come in front of Mg. This gives the following equation.

$$2Mg + O_2 \longrightarrow 2MgO$$

This is the balanced chemical equation of the reaction between magnesium and oxygen.

Study carefully how the balanced chemical equation is written for the following reaction also.

Reaction: Aluminium metal reacts with dilute hydrochloric acid forming aluminium chloride and hydrogen.

Write the formulae of the reactants and products correctly on either side of the arrow.

$$Al + HCl \longrightarrow AlCl_3 + H_2$$

Three chlorine atoms and two hydrogen atoms are present in the products. Since the least common multiple of 2 and 3 is 6, write 6 as the coefficient of hydrochloric acid.

$$Al + 6HCl \longrightarrow AlCl_3 + H_2$$

Now there are 6 hydrogen atoms in the products, so write 3 as the coefficient of H_2. As there are six chlorine atoms in the reactants insert 2 as the coefficient of $AlCl_3$.

$$Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

There are two aluminium atoms in the reactants. Hence write 2 as the coefficient of aluminium.

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

This is the balanced chemical equation of the relevant reaction.

The method of balancing chemical equations as described above is known as the **inspection method.**

Balance the following equations.

- $Na + O_2 \longrightarrow Na_2O$
- $Al + O_2 \longrightarrow Al_2O_3$
- $N_2 + H_2 \longrightarrow NH_3$
- $H_2 + O_2 \longrightarrow H_2O$
- $KClO_3 \longrightarrow KCl + O_2$

Assignment - 16.1

- Consider the word equations from 1 to 5 given below.
  - » Write balanced chemical equations for the word equations given.
  - » State to which type of reactions do those word equations belong.

1. a. magnesium + oxygen ⟶ magnesium oxide

   b. zinc + copper sulphate ⟶ zinc sulphate + copper

2. a. magnesium + hydrochloric acid ⟶ hydrogen + magnesium chloride

   b. ferrous sulphate + sodium hydroxide ⟶ ferrous hydroxide + sodium sulphate

3. a. calcium carbonate $\xrightarrow{heat}$ calcium oxide + carbon dioxide

   b. iron + sulphur ⟶ iron sulphide

4. a. calcium chloride + sodium carbonate ⟶ sodium chloride + calcium carbonate

   b. iron oxide + carbon monoxide ⟶ iron + carbon dioxide

5. a. sodium + oxygen ⟶ sodium oxide

   b. water + sodium ⟶ sodium hydroxide + hydrogen

When words are used to write a given chemical reaction, we face lot of difficulties. Understand this through the following examples.

Given below is the reaction between haematite (Fe_2O_3) and carbon monoxide.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

Writing in words does not show the ratio of atoms of elements constituting compounds. But when written as chemical formulae, the ratio of elements in the compound can be definitely known. Then the equation can be balanced. Once the balanced equation is found, the ratio of masses of the respective elements or compounds that should be mixed to obtain the maxiumum amount of the produts when performing the reaction practically can be calculated. So, writing equations using chemical symbols and formulae not only makes the task easier but also helps calculations.

By the above equation written using the symbols and formulae, following information can be obtained.

» Knowing the relative atomic masses of the elements (Fe =56; O=16; C=12), the relative molar masses can be obtained as Fe_2O_3 = 160 g mol^{-1},

  CO = 28 g $mol^{-1}$and CO_2 = 44 g mol^{-1}.

Thus,

(a) three moles of carbon monoxide (CO) is required to react with one mole of haematite (Fe_2O_3).

Hence, 28 x 3g (84 g) of carbon monoxide are required to react with 160 g of haematite.

(b) Two moles of iron are formed in the above reaction.

Thus, 56 x 2 g (112 g) of iron are formed in the above reaction.

(c) Three moles of carbon dioxide are formed in the above reaction.

So, 44 x 3 g (132 g) of carbon dioxide are formed in the above reaction.

16.3 Reactivity of Metals

We have seen that the objects such as nails, barbed wire and cutting tools made of iron rust fast. But jewellery made of gold do not tarnish even after a long period of time. Have you inquired into the causes for this difference? You can have an answer for this by studing how metals react with air, water and dilute acids.

• Reactions of Metals with Air

Let us carry out Activity 16.3 to investigate how metals react with air.

Activity - 16.3

Requirements: A freshly cut piece of sodium, a cleaned magnesium ribbon about 2 cm long

- Expose the freshly cut piece of sodium and the cleaned 2cm magnesium ribbon to air.
- Observe well the cut surface of the piece of sodium and the magnesium ribbon.
- Record your observations.

It is seen that the lustrous nature of the surface of sodium metal diminishes . We cannot see any noteworthy change in the magnesium ribbon. The reason for the disappearance of the shiny nature of the piece of sodium is that it reacts fast with the components in air. Magnesium does not react fast with the components in air.

When burnt in air, metals like sodium and magnesium react with oxygen to form their oxides.

$$4Na + O_2 \longrightarrow 2\,Na_2O$$
$$2Mg + O_2 \longrightarrow 2MgO$$

When heated in air, the surface of metals like zinc (Zn), iron (Fe) and copper (Cu) becomes dull. Prolonged heating turns them into the oxides.

$$2Zn + O_2 \longrightarrow 2ZnO$$

Metals like silver (Ag), platinum (Pt) and gold (Au) are not converted to their oxides. how strongly they are heated.

Based on these facts, it can be concluded that metals differ in their readiness of reacting with oxygen.

• Reactions of Metals with Water

Some metals react with cold water, hot water and water vapor at different speeds. Hence, it is clear that the reactively of metal towards water differ from one another. To confirm this, let us do activities 16.4 and 16.5.

Activity - 16.4

Requirements: A trough, water, a piece of sodium metal, a red litmus paper

- Under the guidance of the teacher add a small piece of sodium (the size of a seed of green gram) to the water in the trough.
- Record the observations.

The piece of sodium darts on the surface of water swiftly with a hissing sound. The piece of sodium which is small catches fire if it stays motionless. The red litmus paper in the trough turns blue. Sodium reacts violently with water liberating hydrogen gas. Turning red litmus blue shows the formation of an alkaline (basic) solution.

What happens here is that sodium reacts with cold water giving sodium hydroxide, a basic solution and hydrogen.

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

Activity - 16.5

Requirements: A beaker, water, a cleaned magnesium ribbon

- Put the cleaned magnesium ribbon into the beaker of water. Record the observations.
- Heat the beaker of water with the burner. Record the observations.

Magnesium does not give any observable reaction with cold water. But when reacting with hot water, liberation of gas bubbles can be seen.

Magnesium reacts with hot water giving magnesium hydroxide and hydrogen gas.

$$Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$$

Magnesium reacts fast with steam. The products of the reaction are magnesium oxide and hydrogen gas.

$$Mg + H_2O \longrightarrow MgO + H_2$$

Aluminum and zinc do not react with cold water or hot water. On heating in steam, they form the corresponding oxide and hydrogen gas.

$$Zn + H_2O \longrightarrow ZnO + H_2$$

Iron does not react with cold water or hot water. When heated in steam it gives the metal oxide and hydrogen gas.

$$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$$

For extra knowledge

$$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$$

Pay your attention to the $\rightleftharpoons$ sign in the above equation. It indicates that the above reaction is reversible. That means the products can be formed from the reactants and also the reactants can be formed from the produts.

Metals like silver, platinum and gold do not react with cold water, hot water and even with steam. Foregoing facts show that the reactivity of metals with water varies with the metal.

• Reactions of Metals with Dilute Acids

Hydrochloric acid (HCl), nitric acid (HNO_3) and sulphuric acid (H_2SO_4) are the frequently used acids in the laboratory.

Let us engage in Activity 16.6 to study the reactions of metals with dilute hydrochloric acid.

Activity - 16.6

Requirements: About 100 ml of dilute hydrochloric acid solution, identical test tubes, the metals aluminum (Al), copper (Cu), zinc (Zn), magnesium (Mg) and iron (Fe)

Add 100 ml of dilute hydrochloric acid solution each to a few test tubes. Add pieces of metals magnesium, aluminum, zinc, copper and iron with well cleaned surfaces separately to the test tubes and observe. Compare the rate of fizzing.

Gas bubbles evolve fast from the test tubes containing magnesium, aluminum and zinc. Gas bubbles liberate slowly from the test tube containing iron. No gas bubbles are set free from the test tube containing copper.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2$$

HCl is called hudrogen chloride when it exits as a gas. When hydrogen chloride gas is dissolved in water the solution is called hydrochloric acid.

This shows that the rate of reactions of metals with dilute acids differ according to the type of the metal. It is seen that copper metal does not react with dilute hydrochloric acid. Many metals react with dilute sulphuric acid also liberating hydrogen gas.

$$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$$

However, reactions of metals with concentrated sulphuric acid and nitric acid may give other gaseous products. Metals like potassium (K), sodium (Na) and calcium (Ca) react violently with dilute acids. It may cause even an ignition with explosion. Therefore those reactions must not be tried in the laboratory.

From the above it is seen that the reactivity of metals with acids varies with the metal.

• Reactions of Metals with Solutions of Other Metals Salts

Let us conduct activity 16.7 in order to explore how metals react with the solutions of salts of metals. Copper sulphate ($CuSO_4$) is a salt of the metal copper (Cu). An aqueous solution of copper sulphate can be prepared by dissoling this salt in water. Let us use the reaction of the metal zinc (Zn) with the copper sulphate solution in this regard.

Activity - 16.7

Requirements :- A beaker, an aqueous solution of copper sulphate, cleaned zinc metal

- Add copper sulphate solution to the beaker.
- Add a zinc granule to it.
- Record the observations.

Copper sulphate solution is blue in colour. It can be observed that the intensity of the blue colour of the solution dimimishes with the formation of a brown powder.

Here, the following single displacement reaction occurs.

$$CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu$$

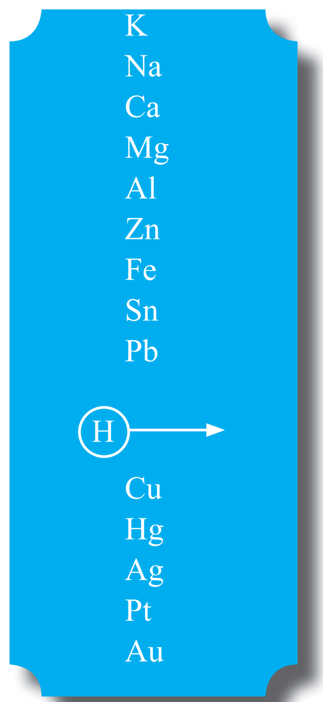
No reaction occurs when copper metal is added to the zinc sulphate solution.

$$ZnSO_4 + Cu \longrightarrow \text{No change is observed}$$

Only a metal which is more reactive can displace another metal from an aqueous solution of it. Accordingly, zinc is more reactive than copper, so it can displace copper from a copper sulphate solution. But, copper cannot displace zinc from a zinc sulphate solution. Thus, of zinc and copper, it can be inferred that zinc is the more reactive metal.

16.4 Activity Series

The relativity shown by metals with oxygen, water and, dilute acids is different from one another. The activity series is built up on the basis of those observations as well as other data. **The series obtained by the arrangement of metals in the descending order of their reactivity is referred to as the activity series.** The activity series is very important in the studies in chemistry.



Activity series

• Uses of the Activity Series

- Activity series is useful to identify the precautions to be taken when storing metals. The metals with high reactivity such as sodium (Na), potassium (K) and calcium (Ca) should be stored in liquids such as kerosene and liquid paraffin. Because of their high reactivity with air, they react with the components in air if they are kept exposed to air.

- Activity series is useful to find methods that prevent corrosion of metals. Keeping iron in contact with metals like zinc and magnesium that are more reactive than iron to prevent rusting of iron is an example.
- Activity series helps select metals to make electrochemical cells.
- Activity series can be used to decide on the methods suitable for extracting metals. Metals extraction involves the separation of the metal from a natural ore which contains that metal. How the metals occur differs according to their reactivity.
- Reactive metals such as sodium (Na) and potassium (K) cannot be seen as native metals in the natural environment. They are found as very stable ionic compounds in the environment. In order to extract them, electrolysis, a robust method of extracting metals has to be used. These metals are extracted by the electrolysis of their fused (molten) chloride (to be discussed in Grade 11).
- The metals of moderate reactivity such as iron (Fe), tin (Sn), zinc (zn) and lead (Pb) are extracted by reducing their compounds by other elements or compounds.
- The metals of low reactivity such as Silver (Ag), gold (Au) and platinum (Pt) occur in nature as the native metals mixed with other compounds. They are extracted by the physical methods used to separate the mixtures.

Hence, strong extraction methods such as electrolysis are used to extract metals at the top of the activity series. More simpler physical methods are used to extract metals at the bottom of the activity series.

• Extraction of Iron

Now, let us pay attention to the extraction of iron, a metal which is very important for the life of the human.

For extra knowledge

There are evidences in support of the fact that there had been a wealth of knowledge about extraction of iron in Sri Lanka in the past. Archeological excavations carried out recently in the Samanala wewa area have disclosed that a furnace smelting iron ores had been operated with the aid of monsoonal winds. A group of archeologists succeeded in reconstructing such a furnace and producing iron by smelting the iron ore. Archeological records state that steel for making the ceremonial sword of the Emperor of Arab had been brought in from 'Serendib'.

Iron is a metal placed somewhere in the middle of activity series. Iron is extracted from the iron ore mined from the soil. The main component containing iron in the iron ore is haematite (Fe_2O_3).

The structure used to extract iron is called the blast furnace. This is illustrated in Fig. 16.1.

It is a special furnace about 60 m high. The raw materials are fed into the furnace from the top while hot air is blown in from the bottom. Heating caused by hot air brings about several reactions inside the furnace giving liquid iron. The temperature range within the blast furnace is 1000 ^{0}C – 1900 ^{0}C.

The raw materials used namely iron ore (Fe_2O_3), limestone ($CaCO_3$) and coke (C) mixed in the correct proportion and powdered finely are charged from the top of the furnace.

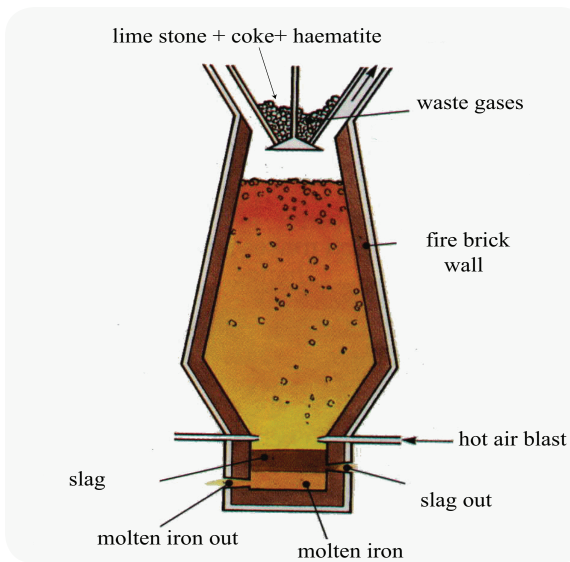


Fig. 16.1 - Blast furnace

During extraction of iron, following reactions occur in the blast furnace.

- Coke burns in air forming carbon dioxide.

$$C + O_2 \longrightarrow CO_2$$

- Carbon dioxide gas reacts with coke giving carbon monoxide gas (CO).

$$CO_2 + C \longrightarrow 2\,CO$$

- Carbon monoxide reduces the iron ore (Fe_2O_3). This produces liquid iron.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

- Calcium carbonate decomposes giving calcium oxide and carbon dioxide.

$$CaCO_3 \longrightarrow CaO + CO_2$$

- Silicon dioxide or silica (SiO_2) and aluminum oxide or alumina (Al_2O_3) present as impurities in the iron ore react with calcium oxide formed by the decomposition of limestone giving the slag, a mixture of calcium silicate ($CaSiO_3$) and calcium aluminate ($Ca\,Al_2O_4$).

$$\left.\begin{array}{l} SiO_2 + CaO \longrightarrow CaSiO_3 \\ Al_2O_3 + CaO \longrightarrow CaAl_2O_4 \end{array}\right] \text{slag}$$

The slag floats on molten iron. Molten iron and liquid slag are separately flown out.

Assignment - 16.2

1. Collect information about the iron industry in ancient Sri Lanka.
2. Iron is used to make alloys. Prepare a table comprising the alloys of iron, the new properties imparted of them and the uses of items made of those alloys because of those properties.
3. Discuss with the teacher the advantage if any of the existence of the slag in the blast furnace.

• Extraction of Gold

Gold (Au) is a metal that has longer historical relations with the human race than even iron does. There are evidences for the utilization of gold to make coins, various statues and documents. Now, let us see how this metal is extracted.

Gold, which is placed at the bottom of the activity services, does not react with any active component of the atmosphere under normal conditions. Therefore it occurs as the native metal in nature. But it is mixed with other impurities.
A certain amount of impurities can be removed by sifting the ore containing gold. The density of gold is very high. Therefore, when the ore is powdered felinely and mixed into a drain of water, gold settles down first on the bottom. The metal separated by such physical methods is purified further by various methods.

For extra knowledge

Presently solvents that dissolve gold have been discovered. When the metal with impurities is dissolved in these solvents, only gold dissolves. In order to get the metal that has gone into the solution, it is displaced by another metal.

16.5 Gases - Their Preparation, Properties and Uses

• Hydrogen (H_2)

In the atmosphere hydrogen occurs in a very small percentage. It is the lightest gas.

Physical and chemical properties of hydrogen gas

- The density of hydrogen is less than that of normal air.
- Its relative molecular mass is 2.
- It is a combustible gas.
- Hydrogen is slightly soluble in water.
- It is colourless.
- The gas is odourless.

In the laboratory hydrogen gas can be prepared by reacting a metal such as zinc or magnesium with an acid such as dilute hydrochloric acid or dilute sulphuric acid.

$$Zn + 2\,HCl \longrightarrow ZnCl_2 + H_2$$

Fig. 16.2 presents a set of apparatus that can be used to collect hydrogen gas prepared by a reaction such as the above.

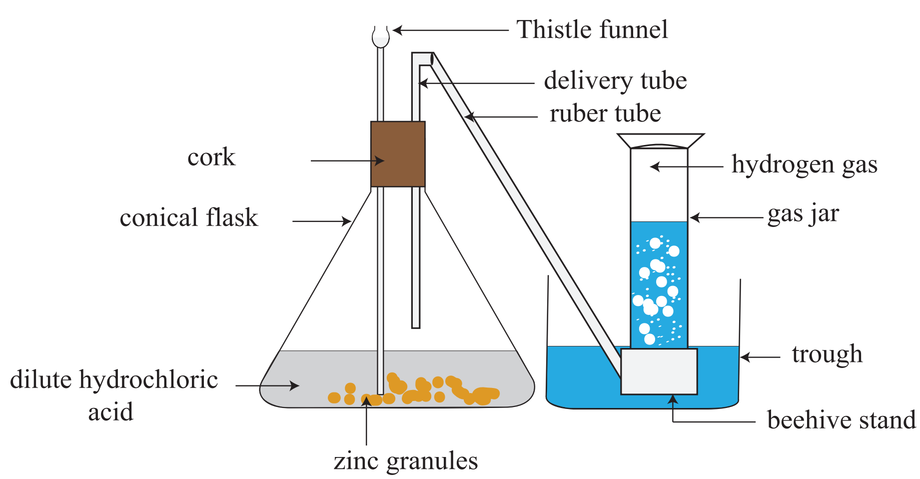


Fig. 16.2 Preparation of hydrogen gas in the laboratory

This method of collecting a gas is known as the downward displacement of water because when the gas enters the gas jar, the water in it is pushed down.
The gas coming from the delivery tub can also be collected by keeping a gas jar as shown in the Fig. 16.3.

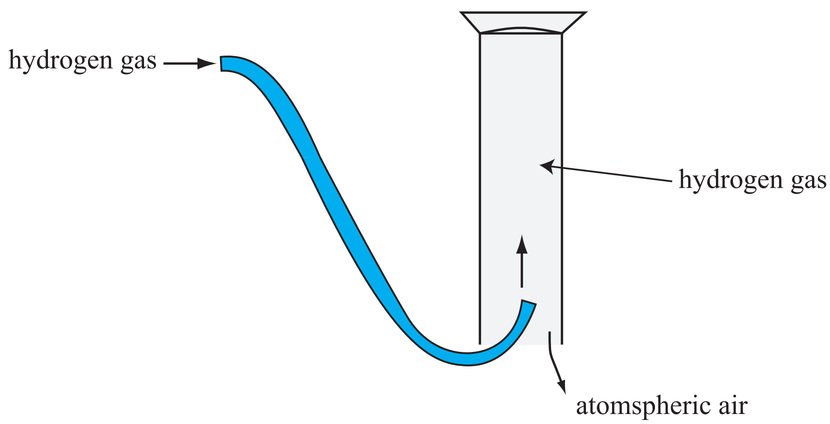


Fig. 16.3 - Collecting hydrogen gas by downward displacement of air

Since the density of hydrogen gas is less than that of the normal air, it moves up the jar. Then the atmospheric air in the jar gets pushed down and removed. This method of collecting a gas is called 'downward displacement of air'.

Activity - 16.8

Requirements: Dilute hydrochloric acid, clean test tubes, zinc granules, a conical flask, a thistle funnel, glass tubes, a rubber tube, a trough of water, a dry ekel, box of matches

- Arrange the apparatus as shown in Fig. 16.2 and collect several samples of hydrogen gas with your teacher (Since a gas jar requires a large amount of gas, use about five test tubes).
- Close well the mouth of the test tubes filled with the gas and take it out of water. Introduce a lighted ekel into this test tube.

What is your observation? The gas burns with a squeaky 'pop'. By this, hydrogen gas can be identified easily.

Uses of hydrogen gas

- Used as a fuel in rocketry
- Production of margarine from vegetable oils
- Production of ammonia gas by reacting with nitrogen (Ammonia is used to produce fertilizers such as urea.)
- Reduction of organic compounds

Assignment - 16.3

Inquire into the substances used to fly a small balloon. Collect the necessary materials and fly several balloons under the guidance of the teacher. Look into the reactions happening.

• Oxygen (O_2)

As regards the composition of normal air, about 20% of it is oxygen gas.

Physical and chemical properties of oxygen

- The density is higher than that of normal air.
- The relative molecular mass is 32.
- A supporter of combustion.
- Slightly soluble in water.
- A colourless and odourless gas.

Some reactions by which oxygen can be prepared in the laboratory are as follow.

1. Heating potassium permanganate ($KMnO_4$)

$$2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2$$

2. Heating potassium nitrate (KNO_3)

$$2KNO_3 \xrightarrow{\Delta} 2KNO_2 + O_2$$

3. Decomposition of hydrogen peroxide (H_2O_2)

$$2H_2O_2 \xrightarrow{\Delta} 2H_2O + O_2$$

4. Heating potassium chlorate ($KClO_3$)

$$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2$$

In the laboratory oxygen gas can be prepared by heating potassium permanganate using the apparatus in Fig. 16.4.

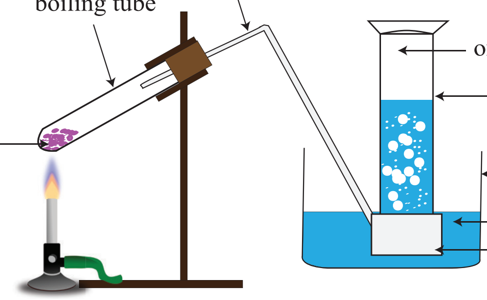


Fig 16.4 - Preparation of oxygen gas in the laboratory

Here, you see that the method of collecting oxygen gas is the downward displacement of water.

Activity - 16.9

Requirement : A stand, a boiling tube, rubber stoppers, a glass tube, rubber tubing, test tubes, a trough of water, a burner, potassium permanganate.

- Under the directions of the teacher set the apparatus as shown in Fig. 16.4 in the laboratory and collect oxygen gas to a few test tubes.
- Do the following test to identify oxygen gas. Take a dry ekel. Light one end of it. When the tip is glowing put out the flame. Take one test tube with oxygen out of water and introduce the glowing splint into it as soon as you open the mouth of the tube.

It is observed that the splint relights with a flame. By this oxygen gas can be identified.

Uses of oxygen gas

- It is essential for the respiration of all organisms.
- When something burns, it reacts with oxygen. Thus, oxygen is essential for combustion.
- It is used during underwater diving and space travel.
- It is used to generate the oxy-acetylene flame used for welding metals.
- Oxygen is used as a raw material in industries such as the production of sulphuric acid and nitric acid.

• Carbon dioxide gas (CO_2)

Carbon dioxide is a gas that contributed to the advent of life on Earth. This gas brought the temperature of the Earth's atmosphere to an optimal level for living organisms and it also acts a raw material for photosynthesis, the process that meets the food requirement of all living beings. Carbon dioxide occurs in a percentage as small as 0.03% by volume in the atmosphere.

Physical properties of carbon dioxide gas

- It is a gas with a density higher than that of normal air.
- Its relative molecular mass is 44.
- It neither burns, nor supports combustion.
- The gas is slightly soluble in water.
- The gas is colourless.
- Carbon dioxide is odourless.

Carbon dioxide gas can be prepared by reacting calcium carbonate ($CaCO_3$) with dilute hydrochloric acid.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

A sample of carbon dioxide gas can be prepared using the set up of apparatus shown in Fig. 16.5.

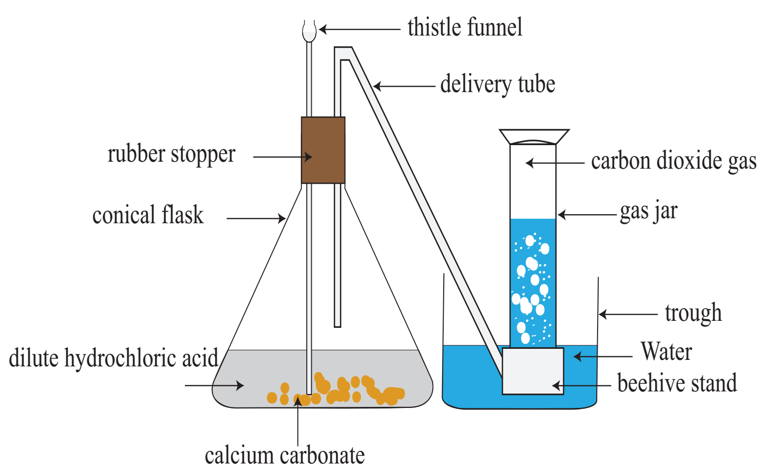


Fig. 16.5 - preparation of carbon dioxide gas in the laboratory

For your attention: Though a little amount of carbon dioxide dissolves in water when it is collected over water, it is not a barrier to collect samples of the gas.
Here also the method used to collect the gas is the downward displacement of water. But, as the density of carbon dioxide is greater than that of normal air, it can also be collected as shown in Fig. 16.6.

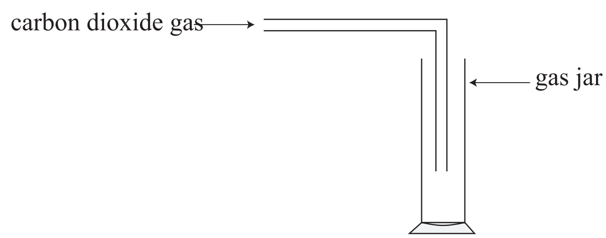


Fig. 16.6 - Collecting carbon dioxide gas by upward displacement of air

Since the density of carbon dioxide gas coming from the delivery tube is high, it reaches to the bottom of the jar. When the gas fills the jar, air inside is displaced upwards. Therefore this method of collecting a gas is known as ‘upward displacement of air.

Activity - 16.10

Requirement: a conical flask, a rubber stopper, a thistle funnel, glass tubing, test tubes, a trough of water, dilute hydrochloric acid, calcium carbonate or egg shells, a dry ekel, lime water, box of matches.

- Under the guidance of the science teacher, set the apparatus given in Fig. 16.5 and fill some test tubes with carbon dioxide gas.
- Light a dry ekel and introduce it with the flame into a test tube containing carbon dioxide gas. The flame is immediately extinguished. The gas quickly puts out the glow also.
- Dissolve a little slaked lime ($Ca(OH)_2$) in about 50 ml of water carefully are filter through a filter paper. Add about 5 ml of this solution to a test tube containing carbon dioxide, stopper the tube tightly and shake well. Add the same volume of lime water to a test tube with normal air, stopper and shake well. Compare the colours of the solutions in the two test tubes.

You will see that lime water turns more milky in the test tube containing carbon dioxide. Calcium hydroxide in lime water reacts with carbon dioxide in the test tube as follows.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

The lime water turns milky because the white calcium carbonate so formed is suspended in water.

If more carbon dioxide is passed into the test tube containing the gas suspension, the gas reacts with calcium carbonate forming water soluble calcium hydrogen carbonate or calcium bicarbonate [($Ca(HCO_3)_2$]. Therefore the milkiness of the solution disappears.

When carbon dioxide is cooled strongly under high pressure, the gas solidifies. When heated the solid carbon dioxide directly turns into the gas without liquefying, so it does not become a liquid like ice. Therefore solid carbon dioxide is known as dry ice. Since the temperature of dry ice (-77^{0}C) is very much lower than that of ice, it is used as a super coolant. Dry ice is largely used in food preservation. It is also used to create artificial rains.

Uses of carbon dioxide

- Since carbon dioxide is a non-supporter of combustion it is used in extinguishing fires.
- Since carbonic acid (H_2CO_3) formed when carbon dioxide dissolves in water gives a taste, it is used in the production of soda water and fizzy drinks.
- Carbon monoxide gas, the reductant essential for extraction of iron is produced by reacting carbon dioxide with coke.

For extra knowledge

When writing a balanced chemicalequations, the physical states related to the reaction are often indicated in front of each reactant and product.

s = solid l = liquid g = gas aq = aqueous

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

Summary

- The changes taking place in matter can be classified as physical changes and chemical changes.
- The changes that involve only the change in physical state of a substance without changing its composition such as melting of a solid, vaporization of a liquid, condensation and solidification of a gas following cooling and freezing of a liquid are physical changes.
- The changes that bring about the formation of new substances from the existing substances are known as chemical changes.
- Chemical reactions are of four types-combination, decomposition, single displacement and double displacement.
- A chemical changes can be represented by a balanced chemical equation.
- Symbols of elements and formulae of compounds that take part in a chemical reaction are used to write the balanced chemical equations.
- A lot of information can be drawn from the correctly written chemical equations.
- The Activity Series has been built up by comparing the reactions of metals with air, water, dilute acids and salt solutions.
- Deciding on the methods of metal extraction, identification of methods that prevent corrosion of metals, selection of metals to construct electrochemical cells according to requirement are uses made from the activity series.
- A structure called blast furnace and the raw materials hematite (Fe_2O_3), limestone ($CaCO_3$) and coke are used to extract iron.
- Gold occurs as the native (uncombined) metal in nature because its reactivity is very low. Various physical methods are used to separate gold mixed with impurities.
- Hydrogen, a component of very low abundance in the atmosphere is a useful gas to man.
- Oxygen, a gas present at an abundance of about 20% in the atmosphere is useful for many tasks including respiration and combustion.
- Carbon dioxide present at a percentage of about 0.03% by volume in the atmosphere has contributed to make the Earth suitable for living organizations. It also acts as a raw material for the production of food in plants by photosynthesis.

- Increase in the amount of carbon dioxide in the atmosphere causes global warming.
- According to the properties of gases, different methods are employed to collect them in the laboratory.
- In the laboratory, various methods are used to identify gases.

Exercise

1. Opposite each of the following statements, place a tick (✓) if it is true and a cross (X) if it is false.

   i. Melting of wax is a chemical change. ( )
   ii. A chemical change occurs in a fire place burning firewood. ( )
   iii. Evaporation of Eau de cologne is a physical change. ( )
   iv. Rusting of iron is not a chemical change. ( )
   v. A chemical change occurs when a salt solution is made by dissolving crystals of salt in water. ( )

2. Identify each of the following reactions as combination, decomposition, single displacement and double displacement.

   i. $4Na + O_2 \longrightarrow 2Na_2O$
   ii. $2Ag_2CO_3 \longrightarrow 4Ag + 2CO_2 + O_2$
   iii. $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$
   iv. $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$
   v. $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

3. Write balanced chemical equations for the following reactions.

   i. Sodium and hydrochloric acid react to produce sodium chloride and hydrogen.
   ii. Lead nitrate and dilute sulphuric acid react forming lead sulphate and nitric acid.
   iii. Calcium reacts with water giving calcium hydroxide and hydrogen gas.
   iv. Aluminum and dilute hydrochloric acid react giving aluminum chloride and hydrogen.
   v. Sodium carbonate reacts with dilute hydrochloric acid forming sodium chloride, water and carbon dioxide.

4. Answer the following questions that are based on the metals given below.

Ca, Mg, Cu, Zn, Al, Fe

i. What is the metal that reacts fastest with water?
ii. What is the metal that does not react with dilute hydrochloric acid?
iii. Which metal effervesces fastest with dilute hydrochloric acid?
iv. What is the metal that tarnishes fastest when exposed to air?
v. What are the metals that would not react if put into a copper sulphate solution?
vi. What are the metals that burn easily with a flame forming the oxide?

5. Explain the following scientifically.
i. Metals like sodium and potassium are stored in kerosene or liquid paraffin.
ii. Copper metal has been in use from ancient times.
iii. Special methods are not essential to prevent tarnishing of objects made of aluminum.
iv. Metals like sodium and potassium have the shortest history of usage.
v. When zinc is added to a copper sulphate solution copper is precipitated. But when copper is added to zinc sulphate solution zinc is not precipitated.

6. Describe the meaning of the following.

Electrolysis Reduction
Corrosion of metals Tarnishing of metals
Extraction of metals

7. Answer the following questions on extraction of iron.

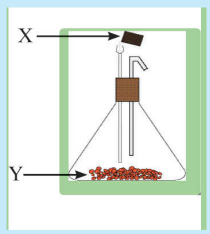
i. Write separately the raw materials, main product and by products.
ii. What are the two methods by which carbon is obtained to produce carbon monoxide that reduces haematite?
iii. How the temperature in the blast furnace rises to 1700^0C though the gas admitted to it is heated to about 650^0C?
iv. Iron is formed from hematite by the following reaction.

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

If the mass of haematite reduced is 100 kg, calculate,
a. the mass of iron produced;
b. the mass of carbon monoxide used up; and
c. the mass of carbon dioxide released to the atmosphere.

8. Some instances which use gases are given below. Write the gas used in each of these instances.
   i. Formation of carbonic acid ( )
   ii. Facilitating respiration of critically ill patients ( )
   iii. Making dry ice ( )
   iv. Using as raw materials to produce ammonia ( )
   v. Making margarine from vegetable oils ( )
   vi. Aiding respiration during diving ( )
   vii. Supporting combustion of firewood ( )

9. The figure illustrates a part of a set of apparatus assembled to collect a certain gas.



   i. There is a fault in this set of apparatus. What is it?
   ii. Write two ways of setting this apparatus overcoming the fault.
   iii. Suggest another method to collect the gas without changing the arrangement of equipment.
   iv. Adding a rubber tube, a gas jar and a trough of water, draw the figure of a complete set of apparatus that can be used to collect hydrogen gas.

   v. Name a substance each for X and Y that can be used to prepare hydrogen.
   vi. What gas could be expected to form if X is egg shells and Y is a solution of vinegar?
   vii. A sample of the gas in part (vi) is collected in a test tube. Write how it could be identified.

Technical terms

Activity series	-	සක්‍රියතා ශ්‍රේණිය	-	தாக்கத்தொடர்
Extraction	-	නිස්සාරණය	-	பிரித்தெடுப்பு
Condensation	-	ඝනීභවනය	-	ஒடுங்கல்
Combination	-	සංයෝජනය	-	சேர்க்கை
Decomposition	-	වියෝජනය	-	பிரிகை
Displacement	-	විස්ථාපනය	-	இடப்பெயர்ச்சி
Rate	-	ශීඝ්‍රතාව	-	வீதம்
Reversible reaction	-	ප්‍රතිවර්ත්‍ය ප්‍රතික්‍රියාව	-	மீளுந் தாக்கங்கள்
Blast Furnace	-	ධාරා ඌෂ්මකය	-	ஊதுலை