3 PHYSICAL AND CHEMICAL CHANGES : CHEMICAL EQUATIONS

In This Chapter You Will Learn :

- Physical and chemical changes
- Chemical reactions
- How a chemical equation represents a chemical reaction
- How to balance a chemical equation
- The various types of chemical reactions.

CHANGES AROUND US : PHYSICAL AND CHEMICAL CHANGES

Almost all substances undergo change. These changes have been taking place around us continuously, such as day and night, change of season, ripening of fruits, burning of fuel, cooking of food, *etc*.

There are different kinds of changes—natural and man-made, slow and fast, periodic and non periodic, desirable and undesirable, small and large, reversible and irreversible, temporary and permanent, *etc*.

All these changes are exciting and each one of them has a reason behind it. Since most of the changes are different in nature it is necessary to study them in detail. (You have studied about various kinds of changes in detail in Class VI).

3.1 PHYSICAL AND CHEMICAL CHANGES

In science, all kinds of changes taking place in substances are broadly classified into two types. They are (i) Physical change and (ii) Chemical change.

Physical change

A physical change is a temporary change, in which no new substance is formed and the chemical composition of the original substance remains the same, even though some of its physical properties, like colour, state, shape, size, etc., might change.

Examples **:** Water changes into ice on freezing which again melts into water when kept at room temperature. This indicates that changing of water into ice and ice into water is a temporary change and there is no change in the chemical composition, only the state changes.

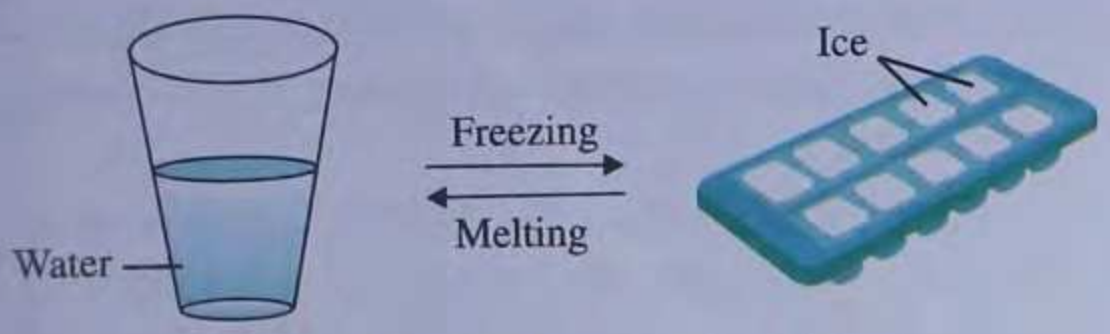


Fig. 3.1 Water freezing into ice or ice melting into water

Similarly, when a carrot is cut into pieces* its shape and size changes but there is no change in its chemical composition and taste. In both the above examples no new substances are formed. Hence they are physical changes.

Characteristics of physical change

1. No new substance is formed.
2. There is no change in the chemical composition of the original substance.
3. The chemical properties of the original substance remain the same.
4. The change is temporary and can be reversed by changing the conditions in most of the cases.
5. There may or may not be any change in the state, size, shape, colour and smell of the substance that undergoes physical change.
6. As a result of the change, there may or may not be any change in the energy possessed by the original substance.

Examples of physical change

Melting of ice, glowing of an electric bulb, cutting of glass, heating of an electric iron, boiling or freezing of water, making of a sugar or salt solution, beating of metals into sheets, formation of clouds, sublimation of iodine, crystallisation of sugar, *etc.*

* The case of carrot cut into pieces cannot be reversed.

Chemical change

A chemical change is a permanent change, in which new substances are formed whose chemical composition, physical and chemical properties are different from those of the original or parent substance(s).

Examples **:** When a piece of paper is burnt, it turns into ash. This is a new substance whose properties are completely different from those of paper. Ash cannot be changed back into paper.

When a piece of iron is left for a few days in air, containing moisture, it slowly forms a reddish brown substance called *rust*. Rust is a new substance completely different from iron in its properties and cannot be changed back into iron.

(a) Burning of paper

(b) Formation of rust on an iron nail

Fig. 3.2

Characteristics of chemical change :

1. New substance(*s*) is/are formed.
2. The composition and the properties of the parent substance(*s*) change(*s*).
3. The change is permanent and cannot be reversed by changing the conditions or through ordinary physical processes.
4. There is an exchange of energy during a chemical change, which means that heat and light may be given out or absorbed.

5. There is usually a change in the mass of the parent substance(*s*), as well.

Examples of chemical change

Cooking of food, formation of curd from milk, ripening of fruits, digestion of food, formation of gases, burning of coal, wood and cooking gas, rusting of iron, respiration in living beings, *etc*.

An example showing simultaneous physical and chemical change

When a candle is lighted, some of the solid wax melts and turns into a liquid. If this liquid drops to the floor or on a table, it re-solidifies. This is a physical change, involving only a change in state, which is reversible.

But most of the molten wax rises up in the wick, turns into vapour and burns with a flame. This forms two new substances, water vapour and carbon dioxide, and the size of the candle decreases. This is a chemical change, and it cannot be reversed.

Thus, we see that the melting of wax is a *physical change* but the burning of a candle is a *chemical change*. Both the changes take place at the same time.

Differences between physical and chemical change

Physical change	*Chemical change*
1. No new substance is formed. There are changes only in physical properties and state.	1. New substance (*s*) with entirely different properties is/ are formed.
2. The change is temporary.	2. The change is permanent.
3. The change can mostly be reversed by simple physical methods.	3. The change cannot be reversed by simple physical methods.
4. Heat or light may or may not be released or absorbed.	4. Heat or light, or both, are given out or absorbed.

EXERCISE – I

1. Classify the following as either physical change or chemical change :
   (a) Melting of wax
   (b) Formation of clouds
   (c) Cooking of food
   (d) Making of a sugar solution
   (e) Formation of curd from milk
   (f) Burning of coal
   (g) Boiling of water
   (h) Heating of mercuric oxide
   (i) Glowing of an electric bulb
2. Give four differences between physical change and chemical change.
3. Give an example which shows physical change and chemical change occur simultaneously.

3.2 CHEMICAL REACTIONS

Any chemical change in matter which involves its transformation into one or more new substances is called a chemical reaction.

The substances that react with one another are called ***reactants****, and the new substances thus formed are called* ***products****.*

Reactants ⟶ Products

Both reactants and products are pure substances, *i.e.*, elements and compounds.

Example **1 :** Hydrogen + Oxygen $\longrightarrow$ Water

In the above reaction we see that hydrogen and oxygen are the elements that undergo chemical change to form a new substance, water, a compound which is completely different from hydrogen and oxygen. Hydrogen and oxygen are the reactants and water is the product.

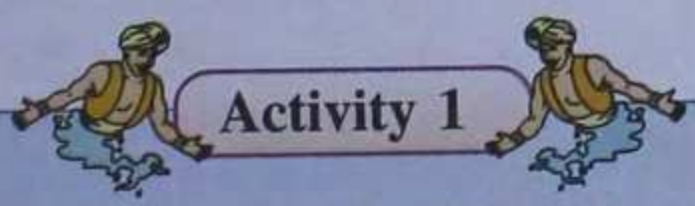
Example **2 :**

$$\text{Potassium chlorate} \xrightarrow[MnO_2]{\text{heat}} \text{Potassium chloride} + \text{Oxygen}$$

In this reaction, potassium chlorate a compound, on heating, changes into two new substances; potassium chloride and oxygen, which are compound and element respectively.

Thus a chemical reaction may involve combination of two or more elements or compounds reacting with each other to form new compound(s) or it may involve splitting of a compound into two or more elements or compounds.

We have already learnt about physical and chemical changes of matter. So whenever a chemical change occurs, we can say that a chemical reaction has taken place. Let us perform the following activity to know how a chemical reaction takes place.



Caution : This activity should be shown by the teachers to the students. It would be better if students wear eye protection.

- Clean a magnesium ribbon about 2 cm long by rubbing it with sand paper.
- Hold it with a pair of tongs. Burn it using a spirit lamp or burner and collect the ash so formed in a watch-glass. Burn the magnesium ribbon keeping it as far away as possible from your eyes.
- What do you observe ?

  You must have observed that magnesium ribbon burns with a dazzling white flame and changes into a white powder. This powder is magnesium oxide. It is formed due to the reaction between magnesium and oxygen present in the air.

Magnesium	+	**Oxygen**	→	**Magnesium oxide**
2Mg	+	O_2	→	2MgO

CONDITIONS NECESSARY FOR CHEMICAL REACTIONS

A chemical reaction takes place when one or more of the following conditions are fulfilled.

1. **Close contact :** For a chemical reaction to take place the reactants should be brought into close contact, *i.e.*, they should be mixed.

   For example : Sodium reacts with water violently when they come in contact with each other to produce two new substances, sodium hydroxide and hydrogen.

   Sodium + Water $\longrightarrow$ Sodium hydroxide + Hydrogen

2. **Solution form :** Some substances react with each other only when they are mixed in the solution form.

   For example : When sodium chloride solution is added to silver nitrate solution a white precipitate* of silver chloride and a soluble sodium nitrate are formed.

   Silver nitrate (aqueous solution) + Sodium chloride $\longrightarrow$ Silver chloride (white ppt.) + Sodium nitrate (solution)

* *Precipitate : An insoluble solid formed on reaction of two solutions is called a precipitate.*

3. **Heat :** Some reactants need to be heated to undergo a chemical change.

For example : Potassium chlorate on heating decomposes to produce two new products, potassium chloride and oxygen.

$$\text{Potassium chlorate} \xrightarrow{\text{heat}} \text{Potassium chloride} + \text{Oxygen}$$

Iron and sulphur when heated together react to produce iron sulphide. Without heating they do not react even if they are in contact with each other.

$$\text{Iron} + \text{Sulphur} \xrightarrow{\text{heat}} \text{Iron sulphide}$$

4. **Light :** Some reactions take place in the presence of light.

For example : Photosynthesis in which carbon-dioxide and water react in presence of chlorophyll and light to produce glucose and oxygen.

$$\text{Carbon-dioxide} + \text{water} \xrightarrow[\text{sunlight}]{\text{chlorophyll}} \text{glucose} + \text{oxygen}$$

5. **Catalyst :** Some reactions need a catalyst to speed up or slow down the reaction.

For example : Manganese dioxide acts as a catalyst for the decomposition of potassium chlorate into potassium chloride and oxygen at a lower temperature.

$$\underset{\text{chlorate}}{\text{Potassium}} + \underset{\text{dioxide}}{\text{Manganese}} \longrightarrow \underset{\text{chloride}}{\text{Potassium}} + \text{Oxygen} + \underset{\text{dioxide}}{\text{Manganese}}$$

Manganese dioxide does not undergo any change in its chemical composition.

Different chemical substances are used as catalysts for different chemical reactions.

CATALYST : *A catalyst is a substance which changes the rate of a chemical reaction without itself undergoing any chemical change.*

All chemical reactions can be represented with the help of symbols. Such representations are called chemical equations and they are universally accepted.

3.3 CHEMICAL EQUATIONS

A chemical equation is the symbolic representation of a chemical reaction using the symbols and the formulae of the substances involved in the reaction.

Example : Burning of coal in air is a chemical reaction in which a new substance, carbon dioxide, is formed.

This reaction can be represented by either a word equation or a chemical equation (using formulae and symbols), as shown below :

$$\text{Carbon} + \text{Oxygen} \xrightarrow{\text{heat}} \text{Carbon dioxide}$$

$$\underset{\text{(reactants)}}{C + O_2} \xrightarrow{\text{heat}} \underset{\text{(product)}}{CO_2}$$

In fact a chemical equation is a short hand description of a chemical reaction.

The steps involved in writing a chemical equation :

(i) Write the symbols or the formulae of the reactants on the left hand side, with a (+) sign between them.

(ii) Write the symbols or the formulae of the products on the right hand side, with a (+) sign between them.

(iii) Put the sign of an arrow (→) in between the reactant side and the product side.

(iv) Represent the reactants and the products in their molecular forms, because their atomic forms are usually neither stable nor capable of separate existence.

Note **:** The physical states of the reactants and the products of a chemical equation are shown using the symbols *(g)* for gas, *(l)* for liquid and *(s)* for solid and (aq.) for aqueous. The word aqueous (aq.) is written if the reactant or the product is present as a solution in water.

For example,

$$\underset{(g)}{6CO_2} + \underset{(l)}{12H_2O} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \underset{\substack{(aq.)\\(\text{glucose})}}{C_6H_{12}O_6} + \underset{(g)}{6O_2} + \underset{(l)}{6H_2O}$$

Sometimes the pressure, the temperature and the catalyst used in the reaction are also shown, they are mentioned above or below the arrow sign.

Now consider the following chemical reactions :

(i) Reaction of zinc oxide with carbon to form zinc and carbon monoxide.

Zinc oxide + Carbon $\longrightarrow$ Zinc + Carbon monoxide
[word equation]

$ZnO\ (s) + C\ (s) \longrightarrow Zn\ (s) + CO\ (g)$
[symbolic equation]

(ii) Reaction between hydrogen and chlorine to form hydrogen chloride [or hydrochloric acid].

Hydrogen + Chlorine $\longrightarrow$ Hydrogen chloride
[word equation]

$H_2 + Cl_2 \longrightarrow HCl$
[symbolic equation]

Note **:** We cannot write the equation as $H + Cl \rightarrow HCl$, because H and Cl represent the atoms of hydrogen and chlorine, which have no independent existence. The two reactants should be written as H_2 and Cl_2, *i.e.*, in their molecular form. Molecules have independent existence.

Note in the reaction $H_2 + Cl_2 \rightarrow HCl$, the numbers of hydrogen and chlorine atoms on the left hand side are not equal to their numbers on the right hand side.

Such an equation is an unbalanced one and it is known as a ***skeletal equation****.*

Some examples of skeletal equations :

$$H_2 + O_2 \longrightarrow H_2O$$
$$Mg + O_2 \longrightarrow MgO$$
$$N_2 + H_2 \longrightarrow NH_3$$

Remember, all chemical equations must be balanced.

The need for balancing a chemical equation

A chemical equation needs to be balanced so as to make the number of the atoms of the reactants equal to the number of the atoms of the products. *This is because a chemical reaction is just a rearrangement of atoms. The atoms themselves are neither created nor destroyed during the chemical reaction.*

Law of conservation of matter : *Matter can neither be created nor be destroyed. It can only be transformed from one form to another form. The total mass of the elements present in the products of a chemical reaction has to be equal to the total mass of the elements present in the reactants.*

Therefore, the balanced chemical equation for the reaction between hydrogen and chlorine is written as : $H_2 + Cl_2 \rightarrow 2HCl$.

A balanced chemical reaction is the one in which the number of atoms of each element on the reactant side is equal to the number of atoms of that element on the product side.

The significance of a balanced chemical equation

A balanced chemical equation is a wonderful way of representing a lot of information in a concise manner.

1. It shows which substances are taking part in a chemical reaction and what products are obtained as a result of it (Qualitative).
2. It shows both the number of molecules and the number of atoms involved in the reaction.
3. It enables us to calculate the actual amount (mass) of reactants and products involved in the reaction (Quantitative).
4. It makes the study of chemistry universally standardized.

Example : $2Mg + O_2 \rightarrow 2MgO$

This chemical equation indicates that :

(i) magnesium reacts with oxygen to form magnesium oxide.

(ii) two monoatomic molecules of magnesium combine with one diatomic molecule of oxygen to produce two molecules of magnesium oxide.

(iii) 48 amu of magnesium reacts with 32 amu of oxygen to produce 80 amu of magnesium oxide.

3.4 HOW TO BALANCE A CHEMICAL EQUATION ?

A chemical equation is balanced by taking the following steps in the given examples :

***Example 1** : Burning of magnesium in the presence of oxygen.*

Magnesium burns in oxygen to give magnesium oxide.

∴ The word equation is :

Magnesium + Oxygen → Magnesium oxide

Formulae for the reactants are Mg and O_2.

Formula for the product is MgO.

∴ The skeletal equation is :

$$Mg + O_2 \rightarrow MgO$$

Steps for balancing the equation

Step I : *Count the number of atoms of each element on either side. It is convenient to start balancing with the compound that contains the maximum number of atoms.*

Number of atoms of each element on the reactant side :

Magnesium = 1

Oxygen = 2

Number of atoms of each element on the product side :

Magnesium = 1

Oxygen = 1

Therefore, we can see that there is an extra oxygen atom present on the reactant side.

Step II : *Multiply the product side by 2, because there are two atoms of oxygen present in the reactant.*

$$Mg + O_2 \rightarrow \boxed{2}\,MgO$$

[Now we have Mg = 1, O = 2 → Mg = 2, O = 2]

But this means that there is now one extra atom of magnesium present on the right hand side (product side).

Step III : *Multiply the magnesium atom on the left hand side by 2.*

$$\boxed{2}\,Mg + O_2 \rightarrow 2MgO$$

[Number of atoms of Mg=2, O=2→ Mg=2, O=2]

This equation is now balanced and can be written as $2Mg + O_2 \rightarrow 2MgO$

Note : For a balanced equation the arrow sign (→) can be replaced by the = sign.

Example 2 :*Reaction of zinc with hydrochloric acid.*

This gives zinc chloride and hydrogen. The word equation is :

Zinc + Hydrochloric acid → Zinc chloride + Hydrogen

Formulae for the reactants are Zn and HCl.

Formulae for the products are $ZnCl_2$ and H_2.

∴ The skeletal equation is :

$$Zn + HCl \rightarrow ZnCl_2 + H_2$$

Step I : *Count the number of atoms of each element on either side.*

Reactant side : Zinc = 1
Hydrogen = 1
Chlorine = 1

Product side : Zinc = 1
Chlorine = 2
Hydrogen = 2

Note that both hydrogen and chlorine have an extra atom present on the product side.

Step II : *Multiply* HCl *on the reactant side by* 2.

$$Zn + \boxed{2}HCl \rightarrow ZnCl_2 + H_2$$

[Now we have Zn=1, H=2, Cl=2→ Zn=1, Cl=2, H=2]

Thus the number of atoms of each element on the reactant side = the number of atoms of that element on the product side.

Further steps are not required here, since the equation is already balanced.

∴ The balanced chemical equation is :

$$Zn + 2HCl = ZnCl_2 + H_2$$

Example :

Zinc + Sulphuric acid → Zinc sulphate + Hydrogen

The above word equation may be represented by the following chemical equation

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

Let us examine the number of atoms of different elements on both sides of the arrow.

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Zn	1	1
H	2	2
S	1	1
O	4	4

As the number of atoms of each element is the same on both sides of the arrow, hence the above equation is a balanced chemical equation.

Intext Questions

1. Why should a magnesium ribbon be cleaned before burning in air ?
2. Explain the following :
   (i) Catalyst (ii) Chemical equation
3. Balance the following skeletal equations.
   (i) $H_2 + O_2 \rightarrow H_2O$
   (ii) $N_2 + H_2 \rightarrow NH_3$
   (iii) $Na + O_2 \rightarrow Na_2O$
   (iv) $Fe + H_2O \rightarrow Fe_3O_4 + H_2$
   (v) $Na + H_2O \rightarrow NaOH + H_2$

SOME ACTIVITIES TO UNDERSTAND CHEMICAL REACTION

Activity 2

To be demonstrated by teacher.

Take some sugar in a porcelain dish. Keep it over a tripod stand and heat it for some time.

What do you observe ?

Sugar first melts and then gets charred into a black residue which is a new substance charcoal. It no more tastes sweet. Some water vapours are also formed which escape in air.

This shows that a chemical reaction may involve a change in colour.

This reaction can be represented as,

Sugar (white solid) $\xrightarrow{\text{heat}}$ Charcoal (black solid mass) + Water vapour

$C_{12}H_{22}O_{11} \xrightarrow{\text{heat}} 12C + 11H_2O$

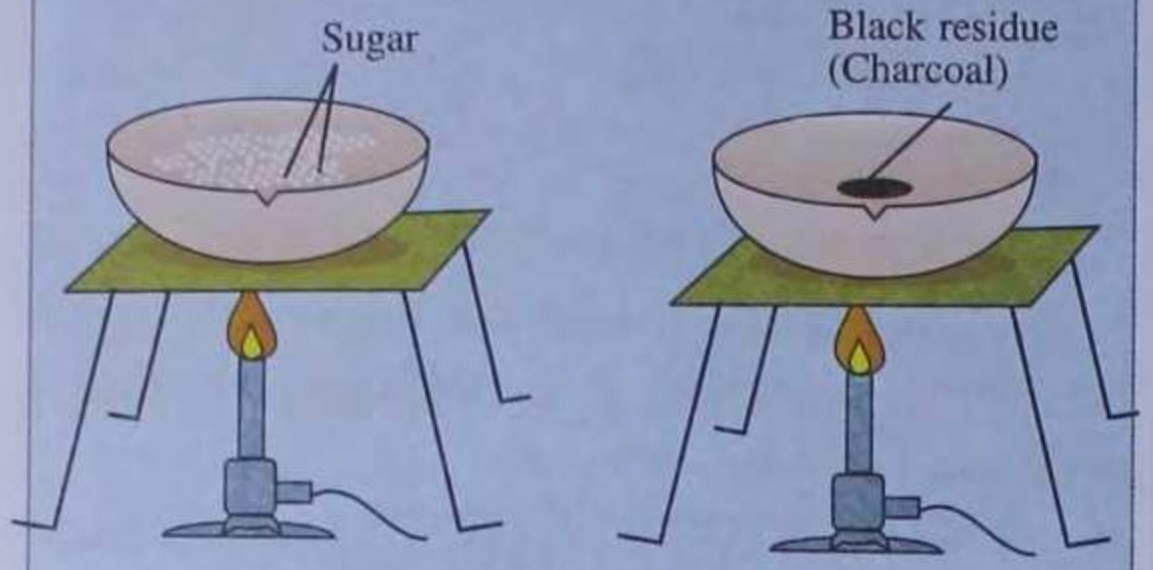


Fig. 3.3

Activity 3

To be demonstrated by teachers.

Take some baking soda in a test tube. Add some dilute acetic acid (vinegar) to it.

What do you observe ?

Strong effervescence (bubbles) indicating evolution of a gas. The gas is carbon dioxide.

This shows that during a chemical reaction a gas may be evolved. This reaction can be represented as,

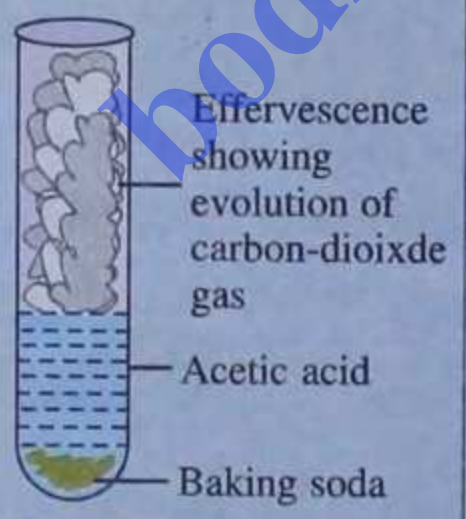


Fig. 3.4

Sodium bicarbonate (Baking soda) + Acetic acid (dil.) → Sodium acetate + Carbon dioxide ↑ + Water

$NaHCO_3 + CH_3COOH \rightarrow CH_3COONa + CO_2\uparrow + H_2O$

Now think and answer what happens when you open a cold drink bottle ? Why does it happen ?

Activity 4

To be demonstrated by teachers.

Take some solid sodium chloride and solid lead nitrate and mix them. They are now in contact of each other. Keep the mixture as it is for some time.

Do you observe any change ? **NO.**

Now take aqueous solution of sodium chloride and lead nitrate in two separate test tubes. Add the solution of sodium chloride to lead nitrate solution.

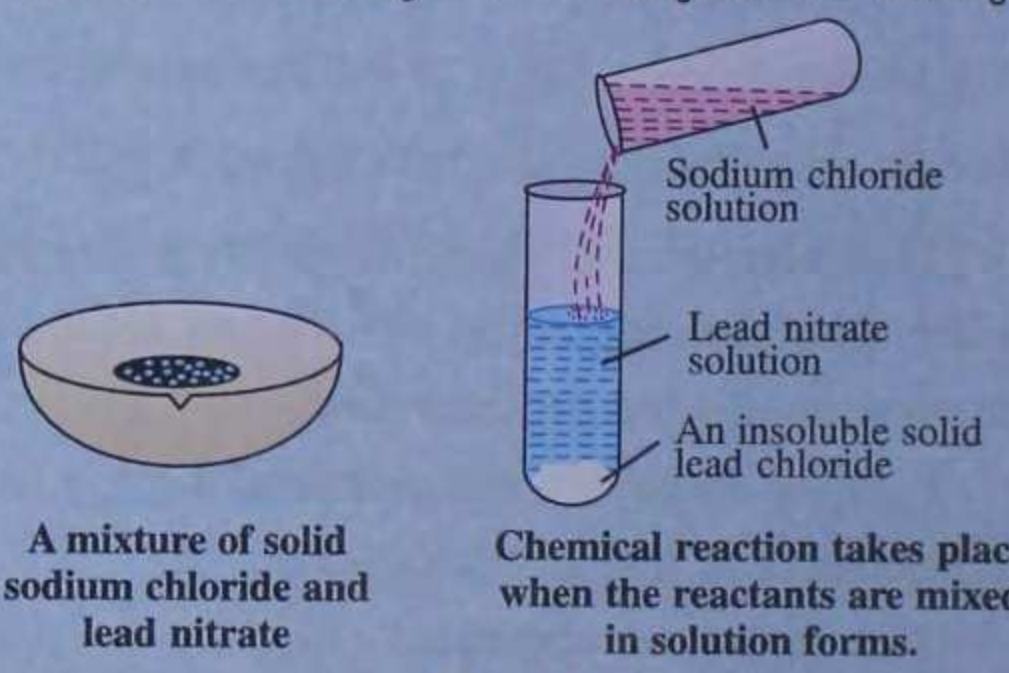
What do you observe ?

A white insoluble solid (precipitate) is formed immediately which is a new substance known as lead chloride.

This shows that some substances react when they are mixed in solution form only. The reaction can be represented as,

Sodium chloride (solution) + Lead nitrate (solution) → Lead chloride ↓ (precipitate) + Sodium nitrate (solution)

$NaCl + PbNO_3 \rightarrow PbNO_3\downarrow(s) + NaNO_3$



A mixture of solid sodium chloride and lead nitrate

Chemical reaction takes place when the reactants are mixed in solution forms.

Fig. 3.5

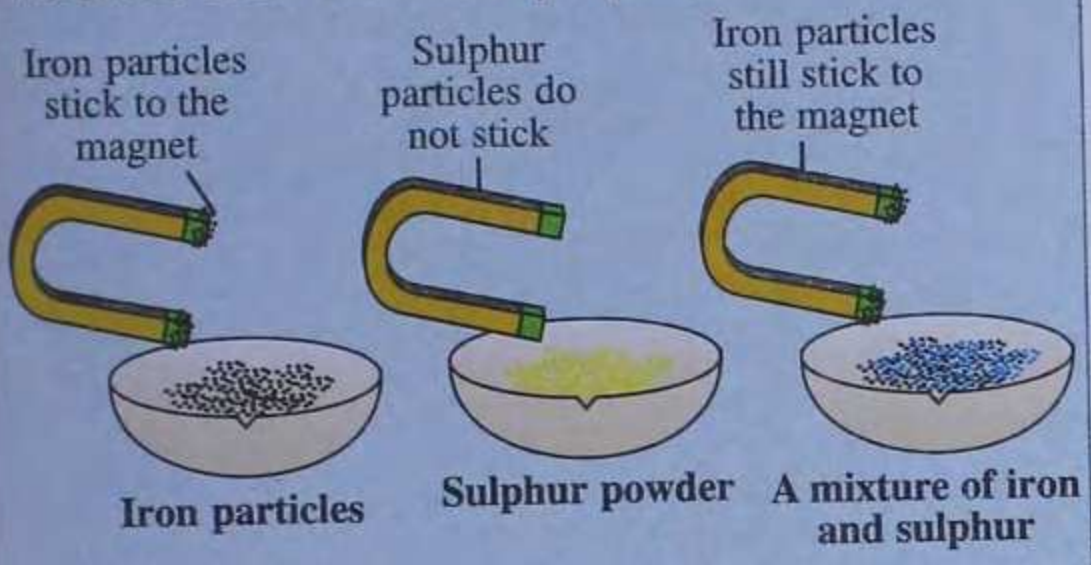
Activity 5

To be demonstrated by teachers.

Take some iron powder in a watch glass and some sulphur powder in another watch glass.

Bring a magnet near the iron powder. We observe that iron powder sticks to the magnet.

Now bring the magnet near the sulphur powder. We observe that the powder does not stick to the magnet. Mix the two powders, *i.e.* of sulphur and iron, and again bring the magnet near the mixture. You will observe that iron still sticks to the magnet but sulphur does not. This indicates that, in the mixture, sulphur and iron have retained their individual properties.



Now, take the mixture in a porcelain dish and heat it for some time. A grey mass is formed.

Allow it to cool and then test it with a magnet. The grey mass is not attracted towards the magnet. This means that the grey mass is a new substance, with its properties different from those of iron or sulphur taken separately. Iron and sulphur have combined to form a compound called iron sulphide. This also shows that heating is necessary for some chemical reactions to take place. This reaction can be represented by the following equation,

$$\text{Iron} + \text{Sulphur} \xrightarrow{\text{heat}} \text{Iron sulphide}$$

$$\text{Fe} + \text{S} \xrightarrow{\text{heat}} \text{FeS}$$

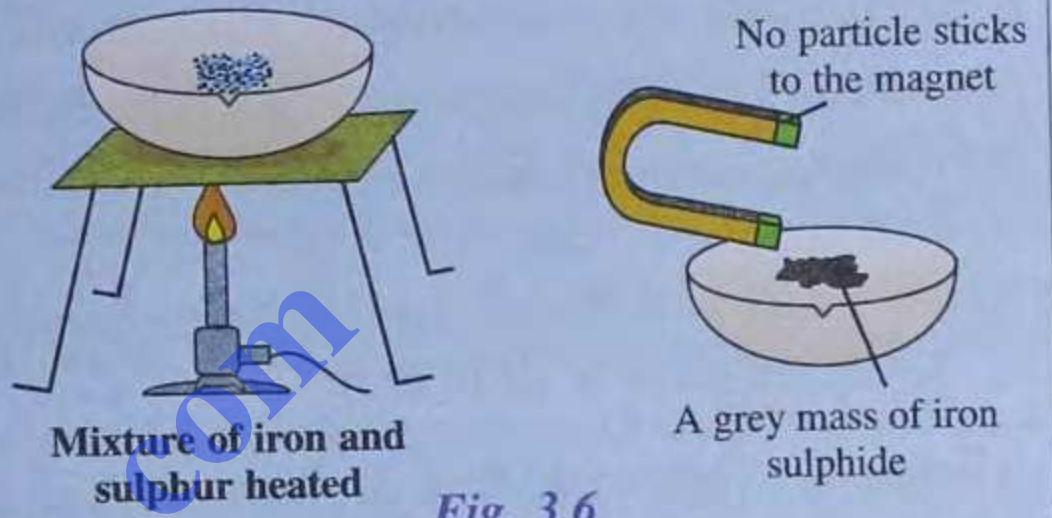


Fig. 3.6

EXERCISE – II

1. (a) What is a chemical equation ?
   (b) Why do we need to balance chemical equations ?
   (c) How is a chemical equation balanced ? Give necessary steps involved in balancing a chemical equation with the help of a suitable example.
2. State four conditions necessary for chemical reactions to take place.
3. Differentiate between :
   (a) Reactants and products
   (b) Chemical formula and chemical equation
   (c) A balanced and an unbalanced chemical equation.
4. Balance the following equations :
   (a) $KClO_3 \rightarrow KCl + O_2$
   (b) $NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$
   (c) $Zn + HCl \rightarrow ZnCl_2 + H_2$
   (d) $FeCl_2 + Cl_2 \rightarrow FeCl_3$
   (e) $CO + O_2 \rightarrow CO_2$
5. Write symbolic representation for the following word equations and balance them :
   (a) Calcium carbonate → calcium oxide + carbon dioxide
   (b) Carbon + oxygen → carbon dioxide
   (c) Calcium oxide + water → calcium hydroxide
   (d) Aluminium + chlorine → aluminium chloride
   (e) Iron + sulphur → iron sulphide
6. What information do you get from the equation
   $$H_2 + Cl_2 \rightarrow 2HCl$$
7. Write your observations for the following chemical reactions and name the products formed :
   (a) When sugar is heated.
   (b) When iron and sulphur are heated.
   (c) When dilute acetic acid is poured on baking soda.
   (d) When an aqueous solution of sodium chloride is mixed with an aqueous solution of silver nitrate.

3.5 TYPES OF CHEMICAL REACTION

Chemical reactions are broadly classified into *four* types

1. Combination reaction
2. Decomposition reaction
3. Displacement reaction
4. Double decomposition reaction

1. Combination reaction

The type of chemical reaction in which two or more substances (elements or compounds) combine to form a new substance (a compound), is known as a ***combination reaction****.*

Example 1 : *Burning of hydrogen in air.*

Hydrogen burns in air to give water.

$$\text{Hydrogen} + \text{Oxygen} \xrightarrow{\text{heat}} \text{Water}$$

$$H_2 + O_2 \longrightarrow H_2O \text{ (unbalanced)}$$

$$2H_2 + O_2 = 2H_2O \text{ (balanced)}$$

Example 2 : *Reaction of water with carbon dioxide.*

This reaction produces an acid called carbonic acid [or hydrogen carbonate].

$$\text{Carbon dioxide} + \text{Water} \longrightarrow \text{Hydrogen carbonate}$$

$$CO_2 + H_2O = H_2CO_3 \text{ (balanced)}$$

Example 3 : *Burning of coal.*

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} + \text{heat}$$

Reaction in which heat is released along with the formation of products are called **exothermic** chemical reactions.

Example 4 : *Reaction of calcium oxide with water.*

$$\underset{\text{quick lime}}{CaO_{(s)}} + H_2O_{(l)} \longrightarrow \underset{\text{slaked lime}}{Ca(OH)_{2(aq.)}} + \text{Heat}$$

Calcium oxide commonly known as quick lime is used for white washing.

2. Decomposition reaction

The type of chemical reaction in which a substance (usually a compound) breaks up on heating to form two or more simpler substances, which can be either elements or compounds, is known as a ***decomposition reaction****.*

Example 1 : *You will see that white silver chloride turns grey in sunlight this is due to the decomposition of silver chloride into silver and chlorine by light.*

$$2AgCl_{(s)} \xrightarrow{\text{sunlight}} 2Ag_{(s)} + Cl_{2(g)}$$

$$2AgBr_{(s)} \xrightarrow{\text{sunlight}} 2Ag_{(s)} + Br_{2(g)}$$

The above reactions are used in black and white photography.

Example 2 : *Electrolysis of water.*

When electric current is passed through acidulated water, the latter breaks up to give hydrogen and oxygen. This can be represented by the following equation :

$$\text{Water} \xrightarrow[\text{current}]{} \text{Hydrogen} + \text{Oxygen}$$

$$H_2O \xrightarrow[\text{current}]{} H_2 + O_2 \text{ (unbalanced)}$$

$$2H_2O = 2H_2 + O_2 \text{ (balanced)}$$

Example 2 : *Action of heat* on potassium nitrate.

This reaction gives potassium nitrite and oxygen.

$$\text{Potassium nitrate} \xrightarrow{\text{heat}} \text{Potassium nitrite} + \text{Oxygen}$$

$$KNO_3 \xrightarrow{\text{heat}} KNO_2 + O_2 \text{ (unbalanced)}$$

$$2KNO_3 = 2KNO_2 + O_2 \text{ (balanced)}$$

We have seen that decomposition reactions require energy either in the form of heat, light or electricity for breaking down the reactants. Reactions in which energy is absorbed are called **endthoermic** reactions.

Activity 6

- Take about 2g ferrous sulphate crystals in a dry boiling tube.
- Note the colour of ferrous sulphate crystals.
- Heat the boiling tube over the flame of a burner or spirit lamp.
- Observe the colour of the crystals after heating.

Have you noticed that the green colour of the ferrous sulphate crystals has changed ? You can also smell the characteristic odour of burning sulphur.

$$\underset{\text{Ferrous sulphate}}{2FeSO_4(s)} \xrightarrow{\text{heat}} \underset{\text{ferric oxide}}{Fe_2O_3(s)} + SO_2(g) + SO_3(g)$$

In this reaction you can observe that a single reactant breaks down to give simpler products. This is a decomposition reaction.

3. Displacement reaction

The type of chemical reaction in which a more reactive element displaces a less reactive element from its compound is called ***displacement reaction.***

Example 1 : When iron pieces are added to an aqueous solution of copper sulphate, iron being more reactive displaces copper from copper sulphate solution to produce ferrous sulphate. The blue colour of the solution gradually changes into pale green and a red deposit of copper is formed.

Iron + Copper sulphate (blue solution) $\longrightarrow$ Ferrous sulphate (pale green solution) + copper (red)

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

In this reaction, iron has displaced or removed another element, copper from copper sulphate solution.

Example 2 : When zinc pieces are added to dilute hydrochloric acid, zinc displaces hydrogen. As a result, zinc chloride and hydrogen gas are produced.

Zinc + Dil. Hydrochloric acid $\longrightarrow$ Zinc chloride + Hydrogen

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

Example 3 :

$$Zn(s) + CuSO_4(aq.) \longrightarrow ZnSO_4(aq.) + Cu(s)$$

Zinc is more reactive than copper, hence it displaces copper from its compounds.

4. Double decomposition reaction

The type of chemical reaction in which two compounds in solution state react with each other to form two new substances by exchanging their radicals is called ***double decomposition reaction.***

Example 1 : When sodium hydroxide solution and dilute hydrochloric acid are mixed they exchange their radicals and produce a salt sodium chloride and water.

Sodium hydroxide + Dil. hydrochloric acid $\longrightarrow$ Sodium chloride + Water

$$\underset{(aq.)}{NaOH} + \underset{(aq.)}{HCl} \longrightarrow NaCl + H_2O$$

Example 2 : An aqueous solution of barium chloride when mixed with dilute sulphuric acid produces a white insoluble solid barium sulphate and hydrochloric acid.

Barium chloride (aq.) + Sulphuric acid (aq.) $\rightarrow$ Barium sulphate (White ppt) + Hydrochloric acid (aq.)

$$\underset{(aq.)}{BaCl_2} + \underset{(aq.)}{H_2SO_4} \rightarrow \underset{(White\ ppt)}{BaSO_4} + \underset{(aq.)}{2HCl}$$

Note : • Aqueous solution is a solution of a substance obtained by dissolving it in water.

• A **precipitate** is an insoluble solid formed during a reaction when two solutions are mixed.

Activity 8

- Take about 3mL of sodium sulphate solution in a test tube.
- In another test tube, take about 3mL of barium chloride solution.
- Mix the two solutions.
- What do you observe ?

You will observe that a white substance, which is insoluble in water is formed. This insoluble substance formed is known as a precipitate. Any reaction that produces a precipitate can be called a precipitation reaction.

$$\underset{\text{Sodium sulphate}}{Na_2SO_{4(aq.)}} + \underset{\text{Barium chloride}}{BaCl_{2(aq.)}} \rightarrow \underset{\text{Barium sulphate}}{BaSO_{4(s)}} + \underset{\text{Sodium chloride}}{2NaCl_{(aq.)}}$$

The white precipitate of $BaSO_4$ is formed by the reaction of SO_4^{2-} and Ba^{2+}. The other product formed is sodium chloride which remains in the solution. Such reactions are called double displacement reaction.

RECAPITULATION

- All changes are classified into two broad types : physical changes and chemical changes.
- No new substance is formed during a physical change whereas new substance(s) is/are formed during a chemical change.
- A chemical change involves the transformation of original substance into an altogether new substance(s).
- A chemical reaction in which two or more substances (usually elements) combine to produce a new substance (usually a compound) is known as a combination reaction.
- A chemical reaction in which a substance (compound) breaks up to give two or more simpler substances (elements or compounds) is known as a decomposition reaction.
- A chemical reaction can be represented with the help of the symbols or the formulae of the elements and the compounds taking part in that reaction. This gives a chemical equation.
- A complete chemical equation represents the reactants, products and their physical states symbolically.
- The substances that react with each other are called reactants and they are represented on the left hand side of the equation. The substances that are formed as a result of the reaction are called products. They are represented on the right hand side of the equation.
- A chemical equation needs to be balanced to make it follow the law of the conservation of mass.
- The law of conservation of mass states that mass can be neither created nor destroyed, it can only be transformed from one form to another.
- A chemical equation gives both qualitative and quantitative information about reactants and products.
- There are four main types of chemical reactions; combination, decomposition, displacement and double decomposition reactions.
- Precipitation reactions produce insoluble substances.

EXERCISE – III

1. Explain the following reactions with one suitable example for each.
   (a) Combination reactions
   (b) Decomposition reaction
   (c) Displacement reaction
   (d) Double decomposition reaction
2. Name the type of chemical reaction shown by the following equations :
   (a) $CaCO_3 \rightarrow CaO + CO_2$
   (b) $2Mg + O_2 \rightarrow 2MgO$
   (c) $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$
   (d) $NaOH + HCl \rightarrow NaCl + H_2O$
   (e) $Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe$
3. Write your observations and name the products when
   (a) Zinc reacts with dilute hydrochloric acid
   (b) Iron nails are added to an aqueous solution of copper sulphate.
   (c) An aqueous solution of barium chloride is added to dilute sulphuric acid.
4. Why are decomposition reactions called the opposite of combination reactions ? Write equation for these reactions.
5. A solution of a substances 'X' is used for white washing.
   (a) Name the substance 'X' and write its formula.
   (b) Write the reaction of the substance 'X' named in (a) above with water.

OBJECTIVE TYPE QUESTIONS

1. Fill in the blanks :
   (a) In a chemical reaction ..... are rearranged.
   (b) The substances taking part in a chemical reaction are called .....
   (c) The melting of iron is a ..... change.
   (d) The burning of coal is a ..... change.
   (e) The substances formed as a result of a chemical reaction are called .....
2. Write **'true'** or **'false'** for the following statements :
   (a) A chemical reaction in which two or more substances combine to produce a single product is called decomposition reaction. .....
   (b) No new substance is formed during a physical change. .....
   (c) When iron and sulphur are heated together a grey mass is formed which is attracted by a magnet. .....
   (d) A black residue is formed when sugar is heated. .....
   (e) A chemical equation gives only qualitative information of a chemical reaction. .....

MULTIPLE CHOICE QUESTIONS

1. A chemical equation is a statement that describes a chemical change in terms of
   (a) symbols and formulae
   (b) energy
   (c) number of atoms
   (d) colours
2. Balancing a chemical equation is based on
   (a) Law of conservation of mass

(b) Mass of reactants and products
(c) Symbols and formulae
(d) None of the above

3. A catalyst is a substance which
(a) Speeds up the reaction
(b) Does not chemically change itself
(c) May decrease the speed of a reaction
(d) All of the above

4. Electrolysis of water is an example of
(a) Combination reaction
(b) Decomposition reaction
(c) Displacement reaction
(d) Double decomposition reaction

PROJECT ACTIVITY

- Take four beakers and label them as A, B, C and D.
- Put 25 mL of water in beakers A, B and C, and copper sulphate solution in beaker D.
- Measure and record the temperature of each liquid contained in the beakers above.
- Add two spatulas of potassium sulphate, ammonium nitrate, anhydrous copper sulphate and fine iron fillings to beakers A, B, C and D respectively and stir.
- Finally measure and record the temperature of each of the above mixtures.

Find out which reactions are exothermic and which ones are endothermic in nature.