Types of chemical reactions: Chemical reactions are of different types. Some of them are described here.

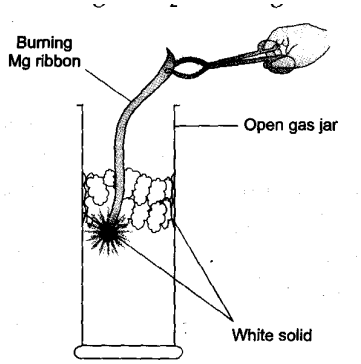
1. Combination Reactions: The reactions in which two or more substances combine to produce a single substance are known as combination reactions or synthesis reactions. This may be represented by: $x + y \rightarrow xy$

(a) When two elements combine to form a compound. Examples:

(i) Hydrogen combines with oxygen to form water. $2H_2 + O_2 \rightarrow 2H_2O$

(ii) When magnesium burns in air or oxygen, magnesium oxide is formed.

$2Mg + O_2 \rightarrow 2MgO$



(iii) Sodium combines with chlorine to form sodium chloride. $2Na + Cl_2 \rightarrow 2NaCl$

(b) When two or more compounds combine to form a new compound: In some combination reactions two or more compounds combine together to produce a new compound. **Examples:**

(i) Ammonia and hydrogen chloride combine together to form ammonium chloride. $NH_3 + HCl \rightarrow NH_4Cl$

(ii) Calcium oxide and carbon dioxide combine together to form calcium carbonate. $CaO + CO_2 \rightarrow CaCO_3$

(iii) When water is added slowly to some calcium oxide (quicklime) taken in a beaker, a vigorous reaction occurs with a hissing sound to form calcium hydroxide. A huge amount of heat is also liberated during the reaction.

$CaO + H_2O \rightarrow Ca(OH)_2 + heat$

The reaction is thus exothermic. The aqueous solution of calcium hydroxide is widely used for white washing walls. On the walls calcium hydroxide reacts with the carbon dioxide of air to form insoluble calcium carbonate.

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

(c) When one element and one compound combine to give a new compound

There are certain combination reactions in which an element combines with a compound to form a new compound. **Examples:**

(i) When oxygen combines with carbon monoxide, carbon dioxide is formed.

$2CO + O_2 \rightarrow 2CO_2$

(ii) When oxygen combines with sulphur dioxide, sulphur trioxide is formed.

$2SO_2 + O_2 \rightarrow 2SO_3$

2. Decomposition Reactions: The reactions in which a compound is broken down into two or more simpler substances are known as decomposition reactions. These reactions may be represented as $XY \rightarrow X + Y$. **Examples:**

(i) When calcium carbonate is heated, it decomposes to give calcium oxide and carbon dioxide. $CaCO_3 \rightarrow CaO + CO_2\uparrow$

CO_2 which comes out turns limewater milky.

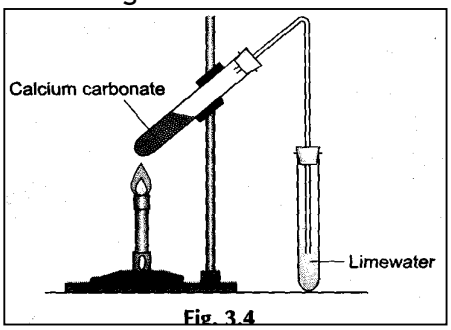


Fig. 3.4

(ii) When lead nitrate is heated, it breaks down into lead monoxide, nitrogen dioxide and oxygen. $2Pb(NO_3)_2 \rightarrow 2PbO + 4NO_2 + O_2$

The colourless lead nitrate becomes black due to the formation of lead monoxide (PbO). Brown fumes are observed due to the evolution of nitrogen dioxide.

(iii) When sodium hydrogen carbonate (baking soda) is heated strongly, baking soda gets decomposed into sodium carbonate, carbon dioxide and water.

$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

3. Electrolytic Decomposition: Some compounds like oxides and chlorides of metals are decomposed by passing electricity through them in their molten state. Water is also decomposed when electric current is passed through it. **Examples:**

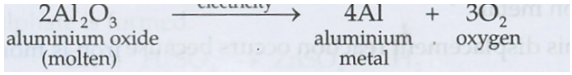
(i) When electric current is passed through water, it decomposes to produce hydrogen and oxygen. electricity $2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$

(ii) When an electric current is passed through molten sodium chloride, it decomposes to give sodium metal and chlorine gas.

$2NaCl \xrightarrow{\text{Electricity}} 2Na + Cl_2$

iii) Aluminium is also extracted from Al_2O_3 by passing electricity through molten $A1_2O_3$. $2Al_2O_3$ electricity $\rightarrow 4Al + 3O_2$

Uses of decomposition reactions:



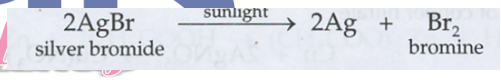
(i) Decomposition reactions are used to extract several metals from their oxides or salts. When the oxide or salt is electrolyzed, metal is obtained.

(ii) Digestion of food in our body is also a decomposition reaction. The food we eat contains carbohydrates and proteins. Carbohydrates get decomposed into glucose and proteins into amino acids inside our body.

4. Photochemical Decomposition: There are some reactions which take place in the presence of light. These are called photochemical reactions.

White silver chloride when exposed to sunlight gets decomposed into silver and chlorine.

Silver bromide behaves similarly.



Take a small amount of silver chloride on a watch glass and keep it in the sun. After some time you will find that white silver chloride has decomposed to give grey silver.

5. Single Displacement Reactions or Substitution Reactions

A reaction, in which an atom or a group of atoms present in a molecule is displaced by another atom, is known as displacement reaction.

(a) Displacement of less active metal by a more active metal: Examples:

(i) When a piece of iron is added to a solution of copper sulphate, iron displaces copper from copper sulphate. $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$

The blue colour of copper sulphate solution disappears due to the formation of $FeSO_4$, which is light green. A reddish coating of copper metal is deposited on the surface of iron metal. This displacement reaction occurs because iron is more reactive than copper.

(ii) When a strip of copper is added to a solution of silver nitrate, silver is displaced by copper. $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$

A shining deposit of silver is seen on the copper strip. This reaction occurs because copper is more reactive than silver.

(iii) When a piece of zinc is added to a solution of copper sulphate, zinc sulphate and copper are formed. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

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In this reaction, copper is displaced from copper sulphate by zinc because zinc is more reactive than copper. A reddish deposit of copper is observed on the zinc strip. The blue colour of copper sulphate disappears due to the formation of colourless zinc sulphate.

(b) Displacement of less active nonmetal from its compounds:

(i) When Cl_2 gas is passed through a solution of sodium bromide (NaBr), sodium chloride and bromine are formed. The solution becomes brown due to the liberation of bromine in solution. $2NaBr + Cl_2 \rightarrow 2NaCl + Br_2$

(ii) When Cl_2 gas is passed through a solution of potassium iodide, potassium chloride and iodine are produced. $2KI + Cl_2 \rightarrow 2KCl + I_2$

These reactions prove that chlorine is more reactive than bromine and iodine.

(c) Displacement of hydrogen from acids by active metals:

(i) When a piece of zinc is added to a dilute solution of sulphuric acid, hydrogen gas is evolved and zinc sulphate is formed. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$

Zinc can displace hydrogen from other acids also, such as hydrochloric acid (HCl), phosphoric acid (H_3PO_4) and acetic acid (CH_3COOH). This can be demonstrated by the following experiment:

- Take hydrochloric acid, phosphoric acid and acetic acid separately in three test tubes. Add equal pieces of zinc metal in each of the test tubes.
- What happens? It is seen that bubbles start coming out from each test tube. A burning splinter is brought near the mouth of the test tubes. The gas in each test tube burns with a bang. It is hydrogen gas coming out from the test tubes. Thus, hydrogen gas has been displaced from acids by zinc.

$$\underset{\text{zinc}}{Zn} + \underset{\text{hydrochloric acid}}{2HCl} \rightarrow \underset{\text{zinc chloride}}{ZnCl_2} + \underset{\text{hydrogen}}{H_2\uparrow}$$

$$3Zn + \underset{\text{phosphoric acid}}{2H_3PO_4} \rightarrow \underset{\text{zi1nc phosphate}}{Zn_3(PO_4)_2} + 3H_2\uparrow$$

$$Zn + \underset{\text{acetic acid}}{2CH_3COOH} \rightarrow \underset{\text{zinc acetate}}{(CH_3COO)_2Zn} + H_2\uparrow$$

6. Double Displacement Reactions: In a double displacement reaction, two compounds exchange their ions to form two new compounds. Such a reaction can be represented by a general equation. $XY + AB \rightarrow XB + AY$.

Here, X and A are the positive ions and Y and B are the negative ions of the two compounds. Such reactions are also called double decomposition reactions or metathesis reactions and occur in ionic compounds. Examples:

(i) When a solution of silver nitrate is added to a solution of sodium chloride, a white precipitate of silver chloride is formed along with sodium nitrate.

$NaCl + AgNO_3 \rightarrow AgCl\downarrow + NaNO_3$

(ii) When a solution of barium chloride is added to a solution of sodium sulphate, a white precipitate of barium sulphate is obtained; sodium chloride formed is left behind in solution. $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$

(iii) When ferrous sulphide reacts with sulphuric acid, a double displacement reaction takes place with the evolution of hydrogen sulphide gas; ferrous sulphate formed remains in solution.

$$\underset{\text{ferrous sulphide}}{FeS} + \underset{\text{sulphuric acid}}{H_2SO_4} \rightarrow \underset{\text{ferrous sulphate}}{FeSO_4} + \underset{\text{hydrogen sulphide}}{H_2S\uparrow}$$

(iv)When hydrogen sulphide gas is passed through a blue solution of copper sulphate, a black precipitate of copper sulphide is obtained;

$$\underset{\text{copper sulphate}}{CuSO_4} + \underset{\text{hydrogen sulphide}}{H_2S} \rightarrow \underset{\text{copper sulphide}}{CuS\downarrow} + \underset{\text{sulphuric acid}}{H_2SO_4}$$

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sulphuric acid formed remains in solution.

7. **Precipitation Reactions:** There are some chemical processes in which a solid gets separated from the solution. These processes are called precipitation reactions. The separated solid is called precipitate.

In the double displacement reaction between the solutions of sodium chloride and silver nitrate, silver chloride is obtained as a precipitate.

8. **Neutralization Reactions:** The process in which an acid reacts with a base to form a salt and water is known as neutralization reaction. In these reactions, the acid and the base neutralize the properties of each other.

$$\underset{\text{hydrochloric acid}}{HCl} + \underset{\text{sodium hydroxide}}{NaOH} \rightarrow \underset{\text{sodium chloride}}{NaCl} + \underset{\text{water}}{H_2O}$$

$$\underset{\text{sulphuric acid}}{H_2SO_4} + 2KOH \rightarrow \underset{\text{potassium sulphate}}{K_2SO_4} + \underset{\text{water}}{2H_2O}$$

9. **Oxidation—reduction Reactions:**

Oxidation is defined as:

(i) the addition of oxygen to an element or compound or (ii) the removal of hydrogen from a compound.

Examples:

(i) Calcium and oxygen combine to form calcium oxide. $2Ca+O_2 \rightarrow 2CaO$

Here, oxygen is added to calcium. Hence, this is oxidation.

(ii) Hydrogen chloride is oxidized to chlorine by the removal of hydrogen. $2HCl \rightarrow Cl_2$

Reduction is defined as (i) the addition of hydrogen to an element or compound or (ii) the removal of oxygen from a compound. Examples:

(i) Hydrogen is added to oxygen to form water. $2H_2 + O_2 \rightarrow 2H_2O$

Hence, this reaction is reduction.

(ii) Oxygen is removed from cupric oxide to form copper. $CuO + H_2 \rightarrow Cu + H_2O$

This is reduction as cupric oxide is reduced to copper.

Oxidizing agent: The substance which oxidizes elements or compounds is known as an oxidizing agent.

(i) Oxygen is an oxidizing agent. It oxidizes iron (Fe) to ferric oxide (Fe_2O_3).

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

(ii) Potassium permanganate solution is an oxidizing agent. It oxidizes ferrous sulphate to ferric sulphate.

Reducing agent: The substance which reduces compounds is known as a reducing agent.

(i) Hydrogen is a reducing agent. It reduces cupric oxide to copper (Cu).

$$\underset{\text{cupric oxide}}{CuO} + H_2 \rightarrow \underset{\text{copper}}{Cu} + H_2O$$

(ii) Stannous chloride is a reducing agent. It reduces ferric chloride to ferrous chloride.

$$SnCl_2 + 2FeCl_3 \rightarrow SnCl_4 + 2FeCl_2$$

Oxidation and reduction processes occur simultaneously. If a substance A oxidizes substance B then substance B reduces substance A. $A + B \rightarrow AB$

Such a reaction is called a redox reaction. Examples:

(i) When cupric oxide is heated with hydrogen, copper metal and water are formed. $CuO + H_2 \rightarrow Cu + H_2O$ In this reaction:

(a) Oxygen is added to hydrogen to produce water. Thus, hydrogen is oxidized to water. Cupric oxide gives oxygen for oxidation. Hence, cupric oxide is the oxidizing agent.

Oxygen is removed (reduction)

$$CuO + H_2 \rightarrow Cu + H_2O$$

Oxygen is added (oxidation)

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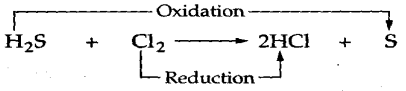
(b) Cupric oxide (CuO) changes into copper (Cu). Oxygen is, thus, removed from cupric oxide. Since removal of oxygen is reduction, cupric oxide is reduced to copper. Hydrogen removes this oxygen from cupric oxide. Hence hydrogen is the reducing agent.

(ii) The reaction between hydrogen sulphide and chlorine is an oxidation–reduction reaction.



Here, H_2S is oxidized to S because this process involves the removal of hydrogen from H_2S. On the other hand, Cl_2 is reduced to HCl because the process involves the addition of hydrogen to it. Hence, in this reaction H_2S is the reducing agent, whereas Cl_2 is the oxidizing agent.

10. Combustion Reactions or Burning: The reaction in which a substance combines with oxygen to produce heat and light is called combustion. Thus, combustion may be considered a fast oxidation reaction. Examples:

(i) When carbon burns in oxygen, carbon dioxide is produced with the emission of heat and light. $C + O_2 \rightarrow CO_2 + \text{heat} + \text{light}$

(ii) Burning of hydrocarbon (e.g., methane) in oxygen is also a combustion reaction. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{heat} + \text{light}$

(iii) Magnesium burns in oxygen to produce magnesium oxide accompanied with heat and light.

$$\underset{\text{magnesium}}{2Mg} + O_2 \rightarrow \underset{\text{magnesium oxide}}{2MgO} + \text{heat} + \text{light}$$

Explosion of a cracker, burning of a gas in a burner, burning of paper, etc., are other examples of combustion.

4. Respiration is a slow combustion reaction in which glucose present in our body cells combines with oxygen to provide energy. This energy is required by us to stay alive. Thus, respiration is an exothermic process.

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{energy}$$

Conditions for combustion: The conditions required for combustion are as follows.

1. **Combustible substance**: The essential condition for a substance to burn is that it must be combustible. For example, paper, kerosene, petrol, wood, dry grass, etc., are combustible substances. On the other hand, there are substances which do not catch fire at all. These substances are called noncombustible substances. Stone, glass, sand, etc., are noncombustible substances.

2. **Presence of oxygen**: The presence of oxygen is essential for combustion to occur. This is explained as: cover a piece of burning coal or wood with a vessel. Burning of coal or wood stops after some time. On covering the burning coal, the supply of oxygen is cut off. This burning coal stops burning soon after the oxygen already present within the vessel gets exhausted.

3. **Ignition temperature**: The minimum temperature to which a substance has to be heated before it can burn is known as the ignition temperature of the substance. Ignition temperature differs from substance to substance. Different forms of the same substance have different ignition temperatures. For example, wood shavings have a lower ignition temperature than that of a large piece of wood. So, a matchstick can light wood shavings but it cannot light a large piece of wood. This is because heat produced by the burning matchstick is sufficient to

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reach the ignition temperature of wood shaving, but insufficient to reach the ignition temperature of a block of wood.

The ignition temperature of white phosphorus is 308 K while that of red phosphorus is 533 K.

Similarly, when water is poured over a burning substance, water absorbs heat from the substance. This makes the temperature of the substance go below its ignition temperature. So, the burning of the substance stops.

When a water-filled paper cup is placed over a flame, the water gets heated but the cup does not burn. This is due to the fact that the water takes away the heat from the cup. So, the cup is not allowed to attain its ignition temperature.

Flames: It has been defined in different ways:

1. A flame is a zone in which chemical combination between gases takes place accompanied by the evolution of heat and light.
2. A flame consists essentially of a mass of intensely ignited gaseous matter.
3. A flame is the phenomenon produced at the surface where two gases meet and undergo combination with the evolution of heat and light.

There can be two kinds of flame.

(I) **Luminous**: A flame produced with the evolution of heat and light is called a luminous flame.

(ii) **Nonluminous**: A flame produced with the evolution of heat and very little light is called a nonluminous flame.

There are many cases of burning in which no flame is produced. For example, charcoal burns in air with the production of heat and light but practically without any flame. Iron burns in oxygen with scintillation but without any flame.

Note:

1. A burning solid does not produce flame unless vapour is produced. Only those solid or liquid fuels which produce vapour on heating, burn with a flame. For example, kerosene is a liquid fuel. It vaporizes on heating. So, it burns with a flame.
2. When the supply of oxygen is sufficient, the fuel burns completely, producing a blue flame. A blue flame does not produce much light, hence it is a nonluminous flame.
3. When the supply of oxygen is inadequate, the fuel burns incompletely, producing a yellow flame.

The candle flame: The inflammable matter in a candle is wax. The wax consists of solid compounds of carbon and hydrogen (or of hydrocarbons). When a candle is lighted, the wax melts and goes up into the wick and is converted into vapour. The vapour burns producing the candle flame. The flame of a candle is yellow and luminous. The yellow colour of the candle flame is due to the unburnt carbon particles present in the flame on account of incomplete combustion of wax in inadequate supply of oxygen.

Why a burning candle gives out light: A burning candle gives out light, i.e., it is luminous. This is chiefly because solid particles of carbon are present in the flame and they become incandescent when the candle burns.

Rancidity: Fresh food containing fats and oils smells and tastes pleasant. But when it becomes stale on long exposure to air, it smells/tastes unpleasant and is no longer fresh. It is said that the food has become rancid. This change in the food is

due to oxidation of fats and oils. Butter, ghee, boiled rice, etc., becomes rancid after prolonged exposure to air.

Food materials can be protected from being stale by keeping them out of contact with water/moisture and air. This can be done in several ways.

(i) Some substances called antioxidants may be added to prevent oxidation of the food.

(ii) Food materials may be kept at a very low temperature. In many homes refrigerators are used to protect food from being oxidized.

(iii) Food may be preserved in airtight containers.

(iv)Chips (e.g., potato chips) sold in the market come in packets filled with nitrogen gas.

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