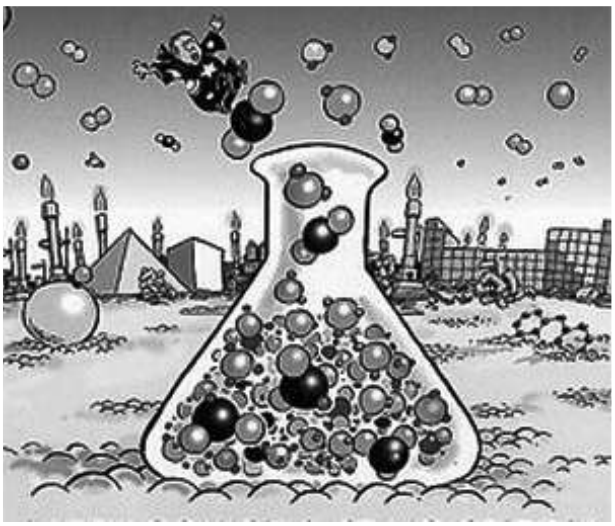
Chemical Reactions & Equations

Chapter Outline

- Physical Change
- Chemical Change
- Chemical Equation
- Balancing of Equation
- Types of Chemical Reaction
  - (a) Combination Reaction
  - (b) Decomposition Reaction
  - (c) Displacement Reaction
  - (d) Double Displacement Reaction
  - (e) Redox Reaction
- Rusting
- Rancidity



INTRODUCTION

Chemistry is defined as the branch of science which deals with the study of matter, dealing with the composition, structure, properties and changes occurring in matter.

Changes occurring in matter may be physical changes like melting of wax, freezing of water or may be chemical changes. In this chapter we will discuss chemical changes occurring in matter.

CHEMICAL REACTIONS

The process involving a chemical change is called a chemical reaction.

Process involved in chemical reactions :

During chemical reaction, a rearrangement of atoms takes place between the reacting substances to form new substances having entirely different properties. Chemical reactions involve breaking of chemical bonds present in the reactant molecules and forming new chemical bonds to give the products. Thus, a chemical reaction simply involves rearrangement of atoms.

The substances which take part in a chemical reaction are called reactants while the new substances produced as a result of chemical reaction are called products.

If the energy required to break the bond is less than the energy required to make the bond, then the additional energy is given out the surroundings. Such reactions are said to be exothermic. If the energy required to break the bond is more than the energy released in making the bond, then energy is taken up from the surroundings. Such reactions are said to be endothermic.

Few examples of chemical reactions in daily life :

(i) a piece of paper is burnt.
(ii) curdling of milk takes place.
(iii) rusting of an iron articles such as pan or nails takes place.
(iv) fermentation of grapes takes place.
(v) cooking of food is done.
(vi) digestion of food takes place in our body.
(vii) we respire.
(viii) burning of candle wax takes place.
(ix) burning of fuels like kerosene oil, petrol, LPG, etc. takes place.

Characteristics of Chemical Reactions :

There are some characteristics by which we can identify the occurrence of a chemical reactions. These are described below :

1. **Evolution of gas :** Some of the chemical reactions occur with the evolution of a gas or a mixture of gases. For example.
   (i) Metals like zinc, magnesium, iron, etc., react with dilute hydrochloric acid with the evolution of hydrogen gas.
   $Zn(s) + 2\,HCl\,(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
   (ii) When lead nitrate is heated, it gets decomposed to give a solid residue to lead monoxide with the evolution of nitrogen dioxide and oxygen gases.
   $\underset{\text{lead nitrate}}{2Pb(NO_3)_2\,(s)} \xrightarrow{\Delta} \underset{\text{lead monoxide}}{2PbO\,(s)} + \underset{\text{nitrogen dioxide}}{4NO_2\,(g)} + \underset{\text{oxygen}}{O_2\,(g)}$
   (iii) When calcium carbonate is treated with hydrochloric acid, gives calcium chloride with evolution of colourless and odourless gas carbon dioxide.
   $CaCO_3(s) + 2HCl\,(aq) \rightarrow CaCl_2(aq) + H_2O(\ell) + CO_2(g)$
   (iv) When carbon disulphide is treated with oxygen, it form Carbon dioxide and Sulphur dioxide.
   $CS_2(\ell) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$
2. **Formation of precipitate :** Sometimes, when two solutions are mixed together, a solid gets separated from the solution. The solid, thus, separated is called the precipitate.
   (i) When an aqueous solution of sodium sulphate is mixed with a solution of barium chloride, a white precipitate of barium sulphate is produced.
   $\underset{\substack{\text{sodium}\\\text{sulphate}}}{Na_2SO_4\,(aq)} + \underset{\substack{\text{barium}\\\text{chloride}}}{BaCl_2\,(aq)} \rightarrow \underset{\substack{\text{barium}\\\text{sulphate}}}{BaSO_4\,(s)} + \underset{\substack{\text{sodium}\\\text{chloride}}}{2NaCl\,(aq)}$
   (ii) When the aqueous solutions of lead acetate and potassium iodide are mixed, a yellow precipitate of lead iodide is produced.
   $\underset{\text{lead acetate}}{(CH_3COO)_2Pb\,(aq)} + \underset{\substack{\text{potassium}\\\text{iodide}}}{2KI(aq)} \rightarrow \underset{\text{lead iodide}}{PbI_2\,(s)} + \underset{\text{potassium acetate}}{2CH_3COOK}$

3. **Change in temperature :** Change in temperature is a necessary characteristic of a chemical reaction. On the basis of change in temperature, reactions are of two types -

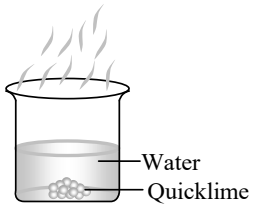
(a) Exothermic :

Exothermic reactions are those which are accompanied with release of energy.

For example :

(i) When quicklime (calcium oxide) is treated with water in a beaker, a large quantity of heat is produced. As a result, the beaker becomes very hot. Such reactions in which heat is produced are called exothermic reactions.

$$\underset{\text{calcium oxide}}{CaO\,(s)} + \underset{\text{water}}{H_2O\,(\ell)} \rightarrow \underset{\text{calcium hydroxide}}{Ca(OH)_2\,(aq)}$$



(ii) $\underset{\text{Methane}}{CH_4(g)} + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + \text{Energy}$

(iii) $\underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O + \text{Energy}$

(iv) $2Mg(s) + O_2(g) \rightarrow \underset{\text{Magnesium oxide}}{2MgO(s)} + \text{Heat}$

(b) Endothermic:

Endothermic reactions are those which are accompanied with absorption of energy.

For example :

(i) When ammonium chloride and barium hydroxide are mixed together in a test tube and the mixture is stirred with a glass rod, the bottom of the test tube becomes cold. In this reaction, heat is absorbed. Such a reaction is called an endothermic reaction.

$$\underset{\text{ammonium chloride}}{2NH_4Cl\,(aq.)} + \underset{\text{barium hydroxide}}{Ba(OH)_2\,(aq.)} \rightarrow \underset{\text{ammonium hydroxide}}{2NH_4OH\,(\ell)} + \underset{\text{barium chloride}}{BaCl_2\,(aq.)}$$

(ii) $N_2(g) + O_2(g) + \text{Heat} \rightarrow \underset{\text{Nitric oxide}}{2NO\,(g)}$

(iii) $2H_2O\,(\ell) \xrightarrow{\text{Electricity}} 2H_2\,(g) + O_2\,(g)$

4. **Change in colour :** In some chemical reactions a change in colour is observed.

For example :

(i) When lead nitrate (colourless) is made to react with potassium iodide (colourless), yellow coloured ppt of lead iodide is formed.

$$\underset{\substack{\text{Lead nitrate}\\\text{(colourless)}}}{Pb(NO_3)_2(aq)} + \underset{\substack{\text{Potassium iodide}\\\text{(colourelss)}}}{2KI(aq)} \rightarrow \underset{\substack{\text{Lead iodide}\\\text{Yellow ppt.}}}{PbI_2(s)} + \underset{\substack{\text{Potassium}\\\text{nitrate (colourless)}}}{2KNO_3(aq)}$$

(ii) When iron (grayish black) is left exposed to air for a long time, the outer surface of iron gets covered with a brown coating of rust.

$$\underset{\text{iron}}{2Fe(s)} + \frac{3}{2}\underset{\substack{\text{Oxygen}\\\text{(from air)}}}{O_2(g)} + x\underset{\substack{\text{Moisture}\\\text{(From air)}}}{H_2O(\ell)} \rightarrow \underset{\substack{\text{Hydrated ferric oxide}\\\text{(Rust)}}}{Fe_2O_3.xH_2O(s)}$$

5. **Physical state :** In some reactions the physical state of the product becomes different from that of the reactant.

For example :

(i) Magnesium ribbon (crystalline) is burnt it changes to white powder of magnesium oxide.

$$\underset{\text{Crystalline}}{2Mg(s)} + O_2(g) \rightarrow \underset{\text{Powder}}{2MgO(s)}$$

(ii) Coal burns to form carbon dioxide which is gaseous.

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

One or more of the above characteristics can certify that a chemical reaction is occurring.

Boost your knowledge

Catalysts are the substances which influence the rate of a chemical reaction and remain unchanged in amount and chemical composition at the end of the reaction.

CHEMICAL EQUATIONS

The method of representing a chemical reaction with the help of symbols and formulae of the substances involved in it is known as a **chemical equation**.

There are two ways of representing a chemical reaction :

(i) In terms of words (called word equation) : Zinc metal reacts with dilute sulphuric acid to form zinc sulphate and hydrogen gas. This reaction can be written in words as

Zinc + Dil. Sulphuric acid ⟶ Zinc sulphate + Hydrogen

This is known as the word equation.

(ii) In terms of symbols and formulae (called symbol equation) : By putting the symbols and formulae of all the substances in the above word equation, we get the following chemical equation.

$$\underbrace{Zn + H_2SO_4}_{\text{Reactants}} \longrightarrow \underbrace{ZnSO_4 + H_2}_{\text{Products}}$$

This is called a chemical equation.

Writing of a Chemical Equation :

To represent a chemical equation we write :

(i) The symbols and formulae of the reactants towards the left hand side (LHS) with plus sign between them.

(ii) The symbols and formulae of the products towards the right hand side (RHS) with plus sign between them.

(iii) An arrow (→) sign is put between the reactants and the products, pointing from reactants towards products.

Balanced and Unbalanced Chemical Equations :

A balanced chemical equation has equal number of atoms of different elements in the reactants and products.

For example,

Zinc + Sulphuric acid → Zinc sulphate + Hydrogen

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

$$\underbrace{Zn + H_2SO_4}_{\text{Reactants}} \longrightarrow \underbrace{ZnSO_4 + H_2}_{\text{Products}}$$

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, the above equation is a balanced chemical equation.

An unbalanced or skeletal equation is one in which the number of atoms of different elements (one or more) is not equal on the two sides of the equation.

For example :

Potassium chlorate → Potassium chloride + Oxygen

The above word equation may be represented as

$$KClO_3 \rightarrow KCl + O_2$$

Let us examine the number of atoms of different elements in the unbalanced equation.

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
K	1	1
Cl	1	1
O	3	2

As the number of atoms of K and Cl are equal on both sides but O-atoms are not equal on both sides, hence the above equation is unbalanced.

- **Balancing of a Chemical Equation :**
  Balancing of a chemical equation means making the number of each element equal on both sides of the equation.
- **Importance of a balanced chemical equation :** The importance of a balanced chemical equation lies in the fact that it satisfies the law of conservation of mass, i.e., in a chemical reaction, total mass of all the products is equal to the total mass of all the reactions.
- **Steps Involved in the Balancing of a Chemical Equation:**
  The balancing of a chemical equation involves in counting up the number of atoms of each element on both sides and trying to equalize them.
  The following steps are involved in the balancing of a chemical equations :

Step-I : To write the word equations : Write the chemical equation in the form of a word equations. Keep the reactants on left hand side (LHS) and the products on the right hand side (RHS). Separated them by an arrow (→) head of which points from the reactants towards the products.

Step-II : To write the skeletal chemical equation : Write down the symbols and formulae of the various reactants and products. This gives us the skeletal chemical equation.

Step-III : Enclose the formula of each reactant and product in a box. Do not change anything inside the boxes while balancing equation.

Step-IV : List the number of atoms of different elements on LHS (Reactants) and RHS (Products) in the unbalanced equation.

Step-V : Select the biggest formula to start balancing : It is often convenient to start balancing with the compound that contains the maximum number of atoms. It may be a reactant or a product.

Step-VI : To start balancing different elements : Having selected the compound with the biggest formula, first balance the element of this compound. Then balance other elements one by one. To balance the atoms of an element, put a whole number coefficient before the formula of the compound.

If selection of the biggest formula appears inconvenient, balance the atoms of that element which occurs at minimum number of places on both sides of the equation. Atoms of the element which occur at maximum places are balanced last of all.

Step-VII : To check the correctness of the balanced equation : Finally, to check the correctness of the balanced equation, count atoms of each element on both sides of the equation. If the number of atoms of elements on both sides of the equation are equal then the equation is balanced.

The method of balancing chemical equation is called **Hit** and **Trial Method** as we make trial to balance the equation by using the smallest whole number coefficient.

- **Examples to Illustrate Balancing of Equations by Hit and Trial Method :**

Ex.1 Combustion of methane in oxygen to form carbon dioxide and water.

Sol. **Step-I :** Writing the equation in word form :

Methane + Oxygen → Carbon dioxide + Water

Step-II : Writing the skeletal equation :

$CH_4 + O_2 \rightarrow CO_2 + H_2O$

Step-III : Selecting the element which occurs at minimum number of places, i.e. C or H.

No. of C-atoms is same on LHS & RHS.

No of H-atoms is 4 on LHS and 2 H-atoms of RHS. To balance H-atoms, multiply H_2O on RHS by 2, we get,

$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$

Step-IV : To balance O-atoms : There are 4 O-atoms on RHS and 2 O-atoms on LHS. To balance O-atoms, multiply O_2 on LHS by 2, we get,

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Step-V : To check the corrections of the balanced equation :

Element	Number of atoms on LHS	Number of atoms on RHS
C	1	1
H	4	4
O	4	4

Since, the number of atoms of each element on both sides of the equation is same, the equation is balanced.

Hence, the balanced equation is : $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Ex.2 Nitrogen and hydrogen combine to form ammonia.

Sol.Step-I : Writing the chemical equation in the word form : Nitrogen + Hydrogen → Ammonia

Step-II : Writing the skeletal chemical equation : $N_2 + H_2 \rightarrow NH_3$

Step-III : Balancing of atoms on both sides : There are 2 N-atoms on LHS and 1 N-atom on RHS. To balance N-atoms, multiply, NH_3 on RHS by 2 we get

$N_2 + H_2 \rightarrow 2NH_3$

Now, there are 6 H-atoms on RHS and 2 H-atoms on LHS. To balance H-atoms, multiply H_2 on LHS by 3, we get, $N_2 + 3H_2 \rightarrow 2NH_3$

Step-IV: To check the correctness of the balanced equations :

Element	Number of atoms of on LHS	Number of Atoms on RHS
N	2	2
H	6	6

Since, the number of atoms of each element is equal on both sides of the equation, it is balanced. Hence, the balanced equations is :

$N_2 + 3H_2 \rightarrow 2NH_3$

- **Limitations of a Chemical Equation :** It gives no information about the following :
  (i) The physical state of the reactants
  (ii) The concentration of the reactants.
  (iii) The conditions necessary to start and carry on the reaction e.g., is any catalyst required ?
  (iv) Is the reaction exothermic or endothermic, i.e., is heat evolved or absorbed during the reaction?
  (v) Reversibility or irreversibility of a reaction.
- **Modification Made for Improvement in Chemical Equations :**
  Several modifications are introduced for making chemical equation more informative and more useful.

(i) The physical states of reactants and products :

The physical state of the reactants and products are specified by putting letters 's' (for the solid state), 'ℓ' (for the liquid state) and 'g' (for the gaseous state) or 'aq' (for the aqueous solution) in parentheses just after the chemical formula of the reactant or the product which needs to be specified. Sometimes if a gas is evolved in a reaction it is shown by putting the symbol ($\uparrow$) of an arrow pointing upwards. Similarly if any precipitate is formed during the reaction, it is indicated by putting the symbol ($\downarrow$) of an arrow pointing downwards.

For example, $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$

$2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq.) + H_2\uparrow$

$AgNO_3(aq.) + NaCl(aq.) \rightarrow AgCl\downarrow + NaNO_3(aq.)$

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g)\uparrow + 2H_2O(g)$

$Ca(OH_2)(aq.) + CO_2(g) \rightarrow CaCO_3\downarrow + H_2O(\ell)$

$Zn(s) + 2HCl(aq.) \rightarrow ZnCl_2(aq.) + H_2(g)$

(ii) The concentration of an acid or a base :

The strength of an acid or a base solution is expressed by writing dil. for a dilute solution and conc. for a concentrated solution. For example,

$$Zn(s) + \underset{(dil.)}{H_2SO_4(aq.)} \rightarrow ZnSO_4(aq.) + H_2(g)$$

$$Cu(s) + \underset{(conc.)}{2H_2SO_4(aq.)} \rightarrow CuSO_4(aq.) + 2H_2O(\ell) + SO_2(g)$$

(iii) Favourable conditions of the reactions : The conditions at which a given reaction is made are mentioned on the arrow between reactants and products. For example,

$$N_2(g) + 3H_2(g) \xrightarrow[200atm]{(Fe+Mo),\,450^oC} 2NH_3(g)$$

This equation signifies that the nitrogen and hydrogen combines at 450ºC and 200 atmospheric pressure in the presence of a catalyst iron (Fe) and promoter molybdenum (Mo).

(iv) Heat changes in the reaction :

Exchange of heat takes place during chemical reactions and therefore heat evolved or absorbed in a chemical reaction should be represented accordingly with their unit.

Evolution of heat :

Reactants $\rightarrow$ Products + Heat

For example, $C(s) + O_2(g) \rightarrow CO_2(g) + 93.4$ kcal

$HCl(aq.) + NaOH(aq.) \rightarrow NaCl(aq.) + H_2O(\ell) + 57.1$ kJ

Absorption of heat :

Reactants $\rightarrow$ Products – Heat

For example, $C(s) + 2S(s) \rightarrow CS_2(\ell) - 22.0$ kcal

$N_2(g) + O_2(g) \rightarrow 2NO(g) - 180.5$ kJ

(v) Reversibility or irreversiblity of a reaction :

This can be represented by use of different arrows in the equation. Double headed ($\rightleftarrows$) or a double half headed ($\rightleftharpoons$) arrow is used for reversible while single headed ($\longrightarrow$) arrow is used for irreversible reactions.

Reversible reactions :

For example, $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

Irreversible reactions :

For example, $2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + H_2(g)$ or $H_2\uparrow$

$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3\downarrow + H_2O(\ell)$

TYPES OF CHEMICAL REACTIONS

The chemical reactions can broadly be classified into following types :

(1) Combination reactions,
(2) Decomposition reactions,
(3) Displacement reactions,
(4) Double displacement reactions,
(5) Redox reactions.

(1) Combination Reactions :

The chemical reaction involving combination of two or more reactants (elements or compounds) to form a single new product is called combination reaction.

Boost your knowledge

- A reaction made to obtain a product by using two or more elements is usually referred as synthesis of that compound.

Combination reaction like other reactions also involves the exchange of energy i.e., heat, light electricity, pressure or catalyst

e.g. A + B → AB (+ or – Energy)

Where, A and B are reactants while AB is the product

(A) Combination reaction between two elements-

(i) Hydrogen burns in an atmosphere of oxygen, to form water only.

$$\underset{\text{Hydrogen}}{2H_2(g)} + \underset{\text{oxygen}}{O_2(g)} \rightarrow \underset{\text{water}}{2H_2O(\ell)} + \text{heat}$$

(ii) Formation of CO_2 by burning carbon (coke or coal) in oxygen (of air).

$$\underset{\substack{\text{Carbon}\\(\text{Element})}}{C(s)} + \underset{\substack{\text{Oxygen}\\(\text{Element})}}{O_2(g)} \rightarrow \underset{\text{Carbondioxide}}{CO_2(g)} + \text{heat and light}$$

(iii) Combination of hydrogen and chlorine to form hydrogen chloride.

$$\underset{\text{Hydrogen}}{H_2} + \underset{\substack{\text{Chlorine}\\(\text{Element})}}{Cl_2} \xrightarrow{\text{Sunlight}} \underset{\text{Hydrogen Chloride}}{2HCl}$$

(iv) Combination of sulphur and oxygen to form sulphur dioxide

$$\underset{\substack{\text{Sulphur}\\(\text{Element})}}{S} + \underset{\substack{\text{Oxygen}\\(\text{Element})}}{O_2} \xrightarrow{\text{Heat}} \underset{\text{Sulphur dioxide}}{SO_2} + \text{heat}$$

(v) Burning of Mg ribbon in air to form MgO

$$\underset{(\text{Magnesium})}{2Mg} + O_2 \rightarrow \underset{(\text{Magnesium oxide})}{2MgO} + \text{heat and light}$$

(vi) Burning of sodium metal in chlorine to form sodium chloride

$$\underset{(\text{Sodium})}{2Na} + \underset{\text{Chlorine}}{Cl_2} \rightarrow \underset{(\text{Sodium chloride})}{2NaCl} + \text{heat}$$

(B) Combination reaction between a compound and an element-

(i) Combination of carbon monoxide and hydrogen to form methyl alcohol

$$\underset{\text{Carbon monoxide}}{CO} + \underset{\text{Hydrogen}}{2H_2} \xrightarrow[Zn+Cr_2O_3]{430^\circ C,\ 200 atm} \underset{\text{Methyl alcohol}}{CH_3OH} - \text{heat}$$

(ii) Combination of sulphur dioxide with oxygen to form sulphur trioxide

$$\underset{\text{sulphur dioxide}}{2SO_2} + O_2 \rightarrow 2SO_3\,(g) + \text{heat}$$

(iii) Combination of carbon monoxide with oxygen to form carbon dioxide (CO_2)

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g) + \text{heat}$$

(iv) Combination of carbon dioxide with carbon to form carbon monoxide

$$\underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Carbon}}{C(s)} \xrightarrow{\Delta} \underset{\text{Carbonmonoxide}}{2CO}$$

(v) Combination of nitric oxide and oxygen to form nitrogen dioxide.

$$\underset{\text{Nitricoxide}}{2NO(g)} + \underset{\text{Oxygen}}{O_2(g)} \rightarrow \underset{\text{Nitrogendioxide}}{2NO_2(g)}$$

(C) Combination reaction between two compounds-

(i) Dissolution of sulphur trioxide in water to form sulphuric acid.

$$\underset{\text{Sulphur trioxide}}{SO_3} + \underset{\text{Water}}{H_2O} \rightarrow \underset{\text{Sulphuric acid}}{H_2SO_4} + \text{heat}$$

(ii) Dissolution of quick lime in water to form lime water.

$$\underset{\text{Calciumoxide}}{CaO(s)} + H_2O \rightarrow \underset{\text{Calciumhydroxide}}{Ca(OH)_2(aq)} + \text{heat}$$

The lime water solution, when applied to the walls of building for white washing, reacts slowly with $CO_2(g)$ present in air and forms thin shining layer of $CaCO_3$ on the walls.

(ii) Combination of ammonia and chlorine to give ammonium chloride.

$$\underset{\text{ammonia}}{NH_3(g)} + \underset{\text{hydrogen chloride}}{HCl(g)} \rightarrow \underset{\text{ammoniumchloride}}{NH_4Cl(s)} + \text{heat}$$

(iv) Action of carbon dioxide on quick lime to form calcium carbonate.

$$\underset{\substack{\text{Calciumoxide}\\(\text{Quicklime})}}{CaO(s)} + \underset{\text{Carbondioxide}}{CO_2(g)} \rightarrow \underset{\text{Calciumcarbonate}}{CaCO_3(s)}$$

(v) Reaction between ammonia and sulhuric acid to form ammonium sulphate.

$$\underset{\text{Ammonia}}{2NH_3(g)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \rightarrow \underset{\text{Ammoniumsulphate}}{(NH_4)_2SO_4(aq)}$$

(2) Decomposition Reactions :

The chemical reaction in which a compound is broken up into two or more simpler substances (elements or compounds) is called a decomposition reaction.

$AB \rightarrow C + D + \ldots\ldots$

A single reactant AB decomposes to give simpler products like C, D etc.

Boost your knowledge

☛ **Analysis reaction or Break down :** Decomposition reactions in which a compound breaks down into its constituent elements, is called analysis reactions.

Ex. : $2H_2O(\ell) \xrightarrow{\text{Electricity}} H_2(g) + O_2(g)$

Decomposition reaction involves absorption of energy e.g. heat, light or electricity. Heat, light and electricity are different form of energy and causes breaking of bonds in the molecules of reactants to yield simpler products.

On the basis of form of energy which is supplied for decomposition, decomposition reactions can be classified as:

(A) Thermal decomposition :

The decomposition reactants involving absorption of heat are called thermal decomposition reactions.

(i) Thermal decomposition of mercuric oxide : Mercuric oxide on heating strongly decomposes to give mercury and oxygen.

$$\underset{\text{Mercuric dioxide}}{2HgO(s)} \xrightarrow{\text{Heat}} \underset{\text{Mercury}}{2Hg(\ell)} + \underset{\text{Oxygen}}{O_2(g)}$$

Experiment : Mercuric oxide a red coloured solid on heating decomposes to give shining droplets of mercury with the evolution of oxygen gas.

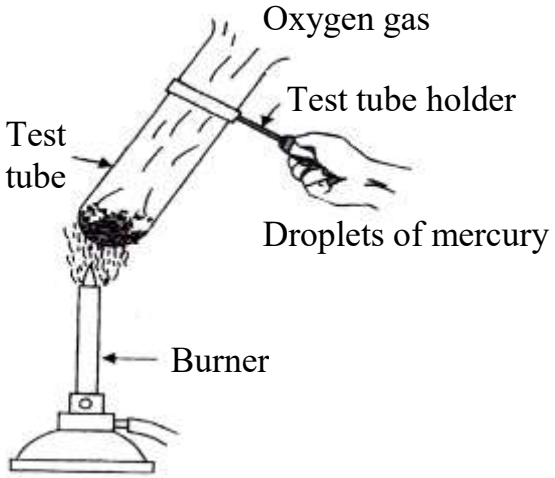


Fig. Heating of mercuric oxide

(ii) Thermal decomposition of calcium carbonate :

$$\underset{\text{Calcium carbonate (Lime stone)}}{CaCO_3(s)} \xrightarrow{\text{Heat}} \underset{\text{Calcium oxide}}{CaO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

(iii) Thermal decomposition of lead nitrate :

$$\underset{\text{Lead nitrate (Colourless)}}{2Pb(NO_3)_2} \xrightarrow{\text{Heat}} \underset{\text{Lead oxide (Yellow)}}{2PbO(s)} + \underset{\text{Nitrogen dioxide (Brown fumes)}}{4NO_2(g)} + \underset{\text{Oxygen}}{O_2(g)}$$

Experiment : About 2 gram of lead nitrate is taken in a hard glass test tube, holding it by a test tube holder and heat is over a burner. Brown fumes of nitrogen dioxide gas are noticed at the mouth of the test tube and lead oxide is left behind in the test tube in the form of a yellow solid.

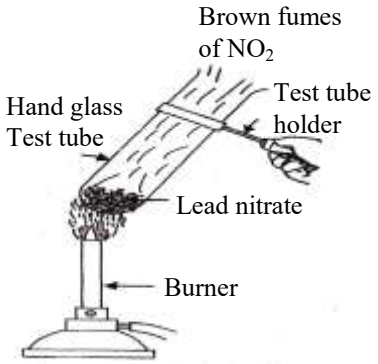


Fig. Thermal decomposition of lead nitrate

(iv) Thermal decomposition of ferrous sulphate : Ferrous sulphate on heating undergoes thermal decomposition to give ferric oxide, sulphur dioxide and sulphur trioxide changing it's green colour to brown along with smell of sulphur (SO_2 gas).

$$\underset{\text{Ferrous sulphate}}{2FeSO_4(s)} \xrightarrow{\text{Heat}} \underset{\text{Ferric oxide}}{Fe_2O_3(s)} + \underset{\text{Sulphur dioxide}}{SO_2(g)} + \underset{\text{Sulphur trioxide}}{SO_3(g)}$$

Experiment: Green crystals of ferrous sulphate are of ferrous sulphate heptahydrate ($FeSO_4.7H_2O$). About 2 gram of these crystals are heated in a tube over the flame of a burner. The green colour of the ferrous sulphate crystals first changes to white and then to brown solid (Fe_2O_3). A gas with smell of burning sulphur evolves from the mouth of the test tube.

(v) Thermal decomposition of potassium chlorate to potassium chloride and oxygen :

$$\underset{\text{Potassium chlorate}}{2KClO_3(s)} \xrightarrow{\Delta} \underset{\text{Potassium chloride}}{2KCl(s)} + 3O_2(g)$$

(B) Electrolytic Decomposition Reactions :

A chemical reaction involving decomposition of a compound by the passage of electric current (direct current) is called electrolytic decomposition. This phenomenon is also known as electrolysis.

(i) Electrolytic decomposition of water: On passing electric current through acidified water, decomposition of water yields hydrogen gas and oxygen gas.

$$2H_2O(\ell) \xrightarrow[(H_2SO_4)]{\text{Electric current}} 2H_2(g) + O_2(g)$$

Electrolytic decomposition of water to hydrogen and oxygen is also termed as Electrolysis of water.

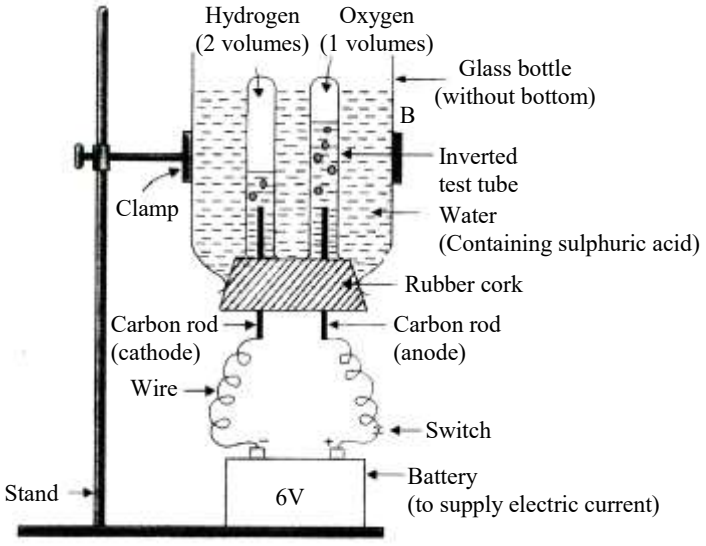


Fig. Electrolysis of acidified water

(ii) Electrolytic decomposition of alumina :

$$\underset{\text{Alumina (Fused)}}{2Al_2O_3(\ell)} \xrightarrow{\text{Electric current}} \underset{\text{Aluminium}}{4Al(s)} + \underset{\text{Oxygen}}{3O_2(g)}$$

(iii) Electrolysis of fused sodium chloride :

$$2NaCl\,(\text{fused}) \xrightarrow{\text{Electrolysis}} \underset{\text{Sodium}}{2Na(s)} + \underset{\text{Chlorine}}{Cl_2(g)}$$

(C) Photochemical Decomposition Reactions :

A chemical reaction involving decomposition by the action of light is called a photochemical decomposition reaction.

(i) Photochemical decomposition of silver chloride : Silver chloride on exposing to sunlight undergoes photochemical decomposition forming silver metal and chlorine gas.

$$\underset{\substack{\text{Silver chloride}\\(\text{White})}}{2AgCl(s)} \xrightarrow{\text{Sunlight}} \underset{\substack{\text{Silver metal}\\(\text{Grey})}}{2Ag(s)} + \underset{\substack{\text{Chlorine}\\(\text{Greenish yellow})}}{Cl_2(g)}$$

(ii) Photochemical decomposition of silver bromide : Silver bromide on exposing to sunlight also undergoes photochemical decomposition to give silver metal (grey) and bromine vapours (brown).

$$\underset{\substack{\text{Silver bromide}\\(\text{White})}}{2AgBr(s)} \xrightarrow{\text{Sunlight}} \underset{\substack{\text{Silver metal}\\(\text{Grey})}}{2Ag(s)} + \underset{\substack{\text{Bromine}\\(\text{Brown})}}{Br_2(g)}$$

3. Displacement Reactions :

The chemical reactions in which an element displaces some other element from a compound are called displacement reaction e.g.

$$AB + C \rightarrow AC + B$$

Where, an element C displaces another element B from the compound AB.

(i) **Displacement of copper by iron from copper sulphate solution :** A piece of iron if placed in aqueous copper sulphate solution, the former displaces copper from the later.

$$\underset{\text{Iron}}{Fe(s)} + \underset{\substack{\text{Copper sulphate}\\(\text{Deep blue solution})}}{CuSO_4(aq.)} \rightarrow \underset{\substack{\text{Iron sulphate}\\(\text{Light green solution})}}{FeSO_4(aq.)} + \underset{\text{Copper}}{Cu(s)}$$

The blue coloured solution of copper fades away due to formation of light green coloured ferrous sulphate solution.

(ii) $\underset{\text{Zinc}}{Zn(s)} + \underset{\substack{\text{Copper sulphate}\\(\text{Deep blue solution})}}{CuSO_4(aq.)} \rightarrow \underset{\substack{\text{Zinc sulphate}\\(\text{Colourless solution})}}{ZnSO_4(aq.)} + \underset{\text{Copper}}{Cu(s)}$

(iii) $\underset{\text{Iron}}{Fe(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq.)} \rightarrow \underset{\text{Iron(II) chloride}}{FeCl_2(aq.)} + \underset{\text{Hydrogen}}{H_2(g)}$

(iv) $\underset{\text{Lead}}{Pb(s)} + \underset{\text{Copper(II) chloride}}{CuCl_2(aq.)} \rightarrow \underset{\text{Lead chloride}}{PbCl_2(aq.)} + \underset{\text{Copper}}{Cu(s)}$

(v) $\underset{\text{Chlorine}}{Cl_2(g)} + \underset{\text{Potassium iodide}}{2KI(aq.)} \rightarrow \underset{\text{Potassium chloride}}{2KCl(aq.)} + \underset{\text{Iodine}}{I_2(s)}$

(vi) $\underset{\text{Copper}}{Cu} + \underset{\text{silver nitrate}}{2AgNO_3(aq.)} \rightarrow \underset{\text{copper nitrate}}{Cu(NO_3)_2(aq.)} + \underset{\text{silver}}{2Ag(s)}$

Boost your knowledge

The displacement of an element by some other element is related to activity of metal expressed in terms of activity series or electrochemical series.

4. Double displacement Reactions :

The chemical reactions involving two compounds reacting together and forming two new compounds by exchanging one of their ion is called a double displacement reaction.

$AB + CD \rightarrow AD + CB$

Two compounds AB and CD react together to from two new compounds AD and CB due to mutual exchange of ions. The ion A^+ of AB combines with ion D^- of CD to form a new compound AD. Similarly, the ion C^+ of CD combines with B^- of AB to form another new compound CB.

(A) The double displacement reactions involving the formation of a precipitate are also called precipitation reactions.

(i) **Reaction of silver nitrate with sodium chloride :**

$$AgNO_3(aq.) + NaI\ (aq.) \rightarrow AgI\ (s) \downarrow + NaNO_3\ (aq.)$$

(ii) $\underset{\text{Barium chloride}}{BaCl_2(aq)} + \underset{\text{Sodium sulphate}}{Na_2SO_4(aq.)} \rightarrow \underset{\substack{\text{Barium sulphate}\\(\text{white ppt.})}}{BaSO_4 \downarrow} + \underset{\text{Sodium Chloride}}{NaCl(aq.)}$

(iii) $\underset{\text{lead nitrate}}{Pb(NO_3)_2(aq.)} + \underset{\text{Potassium iodide}}{2KI(aq.)} \rightarrow \underset{\substack{\text{lead iodide}\\(\text{yellow ppt.})}}{PbI_2 \downarrow} + \underset{\text{potassium nitrate}}{2KNO_3(aq.)}$

(iv) $\underset{\text{Chromium chloride}}{CrCl_3(aq.)} + \underset{\text{Ammonium hydroxide}}{3NH_4OH(aq.)} \rightarrow \underset{\substack{\text{Chromium hydroxide}\\(\text{Green ppt})}}{Cr(OH)_3 \downarrow} + \underset{\text{Ammonium chloride}}{3NH_4Cl(aq.)}$

(v) $\underset{\text{Ferric chloride}}{FeCl_3(aq.)} + \underset{\text{Ammonium hydroxide}}{3NH_4OH(aq.)} \rightarrow \underset{\substack{\text{Ferric hydroxide}\\(\text{Yellow ppt})}}{Fe(OH)_3 \downarrow} + \underset{\text{Ammonium chloride}}{3NH_4Cl(aq.)}$

(vi) $\underset{\text{Barium chloride}}{BaCl_2(aq.)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq.)} \rightarrow \underset{\substack{\text{Barium sulphate}\\(\text{white ppt.})}}{BaSO_4(s) \downarrow} + \underset{\text{Hydrochloric acid}}{2HCl(aq)}$

(B) Double displacement reactions involving acids and bases are called neutralization reactions.

(i) $\underset{\substack{\text{Hydrochloric acid}\\(\text{Acid})}}{HCl(aq.)} + \underset{\substack{\text{Sodium hydroxide}\\(\text{Base})}}{NaOH(aq.)} \rightarrow \underset{\substack{\text{Sodium chloride}\\(\text{Salt})}}{NaCl(aq.)} + H_2O(\ell)$

(ii) $\underset{\substack{\text{Ethanoic acid}\\(\text{Acid})}}{CH_3COOH\ (aq.)} + \underset{\substack{\text{Potassium hydroxide}\\(\text{base})}}{KOH\ (aq.)} \rightarrow \underset{\substack{\text{Potassium acetate}\\(\text{salt})}}{CH_3COOK\ (aq.)} + H_2O(\ell)$

(iii) $\underset{\substack{\text{Sulphuric acid}\\(\text{Acid})}}{H_2SO_4(aq.)} + \underset{\substack{\text{Potassium hydroxide}\\(\text{base})}}{2KOH(aq.)} \rightarrow \underset{\substack{\text{Potassium sulphate}\\(\text{salt})}}{K_2SO_4(aq.)} + H_2O(\ell)$

(iv) $\underset{\substack{\text{Nitric acid}\\(\text{Acid})}}{HNO_3\ (aq.)} + \underset{\substack{\text{Ammonium hydroxide}\\(\text{base})}}{NH_4OH\ (aq.)} \rightarrow \underset{\substack{\text{Ammonium nitrate}\\(\text{salt})}}{NH_4NO_3\ (aq.)} + H_2O(\ell)$

5. Oxidation – Reduction Reactions : (Redox Reaction) :

The reactions in which oxidation and reduction occur simultaneously are called redox reactions. There are various concepts of oxidation and reduction.

(A) Oxidation and reduction in terms of gain or loss of oxygen or hydrogen :

Oxidation is defined as a process which involves :

(i) gain of oxygen.

Ex. $\underset{\substack{\text{Copper}\\(\text{Reddishbrown})}}{2Cu(s)} + \underset{\substack{\text{Oxygen}\\(\text{from air})}}{O_2(g)} \xrightarrow{\Delta} \underset{\substack{\text{Copper(II) oxide}\\(\text{Black})}}{2CuO(s)}$

(ii) loss of hydrogen

Ex. $2HCl(\ell) \longrightarrow H_2(g) + Cl_2(g)$

Reduction is defined as a process which involves :

(i) gain of hydrogen.

Ex. $H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$

(ii) loss of oxygen.

Ex. $2H_2O(\ell) \xrightarrow{\text{Electricity}} 2H_2(g) + O_2(g)$

(B) Oxidation and reduction in terms of gain or loss of electronegative or electropositive substance :

Oxidation is defined as a process which involves:

(i) Gain of electronegative substance

$2Fe + 3Cl_2 \rightarrow 2FeCl_3$

$SnCl_2 + Cl_2 \rightarrow SnCl_4$

(ii) Loss of electropositive substance

$2KI + Cl_2 \rightarrow 2KCl + I_2$

$2NaBr + Cl_2(g) \rightarrow 2NaCl + Br_2(g)$

Reduction is defined as a process which involves:

(i) Gain of electropositive substance

$Cl_2 + Mg \rightarrow MgCl_2$

$I_2 + Hg \rightarrow HgI_2$

(ii) Loss of electronegative substance

$2FeCl_3 \rightarrow 2FeCl_2 + Cl_2$

$FeS \rightarrow Fe + S$

Oxidizing and reducing agents : A substance which helps the other substance to undergo oxidation is called an oxidizing agent. Similarly, a substance which helps the other substance to undergo reduction is called a reducing agent.

(i) $\underset{(\text{Oxidising agent})}{SO_2(g)} + \underset{(\text{Reducing agent})}{2H_2S(g)} \rightarrow 2H_2O + 3S(s)$

(ii) $\underset{(\text{Reducing agent})}{4Na(s)} + \underset{(\text{Oxidising agent})}{O_2(g)} \rightarrow 2Na_2O(s)$

(iii) $\underset{(\text{Oxidising agent})}{2PbO(s)} + \underset{(\text{Reducing agent})}{C(s)} \rightarrow 2Pb(s) + CO_2(g)$

(iv) $\underset{(\text{Oxidising agent})}{MnO_2(s)} + \underset{(\text{reducing agent})}{4HCl(aq.)} \rightarrow MnCl_2\,(aq.) + 2H_2O + Cl_2(g)$

(v) $\underset{(\text{Oxidising agent})}{KMnO_4(aq.)} + \underset{(\text{Reducing agent})}{5H_2C_2O_4} + 3H_2SO_4(aq.) \rightarrow K_2SO_4(aq.) + 8H_2O + 10CO_2(g)\uparrow$

OXIDATION AND REDUCTIONS IN DAY-TO-DAY LIFE

Redox changes are important reactions which influence our day-to-day life in several ways. Some of its examples such as burning of fuels, digestion of food in our body etc. are boon to mankind and are very helpful in sustaining life. On the other hand, some of its effect are quite damaging also e.g. burning of fuels causing air pollution, rancidification of food, corrosion of metals etc.

◈ **Useful Effects of Oxidation :**

1. Combustion Reactions :

Kerosene, coal, charcoal, wood etc. burn in air and undergo combustion. Methane (CH_4) a major constituent of natural gas undergoes combustion in excess of oxygen upon heating.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$

Methane

Similarly, butane (C_4H_{10}) a main constituent of L.P.G. also undergoes combustion.

$$C_4H_{10}(g) + \frac{13}{2}O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$$

Butane

All combustion reactions are exothermic and redox reactions in nature and release heat energy. The human body may be regarded as a furnace or machine to which various food stuffs that we eat undergo combustion or oxidation. The heat energy evolved keeps our body working. Carbohydrates such as glucose, fructose, starch etc, are the major source of energy to the human body. They undergo combustion with the help of oxygen that we inhale to form carbon dioxide and water. For example.

$C_6H_{12}O_6\,(s) + 6O_2\,(g) \rightarrow 6CO_2\,(g) + 6H_2O\,(\ell)$ + energy

All combustion reactions are not accompanied by flame. Combustion is basically oxidation accompanied with release of energy.

2. **Respiration** is the most important biochemical reaction which releases energy in the cells. When we breathe in air, oxygen enters in our lungs and passes into thousands of smalls air sacs (alveoli). These air sacs occupy a large area of membranes and oxygen diffuses from the membranes into blood. It binds itself to haemoglobin present in red blood cells and is carried to millions of cells in the body. Respiration occurs in these cells and is accompanied by the combustion of glucose producing carbon dioxide and water. Since the reaction is exothermic, the energy released during respiration carry out many cell reactions and also keeps our heart and muscles working. It also provides the desired warmth to the body. Both carbon dioxide and water pass back into the blood and we ultimately breathe them out. Respiration takes place in the cells of all living beings.

Harmful effects of oxidation :

1. **Corrosion :** Some metals on exposure to a certain environment may get deteriorated due to its reaction with the environment and its surface may become rough and tarnished.
   "The process of slowly eating up of the metals due to attack of atmospheric gases such as oxygen, carbon dioxide, hydrogen sulphide, water vapour etc. on the surface of the metals so as to convert the metal into oxide, carbonate, sulphide etc. is known as **corrosion**."
   Corrosion is basically an electrochemical phenomenon. The corrosion is defined as the process of slow oxidation of metals into their undesirable compounds (usually oxides) by the action of moisture and other gases present in atmosphere.
   For Example :

(i) When we open the bonnet of a car after a long time, we find a deposit around the terminals of the battery. This is an example of corrosion.

$$Cu(s) + 2H_2SO_4(\ell) \rightarrow CuSO_4(aq) + 2H_2O(\ell) + SO_2(g)$$

(ii) Black coating on the surface of silver due to the formation of Ag_2O and Ag_2S.

$$2Ag(s) + H_2S(g) \rightarrow \underset{\text{Black}}{Ag_2S(s)} + H_2(g)$$

(iii) Green layer on the surface of copper terminals of battery due to the formation of basic copper carbonate are the examples of corrosion.

$$2Cu(s) + \underset{\text{from air}}{CO_2(g) + O_2(g)} + H_2O(\ell) \rightarrow \underset{\substack{\text{Green}\\ \text{basic copper carbonate}}}{CuCO_3.Cu(OH)_2(s)}$$

Rusting : In case of iron, corrosion is called rusting. Rust is hydrated ferric oxide. $Fe_2O_3 . xH_2O$, brown in colour and is formed by the chemical action of moist air (containing O_2 and H_2O) on iron. It is basically an oxidation reaction and is very slow and once started keeps on going.
Rust is formed by the combined action of air, water and carbon dioxide on iron. The formation of rust involves a redox process and can roughly be described by the following equation :

$$\underset{\text{iron}}{2Fe(s)} + \frac{3}{2}\underset{\substack{\text{Oxygen}\\ \text{(from air)}}}{O_2(g)} + x\underset{\substack{\text{Moisture}\\ \text{(From air)}}}{H_2O(\ell)} \rightarrow \underset{\substack{\text{Hydrated ferric oxide}\\ \text{(Rust)}}}{Fe_2O_3 . xH_2O(s)}$$

Corrosion is not a desired phenomenon because it tarnishes metals and reduces their strength. Both corrosion and rusting are very harmful and cause damage to the building, railway tracks, cars and other objects materials where metals are used. Corrosion causes damage to iron railings, bridges, ships, car bodies and to all objects made of metal, particularly those of iron.

2. **Rancidity :** Oxidation has damaging effect on our food and eatables.
   The foodstuffs containing fats and oils on storing for a long time, develop unpleasant smell and bad taste due to aerial oxidation of fats and oils. This phenomenon of slow aerial oxidation of fat and oils leading to unpleasant smell and bad taste in them is called 'rancidity' and such fats and oils are said to be rancid'.
   The rancid fats and oils give unpleasant smell and bad taste and therefore rancid foodstuffs should not be used as they become harmful to human body.

◆ **Rancidity may be prevented :**

(i) By using antioxidants : Manufacturers of food stuffs, sometimes add certain food additives to food material. These substances called antioxidants and prevent oxidation of food stuffs. Butylated hydroxyl toluene (BHT) and butylated hydroxyl anisole (BHA) are commonly used as antioxidants.

(ii) By using nitrogen during packaging : Rancidity is caused by the aerial oxidation of fats and oils during storage and thus, if foodstuffs containing fats and oils are placed in absence of air by replacing air using nitrogen atmosphere, they do not get rancid and remains good to eat for a longer period of time. Nitrogen is chemically inert under normal conditions and does not cause oxidation and hence rancidity is prevented. Therefore manufacturing of bags of chips and other eatables are usually packed in nitrogen atmosphere to prevent them from getting oxidised.

(iii) Keeping the food in refrigerators : At low temperature oxidation of fats and oils becomes very slow.

(iv) Keeping the food in air tight containers.

(v) Preventing exposure of food to light.