Chemical Reactions & Equations
Introduction of Chemical Reactions n Equations

INTRODUCTION:

Chemistry is defined as that branch of science which deals with the composition and properties of matter and the changes that matter undergone by various interactions. A chemical compound is formed as a result of a chemical change and in this process different type of energies such as heat, electrical energy, radiation etc. are either absorbed or evolved. The total mass of the substance remains the same throughout the chemical change.

CHEMICAL ACTION OR REACTION:

When a chemical change occurs, a chemical action is said to have taken place. A chemical change or chemical action is represented by a chemical equation. The matter undergoing change in known as reactant and new chemical component formed is known as product.

(a) Characteristics of a Chemical Reaction:

When we heat sugar crystals they melt and on further heating they give steamy vapour, leaving behind brownish black mass. On cooling no sugar crystals appears. Thus change which takes place on heating sugar is a chemical change and the process which brings about this chemical change is called chemical reaction.

- In this reaction the substance which take part in bringing about chemical change are called reactants.
- The substance which are produced as a result of chemical change are called products.
- These reactions involve braking and making of chemical bonds.
- Product(s) of the reaction is/are new substances with new name(s) and chemical formula.
- It is often difficult or impossible to reverse a chemical reaction.
- Properties of products formed during a chemical reaction are different from thos of the reactants.
- Apart from heat other forms of energies are light and electricity which are also used in carrying out chemical changes.

In all chemical reactions, the transformation from reactants to products is accompanied by various characteristics, which are-

(i) Evolution of gas: Some chemical reactions are characterized by evolution of a gas.

- When zinc metal is treated with dilute sulphuric acid, hydrogen gas is evolved. The hydrogen gas burns with a pop sound.

$$Zn\ (s) + H_2SO_4\ (\text{dilute}) \rightarrow ZnSO_4\ (aq) + H_2(g)$$

- When washing soda is treated with hydrochloric acid, it gives off colorless gas with lots of effervescence.

$$Na_2CO_3(s) + 2HCI \rightarrow 2NaCI\ (aq) + H_2O(I) + CO2(g)$$

- $2NaNCO_3\ (s) \xrightarrow{\text{heat}}$ $Na_2SO_3\ (s)$ + $H_2O\ (\ell)$ + $CO_2\ (g)$

Sodium hydrogen carbonate — Sodium carbonate — Water — Carbon dioxide

(ii) Change of colour: Certain chemical reactions are characterized by the change in colour of reacting substance.

- When red lead oxide is heated strongly it forms yellow coloured lead monoxide and gives off oxygen gas.

$$2Pb_3O_4\ (s) \xrightarrow{\text{heat}} 6PbO(s) + O_2(g)$$

Lead oxide (Red) — Lead monoxide (Yellow)

- When copper carbonate (green) is heated strongly it leaves behind a black residue.

$$CuCO_3\ (s) \xrightarrow{\text{heat}} CuO(s) + CO_2\ (g)$$

Copper carbonate (Green) — Copper oxide (Black) — Carbon dioxide

- $2Pb(NO_3)_2(s) \xrightarrow{heat} 2\,PbO(s) + 4NO_2\,(g) + O_2\,(g)$

  Lead (II) nitrate (White) → Lead (II) oxide (Yellow) + Nitrogen dioxide (Brown)

- $C_{12}H_{22}O_{11}\,(s) \xrightarrow{heat} 12C(s) + 11H_2O$

  White sugar → Carbon Black + Water

(iii) Formation of precipitate : Some chemical reactions are characterized by the formation of precipitate (an insoluble substance), when the solutions of the soluble chemical compounds are mixed together.

- When silver nitrate solution is mixed with a solution of sodium chloride.

$AgNO_3\,(aq) + NaCl\,(aq) \longrightarrow NaNO_3\,(aq) + AgCl\,(s)$

Silver nitrate (Colourless) + Sodium chloride (Colourless) → Sodium nitrate (Colourless) + Silver chloride (White precipitate)

- A dirty green precipitate of ferrous hydroxide is formed, when a solution of ferrous sulphate is mixed with sodium hydroxide solution.

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

Ferrous sulphate (Light green) + sodium hydroxide (Colourless) → Sodium sulpahte (Colourless) + Ferrous hydroxide (Dirty green precipitate)

$BacI_2\,(aq) + dill\ H_2SO_4 \longrightarrow BaSO_4\,(s) + 2HCI\,(aq)$

Barium chloride + Barium sulphate → (White precipitate)

(iv) Energy changes : all chemical reactions proceed either with the absorption or release of energy.

One the basis of energy changes, there are two types of reactions:

(A) Endothermic reaction : A chemical reaction which is accompanied by the absorption of heat energy is called an endothermic reaction.

$$C\,(s) + 2S\,(s) \xrightarrow{\text{Heat}} CS_2\,(\ell)$$

● Light energy is essential for biochemical reaction, photosynthesis, by which green plants prepare their food from carbon dioxide & water.

(B) Exothermic reaction: A chemical reaction which is accompanied by the release of heat energy is called exothermic reaction.

When magnesium wire is heated from its tip in a bunsen flame, it catches fire and burns with a dazzling white flame with release of heat and light energy.

$$2Mg\,(s) + O_2\,(g) \xrightarrow{\text{Heat}} 2MgO\,(s) + \text{Energy}$$

● When quick lie (calcium oxide) is placed in water, the water becomes very hot and sometimes starts boiling. It is because of release of heat energy during the reaction.

$$CaO\,(s) + \quad H_2O \longrightarrow Ca(OH)_2\,(aq) + \quad \text{Heat energy}$$

Calcium oxide Water Calcium hydroxide

(v) Change of state: Some chemical reactions are characterised by a change in state i.e. solid, liquid or gas

● Two volumes of hydrogen gas react with one volume of oxygen gas to from water.

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

or when electric current is passed through water it splits into its elements.

$$2H_2O\,(\ell) \xrightarrow{\text{Electric current}} 2H_2(g) + \quad O_2\,(g)$$

- NH_3 (g) + HCI (g) $\longrightarrow$ NH_4CI (s)

  Ammonia Hydrochloric acid Ammonium Chloride

CHEMICAL EQUATIONS :

All chemical changes are accompanied by chemical reactions. These reactions can be described in sentence form, but the description would be quite long. Chemical equations have been framed to describe the chemical reactions.

A chemical equation links together the substance which react (reactants) with the new substances that are formed (products).

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

(Reactants) (Products)

- **A Chemical reaction can be summarized by chemical equation.**

(a) Types of Chemical Equations :

(i) Word equations: A word equation links together the names of the reactants with those of the products. For example, the word equation, when magnesium ribbon burns in oxygen to form a white powder of magnesium oxide, may be written as follows-

Magnesium + Oxygen $\longrightarrow$ Magnesium oxide

(Reactants) (Product)

Similarly, the word equation for the chemical reaction between granulated zinc and hydrochloric acid may be written as -

Zinc + Sulphuric acid $\rightarrow$ Zinc sulphate + Hydrogen

In a word equation

- The reactants are written on the left-hand side with a plus sign (+) between them.
- The products are written on the right-hand side with a plus sign (+) between them.
- An arrow ($\rightarrow$) separates the reactants from the products.
- The direction of the arrow head points towards the product.

➢ **Although word equations are quite useful, yet they don't give the true picture of the chemical reactions.**

(ii) Symbol equation : A brief representation of a chemical reaction in terms of symbols and formulae of the substance involved is known as a symbol equation.
In a symbol equation, the symbols and formulae of the elements and compounds are written instead of their word names.

For e.g. Burning of magnesium in oxygen to form magnesium oxide may be written as follows :

$$Mg + O_2 \longrightarrow MgO$$

➢ Symbol equations are always written from the word equations.

(b) Unbalanced and Balanced Chemical Equations:

In an unbalanced equation, the number of atoms of different elements on both side of the equation are not equal. For example, in the equation given below, the number of Mg atoms on both sides of the equation is one (same), but the number of oxygen atoms are not equal, It is known as an unbalanced equations.

$$Mg + O_2 \longrightarrow MgO$$

➢ **An unbalanced equation is also called skeletal equation.**

In a balanced equating, the number of different elements on both sides of the equation are always equal. The balanced equation for the burning of magnesium ribbon in oxygen is written as -

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

(i) Importance of balanced chemical equation: The balancing of a chemical equation is essential or necessary to fulfill the requirement of "Law of conservation of mass".

(ii) Balancing of chemical equations: Balancing of chemical equations may be defined as the process of making the number of different types of elements, on both side of the equations, equal.

The balancing of a chemical equation is done with the help of **Hit and Trial method. In this method,** the coefficients before the symbols or formulae of the reactants and products are adjusted in such a way that the total number of atoms of each element on both the side of the arrow head become equal. This balancing is also known as mass balancing because the atoms of elements on both side are equal and their masses will also be equal.

The major steps involved in balancing a chemical equation are as follow –

- Write the chemical equations in the form a word equations. Keep the reactants on the left side and the products on the right side. Separate them by an arrow whose head $(\rightarrow)$ points from the reactants towards the product.
- Convert the word equation into the symbol equation by writing the symbols and formulae of all the reactants and product.
- Make the atoms of different elements on both side of the equation equal by suitable method. This is known as balancing of equation.
- Do not change the formulae of the substance while balancing the equation.
- Make the equations more informative if possible.

Example :

(1) Zinc reacts with dilute sulphuric acid to give zinc sulphate and hydrogen.

Solution :

The word equation for the reaction is -

Zinc + Sulphuric acid $\rightarrow$ Zinc sulphate + Hydrogen

The symbol equation for the same reactions is -

$$Z\,n + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

Let us count the number of atoms of all the elements in the reactants and products on both sides for the equations.

Element (L.H.S.)	No. of atoms of reactants (R.H.S.)	No. of atoms of products
Zn	1	1
H	2	2

S	1	1
O	4	4

As the number of atoms of the elements involved in the reactants and products are equal, the equation is already balanced.

(2) Iron reacts with water (steam) to form iron (II, III) oxide and liberates hydrogen gas.

Solution :-

The word equation for the reactions is -

Iron + Water $\rightarrow$ iron (II, III) oxide + Hydrogen

The symbol equation for the same reaction is-

$$Fe + H_2O \rightarrow Fe_3O_4 + H_2$$

The balancing of the equations is done is the following steps:

I: Let us count the number of atoms of all the elements in the reactants and products on both sides of the equation.

Element	No. of atoms of reactants (L.H.S.)	No. of atoms of products (R.H.S.)
Fe	1	3
H	2	3
O	2	4

Thus, the number of H atoms are equal on both sides, At the same time, the number of Fe and O atoms are not equal.

II : On inspection, the number of O atoms in the reactant (H_2O) is 1 while in the product (Fe_3O_4), these are

(3) To balance the atoms, put coefficient 4 before H_2O on the reactant side. The partially balance equation may be written as

$$Fe + 4H_2O \rightarrow Fe_3O_4 + H_2$$

III : In order to equate H atoms, put coefficient 4 before H_2 on the product side, As a result, the H atoms on both side on of the equation become 8 and are thus balanced. The partially balanced equation may now be written as

$$Fe + 4H_2O \rightarrow Fe_3O_4 + H_2$$

IV : In order to balance the Fe atoms, put coefficient 3 before Fe on the reactant side. The equation formed may be written as -

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

V : on final inspection, the number of atoms of all the elements on both sides of the equation are equal. Therefore, the equation is balanced.

(c) Writing State Symbols:

The chemical equations or symbol equations which we have enlisted don't mention the physical states of the reactant and product species involved in the reaction. In order to make the equation more informative, the physical state are also mentioned with the help of certain specific symbols known as state symbols. These symbols are

- (s) for solid state
- (ℓ) for liquid state
- (g) for gaseous state
- (aq) for aqueous solution i.e., solution prepared in water.

Sometimes a gas if evolved in a reaction is shown by the symbol ($\uparrow$) i.e., by an arrow pointing upwards. Similarly, the precipitate, if formed during the reaction, is indicated by the symbol ($\downarrow$) i.e., by an arrow pointing downwards.

The abbreviation 'ppt' is also use to represent the precipitate, if formed.

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

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

(iii) $AnNo_3(aq) + NaCI(aq) \rightarrow AgCI(\downarrow) + NaNO_3\ (aq)$

(d) Significance of State Symbols:

The state symbols are of most significance for those chemical reactions which are either accompanied by the evolution of heat (exothermic) or by the absorption of heat (endothermic). For example.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell) + 572\ kJ$$

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) + 44\ kJ$$

Both these reactions are of exothermic nature because heat has been evolved in these. Howeve, actual amounts of heat are different when water is in the liquid state i.e. $H_2O(\ell)$ and when it is in the vapour state.

(e) Specialties of Chemical Equation :

(i) We get the information about the substance which are taking part and formed in the reaction.

(ii) We get the information about the number of molecules of elements or compounds which are either taking part or formed in the chemical reaction.

(iii) We also get the information of weight of reactant or products.

For example -

$$\underset{(100gm)}{CaCO_3} \longrightarrow \underset{(56\ gm)}{CaO} + \underset{(44\ gm)}{CO_2}$$

Total weight of reactants is equal to the total weight of products because matter is never destroyed. In the above example total weight of calcium carbonate (reactant) is 100 gram and of product is also 100 g (56 gram + 44 gram).

(iv) In a chemical equation if any reactant or product is in gaseous state, then its volume can also be determined. For example, in the above reaction volume of carbon dioxide is 22.4 liters.

(v) In a chemical equation with the help of product we can get information about the valency as well.

For example

$$Mg + 2HCI \rightarrow MgCI_2 + H_2(\uparrow)$$

In the above reaction one atom of Mg displaces two atoms of hydrogen, so valency of magnesium is two.

- **All chemical equations are written under N.T.P. Conditions (at 273 K and 1 atmosphere pressure) if conditions are not otherwise mentioned.**

(f) Limitations of Chemical Equations:

(i) We do not get information about the physical state of reactants and products.

For example, solid, liquid or gas.

(ii) No information about the concentration of reactants and products is obtained.

(iii) No information about the speed of reaction and sense of timing can be obtained.

(iv) Information regarding the favorable conditions of the reactions such as pressure, temperature, catalyst etc. can't be obtained during the reaction.

(v) We do not get information whether heat is absorbed or evolved during the reaction.

(vi) We do not get information whether the reaction of reversible or irreversible.

(vii) We do not get information about the necessary precautions to be taken for the completion of reaction.

The above limitations are rectified in the following manner –

- The physical sate of reactants and products are represented by writing them in bracket.

- The precipitate formed in the reaction is represented by (↓) symbol and gaseous substance by (↑) symbol.

- To express the concentration, dilute or conc. is written below the symbol.

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

(dilute)

- Favorable conditions required for the completion of reaction are written above and below the arrow.

$$N_2 + 3H_2 \xrightarrow[200\ atm]{500^0.Fe\ /\ Mo} 2NH_3 + 22400 \text{ Calorie heat.}$$

- Reversible reaction is represented by ($\rightleftharpoons$) symbol and irreversible reaction by (→) symbol.

- The heat absorbed in the chemical reaction is written on the right side by putting negative (-) sign and heat evolved in the chemical reaction is written on the right side by putting positive (+) sign.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + 22400 \text{ Calorie (Exothermic Reaction)}$$

$$N_2 + O_2 \rightleftharpoons 2NO - 43200 \text{ Calorie (Endothermic Reaction)}$$