Chemical Reactions

Chemical Reactions and Equations

Chemical Reaction – The transformation of chemical substance into another chemical substance is known as Chemical Reaction. For example: rusting of iron, burning of coal, burning of candle, burning of paper, setting of milk into cottage cheese or ghee, digestion of food etc.

In chemical reaction new substance is formed which is completely different in properties from the original substance, so in a chemical reaction chemical change takes place.

Experiment 1 –

The burning of magnesium in air to form magnesium oxide is an example of a chemical reaction.

Magnesium	+	Oxygen	$\xrightarrow{\text{heat}}$	Magnesium oxide	
(As ribbon)		(From air)		(White powder)	

- Take about 2cm long magnesium ribbon and clean it by rubbing its surface with sand paper.
- Hold it with a pair of tongs. Burn it using a burner.
- The magnesium ribbon starts burning with a dazzling white flame.
- Hold the burning magnesium ribbon over a watch glass so that the magnesium oxide powder being formed collects in the watch glass.

Note: Before burning in air, the magnesium ribbon is cleaned by rubbing with a sand paper. This is done to remove the protective layer of basic magnesium carbonate from the surface of magnesium ribbon so that it may readily combine with the oxygen of air.

Experiment 2 –

Formation of a precipitate:

Some chemical reactions are characterized by the formation of precipitate. A precipitate is a 'solid product' which separates out from the solution during a chemical reaction.

The chemical between potassium iodide and lead nitrate is characterized by the formation of a yellow precipitate of lead iodide.

- Take some lead nitrate solution in test tube.
- Add potassium iodide solution to it.
- A yellow precipitate of lead iodide is formed at once.
- A change in colour also takes place in this chemical reaction.

Experiment 3 –

Evolution of a Gas:

Some chemical reactions are characterized by the evolution of a gas.

The chemical reaction between zinc and dilute sulphuric acid is characterized by the evolution of hydrogen gas.

- Take some zinc granules in a conical flask.
- Add dilute sulphuric acid over zinc granules.
- We will see the bubbles of hydrogen gas being formed around zinc granules.
- If we touch the conical flask with our hand, we will find that it is somewhat hot. So, a change in temperature also occurs in this chemical reaction.

Experiment 4 –

Change in colour:

Some chemical reactions are characterized by a change in colour.

The chemical reaction between citric acid and purple coloured potassium permanganate solution is characterized by a change in colour from purple to colourless.

- Take some dilute potassium permanganate solution in a test tube. It has purple colour.
- Add some lemon juice (it contains citric acid) to it with the help of a dropper and shake the test tube.
- The purple colour of potassium permanganate solution goes on fading and ultimately it becomes colourless.

Experiment 5 – Change in temperature:

Some chemical reactions are characterized by a change in temperature.

The chemical reaction between quicklime and water to form slaked lime is characterized by a change in temperature.

- Take a little of quicklime in a hard-glass beaker.
- Add water to it slowly.
- Touch the beaker.
- The beaker feels to be quite hot.

Experiment 6 –

Change in state:

Some chemical reactions are characterized by a change in state.

- When wax is burned (in the form of wax candle,) then water and carbon dioxide are formed.
- Now, wax is a liquid whereas carbon dioxide is a gas. This means that during the combustion reaction of wax, the physical state changes from solid to liquid and gas.

Common observations in a chemical reaction –

- 1. Change of state of substance.
- 2. Change in colour of substance.
- 3. Evolution of gas.
- 4. Change in temperature.

Chemical Equation –

Reactant: Substances which take part in a chemical reaction are called reactants.

Product: New substance formed after a chemical reaction is called product.

Representation of chemical reaction using symbols of substances is called chemical equation. **Example:**

 $A + B \longrightarrow C + D$

In this equation, A and B are called reactants and C and D are called products. Arrow shows the direction of chemical reaction. Condition, if any, is written generally above the arrow.

When hydrogen reacts with oxygen, it gives water. This reaction can be represented by following chemical equation.

$$Hydrogen + Oxygen \longrightarrow Water - - - - (i)$$

$$H_2 + O_2 \xrightarrow{} H_2 O \xrightarrow{} - - - - - (ii)$$

In first equation, words are used and in second, symbols of substances are used to write the chemical equation. For convenience, symbol of substance is used to represent chemical equations.

Chemical Equation is a way to represent the chemical reaction in concise and informative way.

Chemical equation can be divided into two types -

- (i) Balanced Chemical Equation
- (ii) Unbalanced Chemical Equation.

Balanced Chemical Equation – A balanced chemical equation has number of atoms of each element equal on both sides.

Example:

 $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$ Zinc Sulphuric Acid Zinc Sulphate Hydrogen

In this equation, numbers of atoms of zinc, hydrogen and sulphate are equal on both sides, so it is a balanced chemical equation.

According to Law of Conservation of Mass, mass can neither be created nor destroyed in a chemical reaction. To obey this law, the total mass of elements present in reactants must be equal to the total mass of

elements present in products or we can say that initial number of atoms of an element should be equal to final number of atoms.

Unbalanced Chemical Equation – If the number of atoms of each element in reactants is not equal to the number of atoms of each element present in product, then the chemical equation is called unbalanced chemical equation.

Example:

 $\begin{array}{cccc} Fe + H_2O & \longrightarrow & Fe_3O_4 & + & H_2\\ Iron & Water & Iron (II - III) oxide & Hydrogen \end{array}$

In this example number of atoms of elements are not equal on two sides of the reaction. For example, on the left hand side only one iron atom is present, while three iron atoms are present on the right hand side. Therefore, it is an unbalanced chemical equation.

Balancing a chemical equation -

To balance any chemical equation, we have to follow these steps:

 $\begin{array}{cccc} Fe &+ & H_2O & \longrightarrow & Fe_3O_4 &+ & H_2\\ Iron & Water & & Iron (II - III) oxide & Hydrogen \end{array}$

(1) Write the number of atoms of elements present in reactants and in products in a table; as shown here.

Name of atom	Number of atoms	Number of atom		
	present in reactant	present in product		
Iron (Fe)	1	3		
Hydrogen (H)	2	2		
Oxygen (O)	1	4		

(2) Attack on the problem.

In above equation, number of elements of iron and oxygen are not equal on two sides. Let's take oxygen first.

(3) Attack the side where there is less number of atoms of that particular element. In above equation, number of oxygen atom is minimum on LHS.

(4) Thus to balance the equation, we need to multiply the oxygen by 4 on LHS.

 $\begin{array}{cccc} Fe & +4 \times H_2 O & & Fe_3 O_4 & + & H_2 \\ Iron & Water & Iron (II - III) oxide & Hydrogen \end{array}$

(5) Now again check the number of atoms of each element present in reactants and in products. You can see that the number of hydrogen atoms becomes 8 on the LHS; which is more than that on the RHS. To balance it, one needs to multiply the hydrogen on the RHS by 4.

 $\begin{array}{cccc} Fe & +4 \times H_2O & & Fe_3O_4 & + & 4 \times H_2\\ Iron & Water & Iron (II - III) oxide & Hydrogen \end{array}$

(6) After that number of oxygen and hydrogen atoms becomes equal on both sides. The number of iron is one on the LHS, while it is three on the RHS. To balance it, multiply the iron on the LHS by 3.

$$Fe_{3}O_{4} + 4 \times H_{2}O \longrightarrow Fe_{3}O_{4} + 4 \times H_{2}$$

Iron Water Iron (II – III) oxide Hydrogen

(7) Now the number of atoms of each element becomes equal on both sides. Thus, this equation becomes a balanced equation.

Name of atom	Number of atoms	Number of atom		
	present in reactant	present in product		
Iron (Fe)	3	3		
Hydrogen (H)	8	8		
Oxygen (O)	4	4		

After balancing, the above equation can be written as follows.

Q.1 Balance the given equations.

 $(a) H_{2} + 0_{2} \longrightarrow H_{2}0$ $Answer: 2H_{2} + 0_{2} \longrightarrow 2H_{2}0$ $(b) Fe + H_{2}0 \longrightarrow Fe_{2}0_{3} + H_{2}$ $Answer: 2Fe + 3H_{2}0 \longrightarrow Fe_{2}0_{3} + 3H_{2}$ $(c) C0_{2} + H_{2}0 \xrightarrow{Chlorophyll} C_{6}H_{12}0_{6} + 0_{2}$ (c) Carbon dioxide Water Sunlight Glucose Oxygen $Answer: 6C0_{2}(g) + 6H_{2}0(l) \xrightarrow{Chlorophyll} C_{6}H_{12}0_{6}(aq) + 60_{2}(g)$ $(d) Fe_{2}0_{3} + C \longrightarrow Fe + C0_{2}$ (d) Ferric Oxide Carbon Iron Carbon dixodie $Answer: \frac{2Fe_{2}0_{3} + 3C}{Ferric Oxide Carbon} \xrightarrow{AFe} + 3C0_{2}$ Iron Carbon dixodie

Making Chemical Equation More Informative –

1. By writing the physical states of substances a chemical equation becomes more informative -

Gaseous state is represented by symbol 'g'.

Liquid state is represented by symbol 'l'.

Solid state is written by symbol 's'.

Aqueous solution (substance dissolved in water) is written by symbol 'aq'.

2. Exothermic and Endothermic Reaction -

Reactions which produce energy are called exothermic reaction. Reactions which absorb/require energy are called endothermic reaction.

Respiration is a exothermic reaction as in respiration process energy is released. When quick lime (calcium carbonate) is added to water, it decomposes and releases energy. So it is also an example of exothermic reaction.

Cooking involves chemical reactions which are endothermic as cooking is possible because of heating. Similarly in process of photosynthesis, sunlight is required so it is also an example of endothermic reaction.

3. Writing the condition in which reaction takes place -

The condition is generally written above and/or below the arrow of a chemical equation.

Catalyst is a chemical substance which is neither a reactant nor a product but the reactions takes place only in its presence or the reaction speeds up in its presence.

$$CO + 2H_2 \xrightarrow{300 \text{ atm., } 300^\circ \text{C}} CH_3OH$$

$$ZnO + CrO_2 CH_3OH$$

Thus, by writing the symbols of the physical state of substances and condition under which reaction takes place, a chemical equation can be made more informative.

Example:

Oxidation and Reduction Reactions

Oxidation: Addition of oxygen or non-metallic element or removal of hydrogen or metallic element from a compound is known as oxidation.

Elements or compounds in which oxygen or non-metallic element is added or hydrogen or metallic element is removed are called to be oxidized.

Oxidizing agent: Compounds which can add oxygen or a non-metallic compound or remove hydrogen or metallic element are known as oxidizing agents.

Reduction: Addition of hydrogen or metallic element or removal of oxygen or non-metallic element from a compound is called reduction. The compound or element which goes under reduction is called to be reduced.

Reducing agent: Compounds or elements which can cause reduction are called reducing agents. In a chemical reaction oxidation and reduction both take place simultaneously and such reactions are also known as REDOX REACTIONS. In the word REDOX, 'Red' stands for reduction and 'Ox' stands for oxidation.

Example:

When iron reacts with air, it forms iron oxide (rust).

 $\begin{array}{cccc} 4Fe + & 3O_2 & & & Fe_2O_3 \\ Iron & Oxygen & & Iron oxide (Ferric oxide or rust) \end{array}$

In this reaction, oxygen is added to iron, thus, iron is oxidized. Here oxygen is oxidizing agent. When cupric oxide reacts with hydrogen, it gives copper and water.

CuO	+	H_2	 Cu	÷	H ₂ 0
Cupric oxide	e E	Iydrogen	 Copper	1	Nater

In this reaction, oxygen is removed from copper and oxygen is added to hydrogen. So, cupric oxide is reduced to copper and hydrogen is oxidized to water. Cupric oxide is oxidizing agent and hydrogen is reducing agent. When sodium hydroxide reacts with hydrochloric acid, it gives sodium chloride and water.

NaOH	+	HCl	 NaCl	÷	H_2O
Sodium hydroxide	Ну	vdrochloric acid	Sodium chloride	1	Nater

In this reaction, sodium hydroxide is reduced to sodium chloride since hydrogen is removed from sodium hydroxide. Hydrochloric acid is oxidized to water, since oxygen is added to hydrogen chloride and non-metallic element chloride is removed. Sodium hydroxide is oxidising agent and hydrochloric acid is reducing agent. In this reaction oxidation and reduction both takes place simultaneously, thus it is an example of redox reaction.

Effects of Oxidation -

1. Respiration is oxidation reaction in which food is oxidized to produce energy.

2. Iron gets oxidized to form rust; which leads to corrosion of iron in the long run.

3. Most of the metals react with atmospheric oxygen and it leads to formation of a layer on the metal article. The metal gets corroded in the long run.

4. Rusting of iron can be prevented by painting the iron article. This can also be prevented by applying a layer of zinc over iron article. This process is known as galvanization.

5. Fried food gets oxidized when exposed to air. This spoils the taste of the food and the food becomes unfit for consumption. The spoiling of fried food because of oxidation is called rancidity. Fried food is often packed in airtight packets to prevent rancidity.

6. We are able to utilize various types of fuel because of oxidation. Oxidation of fuel helps in producing energy.

Types of Chemical Reaction –

Chemical reactions can be classified in following types:-

a. Combination Reactions

- b. Decomposition Reactions
- c. Displacement Reactions
- d. Double Displacement Reactions

a. Combination Reaction – Reactions in which two or more reactants combine to form one product are called combination reactions.

A general combination reaction can be represented by the chemical equation given here.

 $A + B \longrightarrow AB$

Example:

When magnesium is burnt in air (oxygen), magnesium oxide is formed. In this reaction, magnesium is combined with oxygen.

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

Magnesium Oxygen Magnesium Oxide

 $C(s) + \theta_2 \longrightarrow C\theta_2$

When carbon is burnt in oxygen (air), carbon dioxide is formed. In this reaction, carbon is combined with oxygen.

Carbon Oxygen Carbon dioxide

When hydrogen reacts with chlorine, hydrogen chloride is formed.

 $H_2 + Cl_2 \longrightarrow 2HCl$ Hydrogen Chlorine Hydrogen chloride

When calcium oxide reacts with water, calcium hydroxide is formed

$$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq)$$

Calcium Oxide Water Calcium Hydroxide

When carbon monoxide reacts with oxygen, carbon dioxide is formed.

 $2CO(g) + O_2(g) \longrightarrow 2CO_2$ Carbon monoxide Oxygen Carbon dixoide

b. Decomposition Reaction – Reactions in which one compound decomposes in two or more compounds or element are known as decomposition reaction. Decomposition reaction is just opposite of combination reaction.

A general decomposition reaction can be represented as follows:

$$AB \longrightarrow A + B$$

Example:

When calcium carbonate is heated, it decomposes into calcium oxide and carbon dioxide

HeatCalcium CaCO_3(s)HeatCalcium Calcium OxideCalcium Calcium OxideCalcium Carbon dioxideWhen ferric hydroxide is heated, it decomposes into ferric oxide and water. $2Fe(OH)_3(s)$ HeatFe $_2O_3$ + 3H_2OFerric hydroxideFerric oxideWater

Thermal Decomposition:

When lead nitrate is heated, it decomposes into lead oxide, nitrogen dioxide and oxygen.

$2Pb(NO_3)_2(s)$	Heat	2PbO(s)	Ŧ	$4NO_2(g)$	+	02
Lead Nitrate	1	ead Oxide	2 1	Nitrogen dioxide		Oxygen

In the above examples, compound is decomposed because of heating, so, these reactions are called **thermal decomposition**.

Electrolytic Decomposition:

Reactions in which compounds decompose into simpler compounds because of passing of electricity, are known as **electrolytic decomposition**. This is also known as **electrolysis**. **Example:**

 $\begin{array}{ccc} 2H_2O(l) & \underbrace{ & Electricity \\ Water & & Hydrogen & Oxygen \end{array} } 2H_2(g) & + & O_2(g) \\ \end{array}$

When electricity is passed in water, it decomposes into hydrogen and oxygen.

Photolysis or Photo Decomposition: Reactions in which a compound decomposes because of sunlight are known as **photolysis** or **photo** decomposition. **Example:** When silver chloride is put in sunlight, it decomposes into silver metal and chlorine gas. Sunlight 2AgCl(l) $2Ag(s) + Cl_2(g)$ Silver chloride Silver Chlorine Similarly, when silver bromide is put under sunlight, it decomposes into silver metal and bromine gas. Sunlight 2AgBr(l) $2Ag(s) + Br_2(g)$ Silver bromide Silver Bromide Photographic paper has coat of silver chloride, which turns into grey when exposed to sunlight. It happens because silver chloride is colourless while silver is a grey metal. c. Displacement Reaction – Reactions in which atoms or ions move from one compound to other to form new compound are known as **displacement reaction**. Displacement reaction is also known as **Substitution** Reaction or Single displacement /Replacement Reaction. A general displacement reaction can be represented using chemical equation as follows: $A + BC \longrightarrow AC + B$ Displacement reaction takes place only when 'A' is more reactive than B. If 'B' is more reactive than 'A', then 'A' will not displace 'C' from 'BC' and reaction will not be taken place. **Example:** When zinc reacts with hydrochloric acid, it gives hydrogen gas and zinc chloride. 2HCl(l) \longrightarrow ZnCl₂(s) + Zn + H_2 Zinc Hydrochloric acid Zinc chloride Hydrogen When zinc reacts with copper sulphate, it forms zinc sulphate and copper metal. Zn(s)+ $CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu$ Zinc Copper sulphate Zinc sulphate Copper When silver metal is dipped in copper nitrate, no reaction takes place because silver metal is less reactive than copper. $Ag(s) + Cu(NO_3)_2$ No reaction takes place Silver Coppernitrate **d.** Double Displacement Reaction – Reactions in which ions are exchanged between two reactants forming new compounds are called double displacement reactions. A general double displacement reaction can be represented using the following general chemical equation. $AB + CD \longrightarrow AD + CB$ **Example:** When the solution of barium chloride reacts with the solution of sodium sulphate, white precipitate of barium sulphate is formed along with sodium chloride. $BaCl_2(aq) + Na_2SO_4(aq) BaSO_4(s)$ + NaCl(aq)Barium chloride Sodium sulphate Barium sulphate(white ppt) Sodium chloride When sodium hydroxide (a base) reacts with hydrochloric acid, sodium chloride and water are formed. NaOH(aq) HCl(aq)NaCl(aq) + ----- $+H_2O(l)$ Sodium hydroxide Hydrochloric acid Sodium chloride Water Double displacement reaction, in which precipitate is formed, is also known as a precipitation reaction. Neutralisation reactions are also examples of double displacement reaction.