REDOX REACTIONS

Chemical Reactions :

The Chemical reactions are the back bone of Chemistry. There is no chemistry without chemical reactions. In order to understand chemical reactions it is necessary to know about the changes.

In our day to day life we come across several types of changes. **A substance is said to undergo a change if it gets converted from one state to another.**

A substance can undergo two types of changes.

1. Physical Change
2. Chemical Change

Physical Change :

A physical change is a temporary change in which a specific property of the substance alters keeping the composition same.

i) Melting of ice, wax or ghee.
ii) Evaporation of Water.
iii) Condensation of Water Vapour
iv) Magnetization of iron
v) Glowing of an electric bulb.
vi) Expansion or contraction of metals on heating or cooling.
vii) Change of colour in some cases.
viii) Stretching of rubber within the elastic limit.

Characteristics of physical changes :

i) It is temporary and reversible.
ii) There is no change in mass & chemical composition.
iii) No new substance is formed.
iv) Only a little heat is absorbed or liberated.

Chemical change:

A Chemical change is a permanent change in which the chemical composition of the substance changes.

Examples:

i) Combustion of carbon or any substance.
ii) Decomposition of lime stone
iii) Rusting of iron.
iv) Electroplating
v) Electrolysis of water

Characteristics of a chemical change :

i) It is a permanent change.
ii) One or more new substances with different composition are formed.
iii) It may be reversible or irreversible.
iv) A certain amount of heat may be absorbed or liberated.

Chemical Reactions:

A Chemical reaction can be defined as the process in which one or more substances (element or compound) undergo a chemical change with absorption or liberation of heat.

The substances present before the chemical reaction (or chemical change) are called **reactants**.

The substances formed after the chemical reactions (or chemical change) are called as **products**.

Chemical Equation:

A Chemical equation can be defined as the short scientific representation of a chemical reaction by using the symbol or formulae of the substances involved in the reaction.

A Chemical equation for a given chemical reaction is written by following these steps.

i) The symbol or formulae of all the reactants are written, each one of them separated by "+" sign. This "+" sign indicates that the reactants interact or combine with each other.

ii) A horizontal arrow mark ($\rightarrow$) pointing towards right side is written after the last reactant. If the reaction is reversible, then arrow mark is replaced by "$\rightleftharpoons$" mark.

iii) Now the symbol or formulae of all the products are written, each one of them again separated by "+" sign. This "+" sign indicates that a mixture of products is formed.

iv) The gaseous products are indicated by writing a vertical arrow mark pointing upward (↑) after its formula.

v) If a precipitate is formed in the reaction, then it is indicated by writing a vertical arrow mark pointing downward (↓) after its formula.
A precipitate is an insoluble substance that separates when two solutions are mixed with each other.

vi) The conditions of the reactions like temperature, pressure etc and catalyst if any, used in the reaction are indicated on the arrow mark between the reactants and products. In some reactions, the physical states of the reactants and products are also indicated.

Now let us write the chemical equation for the following chemical reactions.

Example 1: Combustion of Carbon**:** Carbon burns in air or oxygen to form Carbon dioxide gas.

$$\underbrace{\underset{\text{Carbon}}{C} + \underset{\text{Oxygen}}{O_2}}_{\text{Reactants}} \longrightarrow \underbrace{\underset{\text{Carbon dioxide}}{CO_2 \uparrow}}_{\text{Product}}$$

Carbon dioxide is a gas. It is indicated by an arrow mark↑.

Example 2: Decomposition of Limestone**: -** Limestone decomposes on heating to give calcium oxide and carbon dioxide gas.

$$\underset{\substack{\text{Limestone}\\ \text{(Reactant)}}}{CaCO_3} \longrightarrow \underbrace{\underset{\substack{\text{Calcium}\\ \text{Oxide}}}{CaO} + \underset{\substack{\text{Carbon}\\ \text{dioxide}}}{CO_2 \uparrow}}_{\text{Products}}$$

Carbon dioxide is a gas. It is indicated by arrow mark (↑)

Example 3: Decomposition of Lead nitrate

Lead nitrate decomposes on heating to give lead oxide, nitrogen dioxide gas and oxygen gas.

$$\underset{\substack{\text{Lead}\\ \text{Nitrate}\\ \text{(Reactant)}}}{2Pb(NO_3)_2} \longrightarrow \underbrace{\underset{\substack{\text{Lead}\\ \text{oxide}}}{2PbO} + \underset{\substack{\text{Nitrogen}\\ \text{dioxide}}}{4NO_2 \uparrow} + \underset{\text{Oxygen}}{O_2 \uparrow}}_{\text{products}}$$

Nitrogen dioxide and Oxygen are gases. They are indicated by arrow mark (↑)

Example 4: When silver nitrate solution is added to sodium chloride solution, an insoluble substance silver chloride separates out

$Ag\ NO_3(aq)$	+	$NaCl(aq)$	$\longrightarrow$	$AgCl(aq)\downarrow$	+	$NaNO_3\ (aq)$
Silver Nitrate		Sodium Chloride		Silver Chloride		Sodium Nitrate
Reactants				Products		

Silver chloride is a precipitate. It is indicated by an arrow mark ($\downarrow$)

Example: 5 when a solution of barium chloride is added to a solution of sodium sulphate, an insoluble substance barium sulphate separates out.

$BaCl_2\ (aq)$+	$Na_2SO_4(aq)$	$\longrightarrow$	$BaSO_4\ (aq)\downarrow$	+	$2NaCl\ (aq)$
Barium Chloride	Sodium Sulphate		Barium Sulphate		Sodium Chloride
Reactants			Products		

Barium sulphate is a precipitate. It is indicated by an arrow mark. ($\downarrow$)

<u>Balancing the chemical Equations :</u>

When a chemical reaction takes place. There is change in chemical composition of the reactants, however there is no change in mass. According to law of conservation of mass.**" Mass can neither be created nor destroyed"**. The number of atoms of different elements present in the molecules of reactants and products must be the same. It is therefore necessary to equalise the number of atoms of different elements present in both reactants and products.

The process of equalising the number of atoms present in the molecules of reactants and products is called balancing the chemical equations. The following are different methods of balancing the equations.

1) Trial and error method (or Hit and Trial method)
2) Oxidation number method.

<u>Balancing a chemical equation by trial and error method.</u>

There are no hard and fast rules for balancing a chemical equation by trial and error method. However following procedure can be applied.

1) Write the skeleton of chemical equation.
2) First consider a particular element either from the reactants or from the products
3) Count the number of atoms of that element in molecules of reactants and products.

4) If this number is equal then consider another element. Otherwise balance this element by writing a suitable number as coefficient of the formula of molecule containing that element in reactants (or products)

5) After writing this co-efficient, the number of other element/ elements present in the molecule of that compound will be affected. Now balance the affected element with a suitable coefficient to the formula on the other side.

6) The same method is applied to balance every element in the equation.

7) In some equations, there may be diatomic molecules as one of the reactants or products and the atom of the same molecule exists in odd number on the other side. In such cases, equalise that element with a suitable number as coefficient such that it becomes even.

Consider the following examples.

1) Potassium chlorate decomposes on heating to give potasium chloride and oxygen. Skeleton of chemical equation for this reaction is as follows :

$$KClO_3 \longrightarrow KCl + O_2 \uparrow$$

i) Consider oxygen atom, there are 3 oxygen atoms on the left side and 2 on the right. To balance this, we have to make even number of oxygen atoms on both sides by writing $2KClO_3$ and $3O_2$.

$$2KClO_3 \longrightarrow KCl + 3O_2 \uparrow$$

ii) Now K & Cl are 2 on the left side therefore write 2KCl on the right side.

$$2KClO_3 \longrightarrow 2KCl + 3O_2 \uparrow$$

Now it is a balanced chemical equation.

2) Zinc reacts with concentrated sulphuric acid to form zinc sulphate liberating sulphur dioxide gas.

Skeleton of chemical equation for this reaction is as follows

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + SO_2 \uparrow + H_2O$$

i) Consider sulphur, there are 2 sulphur atoms on right side, therefore write $2H_2SO_4$ on left side

$$Zn + 2H_2SO_4 \longrightarrow ZnSO_4 + SO_2 \uparrow + H_2O$$

ii) Now there are 4 H atoms on left side therefore write $2H_2O$ on right side.

$$Zn + 2H_2SO_4 \longrightarrow ZnSO_4 + SO_2\uparrow + 2H_2O$$

Now it is a balanced chemical equation.

3) Lead ritrate decomposes on heating to give lead oxide, nitrogen dioxide gas and oxygen gas. The skeleton of the chemical equation for this reaction is.

$$Pb(NO_3)_2 \longrightarrow PbO + NO_2\uparrow + O_2\uparrow$$

i) Consider oxygen, there are odd number of oxygen atoms (5) on right side make it even by writing 2PbO.

$$Pb(NO_3)_2 \longrightarrow 2PbO + NO_2\uparrow + O_2\uparrow$$

ii) Now there are 2 lead atoms on right side,therefore write 2 $Pb(NO_3)_2$.on left side.

$$2Pb(NO_3)_2 \longrightarrow 2PbO + NO_2\uparrow + O_2\uparrow$$

iii) Lead is balanced. Now there are 4 nitrogen atoms on left side, therefore write 4 NO_2 on the right side.

iv) $2\ Pb(NO_3)_2 \longrightarrow 2PbO + 4NO_2\uparrow + O_2\uparrow$

This is a balanced chemical equation.

4) Sodium carbonate reacts with dilute hydrochloric acid to form sodium chloride and water, liberating carbon dioxide gas with effervescence.
The skeleton of the chemical equation for this reaction is as follows :

$Na_2CO_3 + HCl \longrightarrow NaCl + CO_2\uparrow + H_2O$

i) Consider sodium, there are 2 sodium atoms on the left side, therefore write 2NaCl.

$Na_2CO_3 + HCl \longrightarrow 2NaCl + CO_2\uparrow + H_2O$

ii) Now there are 2 Cl atoms on right side, therefore write 2 HCl on left side.

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2\uparrow$

Now this is a balanced chemical equation.

5) When Potassium dichromate is heated with concentrated sulphuric acid, it forms potassium sulphate, chromium sulphate, water and oxygen gas.

The skeleton of the chemical equation for this reaction is

$K_2Cr_2O_7 + H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + H_2O + O_2\uparrow$

i) There are 2 potassium atoms and 2 chromium atoms on both sides, therefore both potassium and chromium are balanced.

ii) There are 4 SO_4 groups on right side and 1 on left side, threfore write 4 H_2SO_4 on left side.

$K_2Cr_2O_7 + 4H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + H_2O + O_2\uparrow$

iii) Now there are 8 hydrogen atoms on left side and 2 on right side, therefore write 4 H_2O on right side.

$K_2Cr_2O_7 + 4H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + O_2\uparrow$

iv) Now there are 23 oxygen atoms on left side and 22 on right side, therefore make even number on both sides by multiplying the equation throughout by 2 except O_2.

$K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 2K_2SO_4 + Cr_2(SO_4)_3 + 8H_2O + O_2\uparrow$

v) Now there are 46 oxygen atoms on left side and 42 on right side, therefore write $3O_2$on right side.

$2K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 8H_2O + 3O_2\uparrow$

Exercise

Balance the following chemical equations

i) $N_2 + H_2 \longrightarrow NH_3$
ii) $SO_2 + O_2 \longrightarrow SO_3$
iii) $H_2 + I_2 \longrightarrow HI$
iv) $K_2Cr_2O_7 + KOH \longrightarrow K_2CrO_4 + H_2O$
v) $Cu + H_2SO_4 + O_2 \longrightarrow CuSO_4 + H_2O$
vi) $Cu(NO_3)_2 \longrightarrow CuO + NO_2\uparrow + O_2\uparrow$
vii) $Cu + HNO_3 \longrightarrow Cu(NO_3)_2 + NO_2\uparrow + H_2O$
viii) $KMnO_4 + H_2SO_4 \longrightarrow K_2SO_4 + MnSO_4 + H_2O + O_2\uparrow$
ix) $Al_2(SO_4)_3 + BaCl_2 \longrightarrow AlCl_3 + BaSO_4$
x) $KMnO_4 + FeSO_4 + H_2SO_4 \longrightarrow K_2SO_4 + MnSO_4 + Fe_2(SO_4)_3 + H_2O$

A balanced chemical equation gives information about

i) the substances that react with each other.
ii) the products formed during the reaction.
iii) the symbol and formulae of the reactants and products.
iv) the substance formed is a gas or a precipitate.
v) the number of moles of different reactants & products.

Types of Reactions:

The following are different types of chemical reactions.

1)	Combination reactions	2)	Decomposition
3)	Displacement reactions	4)	Double displacement
5)	Neutralisation	6)	Redox reactions

1) Combination reactions: It is a type of chemical reaction in which two or more simple substances combine with each other to form a single substance.

Examples: i) When magnesium ribbon is burnt in air, magnesium oxide is formed.

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

ii) When Iron is heated with sulphur, ferrous sulphide is formed.

$$Fe + S \longrightarrow FeS$$

2) Decomposition : It is a type of reaction in which one substance splits or breaks into two or more simple substances.

Examples :

i) Cupric nitrate decomposes on heating to give cupric oxide, nitrogen dioxide and oxygen gas.

$$2Cu(NO_3)_2 \longrightarrow 2CuO + 4NO_2\uparrow + O_2\uparrow$$

ii) Limestone decomposes on heating to give calcium oxide and carbon dioxide.

$$CaCO_3 \longrightarrow CaO + CO_2\uparrow$$

3) Displacement reactions : It is a type of reaction in which one element displaces another element from its compound in the solution.

Examples : i) Zinc displaces copper from cupric sulphate solution.

$$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu.$$

ii) Magnesium reacts with dilute hydrochloric acid to form magnesium chloride liberating hydrogen gas.

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2\uparrow$$

4) Double displacement: It is a type of reaction in which there is mutual exchange of radicals present in two compounds in there solutions.

Examples:

i) A solution of sodium chloride reacts with a solution of silver nitrate to form a precipitate of silver chloride and sodium nitrate.

$$NaCl(aq) + AgNO_3(aq) \longrightarrow AgCl(aq)\downarrow + NaNO_3(aq)$$

ii) A solution of sodium sulphate reacts with a solution of barium chloride to form a precipitate of barium sulphate and sodium chloride.

$$Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4(aq)\downarrow + 2NaCl(aq).$$

5) Neutralisation : It is a type of reaction in which acid reacts with base to form salt and water.

Examples :

i) Hydrochloric acid reacts with sodium hydroxide to form sodium chloride and water.

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

ii) Nitric acid reacts with potassium hydroxide to form potassium nitrate and water.

$$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$$

Neutralisation is also a type of double displacement reaction

6) Redox reactions: It is a reaction which involves both oxidation and reduction of the processes.

Examples :

i) Concentrated sulphuric acid oxidises carbon to carbon dioxide, getting itself reduced to sulphur dioxide.

$$2H_2SO_4 + C \longrightarrow 2SO_2 \uparrow + CO_2 \uparrow + 2H_2O$$

ii) Acidified Potassium permanganate oxidises ferrous sulphate to ferric sulphate getting itself reduced to manganous sulphate

$$2KMnO_4 + 8H_2SO_4 + 10FeSO_4 \longrightarrow K_2SO_4 + 2MnSO_4 + 5Fe_2(SO_4)_3 + 8H_2O$$

Redox Reactions (Oxidation-Reduction Reactions)

Before we understand Redox reactions, let us know what are oxidation and reduction reactions.

Oxidation : A reaction in which a substance gains oxygen or loses hydrogen is called oxidation.

Examples

1) Coke burns in air to form carbon dioxide.

$$C + O_2 \longrightarrow CO_2 \uparrow$$

Carbon is gaining oxygen to form carbon dioxide. It is oxidation of carbon

2) When sulphur is burnt in air sulphur dioxide is formed.

$$S + O_2 \longrightarrow SO_2 \uparrow$$

Sulphur gains oxygen to form Sulphur dioxide. It is oxidation of Sulphur.

3) When magnesium ribbon is burnt in air, magnesium oxide is formed.

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

Magnesium gain oxygen to form magnesium oxide. It is oxidation of Magnesium.

4) When chlorine gas is passed through hydrogen sulphide solution, sulphur is precipitated.

$$H_2S + Cl_2 \longrightarrow 2HCl + S \downarrow$$

Hydrogen sulphide loses hydrogen, it is oxidation of hydrogen sulphide.

(Oxidation is also defined as a reaction in which a species loses one or more electrons).

Reduction :

A reaction in which a substance gains hydrogen or loses oxygen is called Reduction.

Example :

i) Hydrogen combines with chlorine to form hydrogen chloride.

$$H_2 + Cl_2 \longrightarrow 2HCl.$$

Chlorine gain hydrogen. It is reduction of chlorine.

iii) When zinc oxide is heated with coke, zinc and carbon monoxide are formed.

$$ZnO + C \longrightarrow Zn + CO\uparrow$$

Zinc oxide is losing oxygen. It is reduction of zinc oxide.

iv) Hydrogen combines with iodine to form hydrogen iodide.

$$H_2 + I_2 \longrightarrow 2HI$$

Iodine gains hydrogen. It is reduction of Iodine.

v) When hydrogen gas is passed through vegetable oil in presence of nickel catalyst at 180^0C, a vegetable ghee is formed.

$$\text{Vegetable oil} + H_2 \xrightarrow[180^0C]{Ni} \text{vegetable ghee(vanaspathi)}$$

Hydrogen is added to vegetable oil, threfore it is reduction of vegetable oil. (Reduction is also defined as a reaction in which a species gains one or more electrons.)

Redox Reaction :

A reaction in which both oxidation and reduction reactions take place simultaneously is called Redox reaction.

These reactions contain an oxidising agent and a reducing agent.

Oxidising agent

An oxidising agent is a substance which gives oxygen to or takes hydrogen from another substance.

Reducing agent

A reducing agent is a substance which gives hydrogen to or takes oxygen from another substance.

Examples :

1) When steam is passed over red hot iron ferroso ferric oxide is formed and hydrogen gas is liberated.

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2\uparrow$$

Iron gains oxygen and steam loses hydrogen. It is oxidation of iron and reduction of steam. Iron takes oxygen from steam. Iron is a reducing agent. Steam gives oxygen to iron, steam is oxidising agent.

2) When Zinc oxide is heated with coke, carbon monoxide and zinc are formed.

$$ZnO + C \longrightarrow Zn + CO\uparrow$$

Zinc oxide gives oxygen to carbon. It is oxidation of carbon and reduction of Zinc oxide. Carbon is a reducing agent and zinc oxide is an oxidising agent.

3) When chlorine gas is passed through a solution of hydrogen sulphide. A precipitate of sulphur is formed.

$$Cl_2 + H_2S \longrightarrow 2HCl + S\downarrow$$

Chlorine takes hydrogen from hydrogen sulphide. It is oxidation of hydrogen sulphide and reduction of chlorine. Hydrogen sulphide is a reducing agent and chlorine is an oxidising agent.(An oxidising agent is also defined as a species which takes one or more electrons from other species. A reducing agent is also defined as a species which gives one or more electrons to other species.)

Definition of oxidation, reduction, redox reactions, oxidising agent, reducing agent in terms of electrons and balancing the chemical equation by oxidation number method are discussed in XI Std.

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