CHEMICAL REACTION

A process in which the original substance *loses its nature and identity* and *form new substances* with different properties. In a chemical reaction, *breaking* of the chemical bonds and *formation* of new chemical bonds is responsible for the occurrence of a chemical reaction.

The substances which take part in a chemical reaction are called **Reactants** and the new substances formed are called **Products**.

Characteristics of a chemical reaction:

	Characteristics	Examples
1	Change in state	**The burning of candle wax** is characterized by a change in state from $solid \rightarrow liquid \rightarrow gas$
2	Change in colour	The chemical reaction between **Citric acid** $[C_6H_8O_7]$ and **purple** coloured **Potassium permanganate** $[KMnO_4]$ solution is characterized by a change in colour from purple to colourless
3	Evolution of gas	The chemical reaction between **Zinc** $[Zn]$ and dilute **Sulphuric Acid** $[H_2SO_4]$ is characterized by evolution of *Hydrogen gas*.
4	Change in temperature	The reaction between **Quicklime** $[Calcium\ oxide\ i.e.\ CaO]$ and **Water** to form **Slaked lime** $[Calcium\ hydroxide\ i.e.\ Ca(OH)_2]$ is characterized by an increase in temperature.
5	Formation of a precipitate	When an aqueous solution of **Sodium sulphate** $[Na_2SO_4]$ is mixed with the aqueous solution of **Barium chloride** $[BaCl_2]$, **Barium sulphate** $[BaSO_4]$ comes in the form of precipitate.

REPRESENTATION OF CHEMICAL REACTIONS

A chemical reaction can be represented by chemical equations. It involves uses of symbol of elements or chemical formulas of reactants and products with *mention of physical state*.

The *necessary conditions* such as temperature, pressure or any catalyst should be written on arrow between reactants and products.

Example: **Magnesium is burnt in air to form Magnesium oxide.**

This statement can be written as chemical equation as

$$\boldsymbol{Magnesium + Oxygen \rightarrow Magnesium\ oxide}$$

However, it can be properly represented as a skeletal chemical equation using symbols as

$$\boldsymbol{Mg + O_2 \rightarrow MgO}$$

This is an unbalanced chemical equation, hence cannot be used to represent a reaction. In next section, we'll learn to write balanced chemical equations.

VERY IMPORTANT

- **Balanced Chemical Equations:** A chemical reaction always follows the *law of conservation of mass* i.e. Mass can neither be created nor be destroyed. Hence the number of elements involved in a chemical reaction should remain same at reactants side and products side.

  In the previous example, the number of Magnesium atoms are same on both sides, however, the number of oxygen atoms are different. Hence it is not following the law of conservation of mass.

  - **Step-wise Balancing:**

    i) Write the chemical equation.

    $$\boldsymbol{Mg + O_2 \rightarrow MgO}$$

    ii) Count the number of atoms on both the sides of the equation

Element	No. of atoms at reactant side (LHS)	No. of atoms at product side (RHS)
$\boldsymbol{Mg}$	1	1
$\boldsymbol{O_2}$	2	1

    iii) Now try to balance the atom which has the maximum number of atoms on either side of the equation. Here Oxygen has 2 atoms on LHS. To balance this, we need to multiply 2 on the RHS so that number of oxygen atoms becomes same on both sides.

    $$\boldsymbol{Mg + O_2 \rightarrow 2MgO}$$

iv) However, this makes the number of Magnesium atoms change to 2 on RHS.

To balance this, we need to multiply the Magnesium by 2 on LHS.

$$\boldsymbol{2Mg + O_2 \rightarrow 2MgO}$$

v) Now we can see that the atoms of elements are equal on both sides.

vi) Now write the physical states of reactants and products as well.

$$\boldsymbol{2Mg\ (s) + O_2\ (g) \rightarrow 2MgO\ (s)}$$

This is a properly balanced chemical equation.

Example: $\boldsymbol{Iron + Water \rightarrow Iron\ (II, III)\ oxide + Hydrogen}$

i) Write the chemical equation: $\boldsymbol{Fe + H_2O \rightarrow Fe_3O_4 + H_2}$

ii) Count the number of atoms on both sides of the equation.

Element	No. of atoms at reactant side (LHS)	No. of atoms at product side (RHS)
$\boldsymbol{Fe}$	1	3
$\boldsymbol{H}$	2	2
$\boldsymbol{O}$	1	4

iii) Here Oxygen has 4 atoms on RHS. To balance this, we need to multiply 4 on the LHS with H_2O as it contains the oxygen atom so that number of oxygen atoms becomes same on both sides.

$$\boldsymbol{Fe + 4H_2O \rightarrow Fe_3O_4 + H_2}$$

iv) However, this makes the number of Hydrogen atoms change to 8 on LHS. To balance this, we need to multiply the Hydrogen by 4 on RHS.

$$\boldsymbol{Fe + 4H_2O \rightarrow Fe_3O_4 + 4H_2}$$

v) Lastly, we can see that on RHS we have 3 iron atoms and on the LHS we have 1 iron atom. Hence multiplying 3 with Iron atom on LHS to balance the number of iron atoms.

$$\boldsymbol{3Fe + 4H_2O \rightarrow Fe_3O_4 + H_2}$$

vi) Now, writing the physical states to complete the chemical equation:

$$\boldsymbol{3Fe\ (s) + 4H_2O\ (g) \rightarrow Fe_3O_4\ (s) + H_2\ (g)}$$

i. $Iron\ (II, III)\ oxide$ is a mixed oxide containing both Fe^{2+} & Fe^{3+}. It is commonly called $Magnetite$. It is strongly magnetic.

ii. Iron reacts with hot steam, not with liquid water.

TYPES OF CHEMICAL REACTIONS

The various chemical reactions can be classified in the following types:

1. Exothermic & Endothermic Reaction
2. Combination Reaction
3. Decomposition Reaction
4. Displacement Reaction
5. Double Displacement Reaction
6. Redox Reaction

❖ EXOTHERMIC & ENDOTHERMIC REACTIONS:

Reactions in which heat is released along with formation of products are called Exothermic reactions.

E.g. Burning of natural gas such as methane.

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

Reactions which require energy in the form of heat, light or electricity i.e. in order to break the reactants it absorbs heat are called Endothermic reactions.

E.g. 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.

$$2NH_4Cl + Ba(OH)_2 \rightarrow 2NH_4OH + BaCl_2$$

❖ COMBINATION REACTIONS:

The reactions in which two or more reactants combine to form a single product are called combination reactions. *Most of the combination reactions are exothermic.*

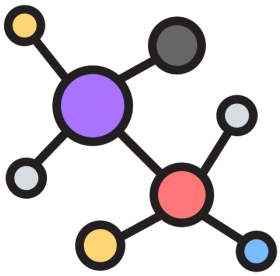
E.g.

i) Burning of coal: $C\,(s) + O_2\,(g) \rightarrow CO_2\,(g)$

ii) Formation of water: $2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(l)$

iii) The reaction between Quicklime and Water to form Slaked lime:

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



❖ DECOMPOSITION REACTIONS:

The reaction in which a compound splits into two or more simple substances is called decomposition reaction. *Most of the decomposition reactions are endothermic.*

Based on the form of energy absorbed, decomposition reactions are classified into 3 types:

i) **Thermal Decomposition:** When decomposition is carried out by heating is called thermal decomposition.

E.g. When Calcium carbonate is heated, it decomposes into Calcium oxide and Carbon dioxide.

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

E.g. When Lead nitrate is heated, it decomposes into Lead oxide, Nitrogen dioxide and Oxygen.

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

ii) **Electrolytic Decomposition:** When decomposition is carried out by passing electricity is called electrolytic decomposition.

E.g. When electricity is passed through water, it decomposes into Hydrogen and Oxygen.

$$2H_2O \xrightarrow{electricity} 2H_2 + O_2$$

E.g. When an electric current is passed through a solution of Sodium chloride, it decomposes into Sodium hydroxide, Hydrogen gas and Chlorine gas.

$$2NaCl + 2H_2O \xrightarrow{electricity} 2NaOH + H_2 + Cl_2$$

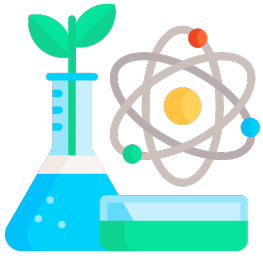
iii) **Photolytic Decomposition:** When decomposition is carried out in presence of sunlight is called photolytic decomposition.

E.g. When Silver chloride is put in sunlight, it decomposes into Silver metal and Bromine gas.

$$2AgCl_2 \xrightarrow{sunlight} 2Ag + Cl_2$$

E.g. When Silver bromide is put under sunlight, it decomposes into silver metal and Bromine gas.

$$2AgBr \xrightarrow{sunlight} 2Ag + Br_2$$



❖ DISPLACEMENT REACTIONS:

The chemical reactions in which a more reactive element displaces a less reactive element from its salt solution. It is also known as 'Substitution reaction / Single-displacement reaction / Replacement reaction'

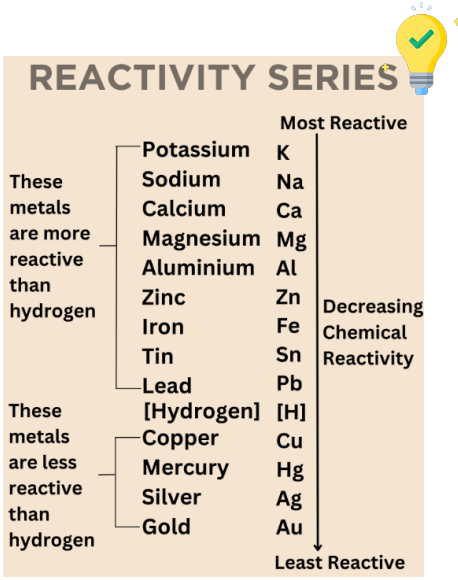
E.g. When Zinc reacts with Copper sulphate, Zinc displaces Copper from Copper sulphate and forms Zinc sulphate and Copper metal.

$$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$$

E.g. When Zinc reacts with Hydrochloric acid, Zinc displaces Hydrogen from Hydrochloric acid and gives Zinc chloride and Hydrogen gas.

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

E.g. When Silver metal is dipped in Copper nitrate, no reaction takes place as Silver metal is less reactive than Copper.



❖ DOUBLE-DISPLACEMENT REACTIONS:

The chemical reactions in which compounds are formed by mutual exchange of ions between two compounds. This reaction occurs mostly in aqueous solutions. This type of reaction takes place mostly to form a more stable product by exchanging of ions. In this reaction, mostly precipitate is formed. This is why it is also called precipitation reaction.

E.g. Sodium sulphate when reacts with Barium chloride, Sodium and Barium atoms exchange their place to form Barium sulphate and Sodium chloride.

$$Na_2SO_4\,(aq) + BaCl_2\,(aq) \rightarrow BaSO_4\,(s) + 2NaCl\,(aq)$$

E.g. When Sodium hydroxide (a base) reacts with Hydrochloric acid (an acid), Sodium chloride (a salt) and water are formed.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

❖ REDOX REACTIONS:

- ✓ **Oxidation:** In a reaction, addition of oxygen or non-metallic element / removal of hydrogen or metallic element from a compound is known as oxidation.
  E.g. $4Fe + 3O_2 \rightarrow 2Fe_2O_3$, here Fe is gaining an oxygen and hence Fe is getting oxidized.
  - ***Oxidizing agent:*** Compounds which can add oxygen or remove hydrogen are known as Oxidizing agent.
    E.g. **Nitric acid** $[HNO_3]$, **Potassium permanganate** $[KMnO_4]$ are good oxidizing agents.

- ✓ **Reduction:** In a reaction, addition of hydrogen or metallic element / removal of oxygen or non-metallic element from a compound is known as reduction.
  E.g. $CuO + H_2 \rightarrow Cu + H_2O$, here Cu is losing an oxygen and hence Cu is getting reduced.
  - **Reducing agent:** Compounds which can remove oxygen or add hydrogen are known as Reducing agent.
    E.g. **Carbon monoxide** $[CO]$, **Formic acid** $[HCOOH]$, **Oxalic acid** $[(COOH)_2]$ are good reducing agents.

The chemical reactions in which both oxidation and reduction takes place at the same time are called Redox reactions.

E.g. When Sodium hydroxide reacts with Hydrochloric acid, it gives Sodium chloride and water.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

In this reaction, Sodium hydroxide is reduced to Sodium chloride as hydrogen is removed from Sodium hydroxide. Also, Hydrochloric acid is oxidized to form water. as oxygen is added to Hydrogen chloride and non-metallic element chloride is removed.

In this reaction, Oxidation and Reduction both takes place simultaneously, thus it is an example of Redox reaction.

❖ EFFECTS OF REDOX REACTIONS IN DAILY LIFE:

(a) Corrosion: Corrosion is a slow and steady process of destruction of a metal by the action of air, moisture, chemicals etc. It is a redox reaction where metal gets oxidised to metal oxide and oxygen gets reduced to oxide ion.

- **Rusting: Brown coating** on the surface of **iron** is known as rusting. When the surface of iron is in contact with moisture and other gases, an electro-chemical reaction occurs. Here, Fe^{2+} ions are oxidized to Fe^{3+} ions and then Fe^{3+} ions combine with OH^- ions to form $Fe(OH)_3$. This becomes **rust** i.e. Hydrated Ferric Oxide $(Fe_2O_3.xH_2O)$.

$$\mathbf{4\,Fe\,(s) + 3O_2\,(g) + x.H_2O\,(l) \rightarrow 2Fe_2O_3.xH_2O\,(s)}$$

- **Green coating** on the surface of **copper** articles and **black coating** on **silver** ornaments are other examples of corrosion.

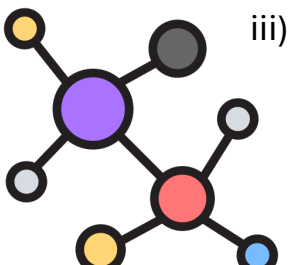
➢ **Prevention of Rusting:** Corrosion is prevented by not allowing the metal surface to come in contact with moisture, CO_2 and O_2. This is done by the following methods:

i) Metal surfaces are painted to keep out air and moisture.
ii) Application of oil and grease on the surface of iron tools.
iii) By alloying with other metals with more resistance to corrosion. E.g. Stainless steel
iv) By the process of **Galvanization**. This is a process of coating Zinc on Iron sheets by using electric current. In this Zinc forms a protective layer of Zinc carbonate on the surface of iron.
v) By the process of **Electroplating**. It is a method of coating one metal with another by passing electric current. E.g. Silver plating, Nickel plating. etc

(b) Rancidity: The oxidation of fats and oils when exposed to air is known as rancidity. It leads to bad smell and bad taste of food. Rancidity is the chemical decomposition of fats, oils and other lipids.

➢ **Prevention of Rancidity:**

i) Storing food in air tight containers.
ii) Storing food in refrigerators.
iii) Adding antioxidents such as **Ascorbic acid**, **BHA (Butylated hydroxyanisole)** etc.



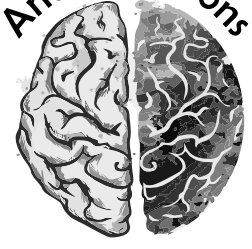
SOME ADDITIONAL COMPOUNDS & FORMULAE that you should know

Compounds	Formula		Compounds	Formula
Lead nitrate	$Pb(NO_3)_2$		Phosphoric acid	H_3PO_4
Lead monoxide	PbO		Acetic acid	CH_3COOH
Lead iodide	PbI_2		Zinc phosphate	$Zn_3(PO_4)_2$
Lead acetate	$(CH_3COO)_2Pb$		Zinc acetate	$Zn(CH_3COO)_2$
Nitrogen dioxide	NO_2		Ferrous sulphide	FeS
Potassium acetate	CH_3COOK		Ferrous sulphate	$FeSO_4$
Potassium iodide	KI		Potassium sulphate	K_2SO_4
Potassium nitrate	KNO_3		Ammonium hydroxide	NH_4OH
Potassium nitrite	KNO_2		Aluminium oxide	Al_2O_3

EXTRA INFORMATION that you should know

- ✓ Precipitate: An insoluble substance formed in a chemical reaction.
- ✓ Two metals that do not corrode: Gold and Platinum.
- ✓ Decomposition reactions that occur in nature: Rotting of fruits and vegetables.
- ✓ Exothermic reactions that occur in nature: Respiration.
- ✓ Endothermic reactions that occur in nature: Photosynthesis.

Chemical Reactions And Equations



Types of chemical reactions

Oxidation
$2Cu + O_2 \xrightarrow{heat} 2CuO$

Reduction
$CuO + H_2 \xrightarrow{heat} Cu + H_2O$

Oxidation-Reduction
- Reduction: Addition of H_2, Removal of O_2
- Oxidation: Addition of O_2, Removal of H_2

Double displacement
$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$
Exchange of ions or reactants

Combination
$C(s) + O_2(g) \rightarrow CO_2(g)$
Addition of two elements or compounds to synthesize new compound

Exothermic
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) + Heat$
Heat released

Endothermic
$2AgBr(s) \xrightarrow{Sunlight} 2Ag(s) + Br_2(g)$
Heat absorbed
Energy absorbed: endothermic
Energy released: exothermic

Decomposition
$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$
Reactant decomposes to form two or more compounds.

Displacement
$Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$
More reactive element displaces a less active metal from its salt solution

Effects of Oxidation / Reduction

Rancidity
Slow oxidation of oil and fat

Prevention
- by adding antioxidants
- use air tight containers

Corrosion
Deterioration of metals by action of air, moisture, chemicals, etc.

Prevention of corrosion
- Paint iron articles
- Oiling and greasing machine parts
- Galvanization

Effects of corrosion
- Causes damage to ships, car bodies, bridges, railings.
- It is a wasteful process

Reactions

How to write the reaction In-words
Simplest way to write word equation
e.g., Magnesium + Oxygen → Magnesium oxide

In symbol
e.g., $2Mg + O_2 \rightarrow 2MgO$

change in
- Colour
- State
- Temperature

Steps to balance the reaction

- Follows law of conservation of mass
- No. of atoms remains same
- Elements with maximum atoms balanced and aqueous as (*aq*) first
- Reactants & products both balanced
- Physical state of elements written as gas (*g*), liquid (*l*) and solid (*s*) aqueous as (*aq*)

Trace the Mind Map
First Level · Second Level · Third Level