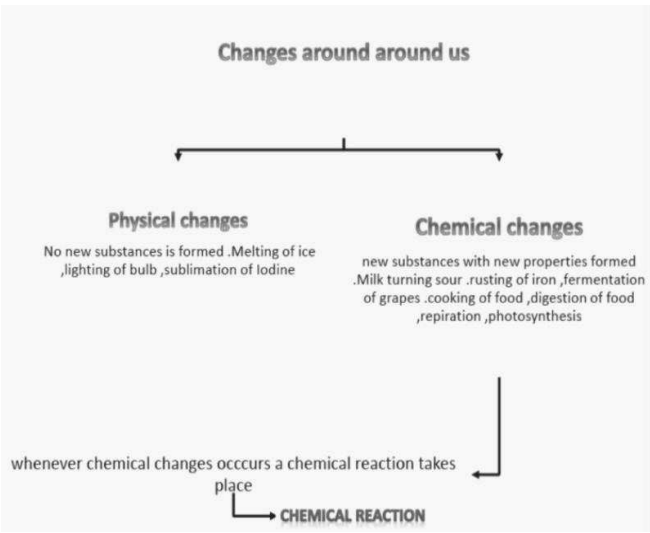
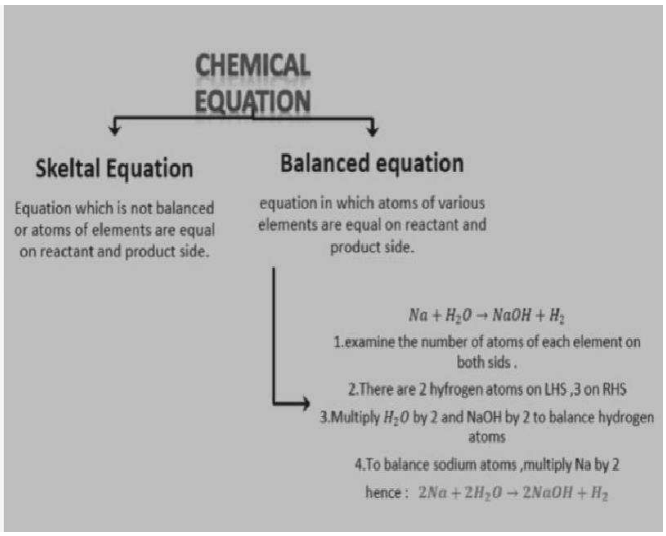
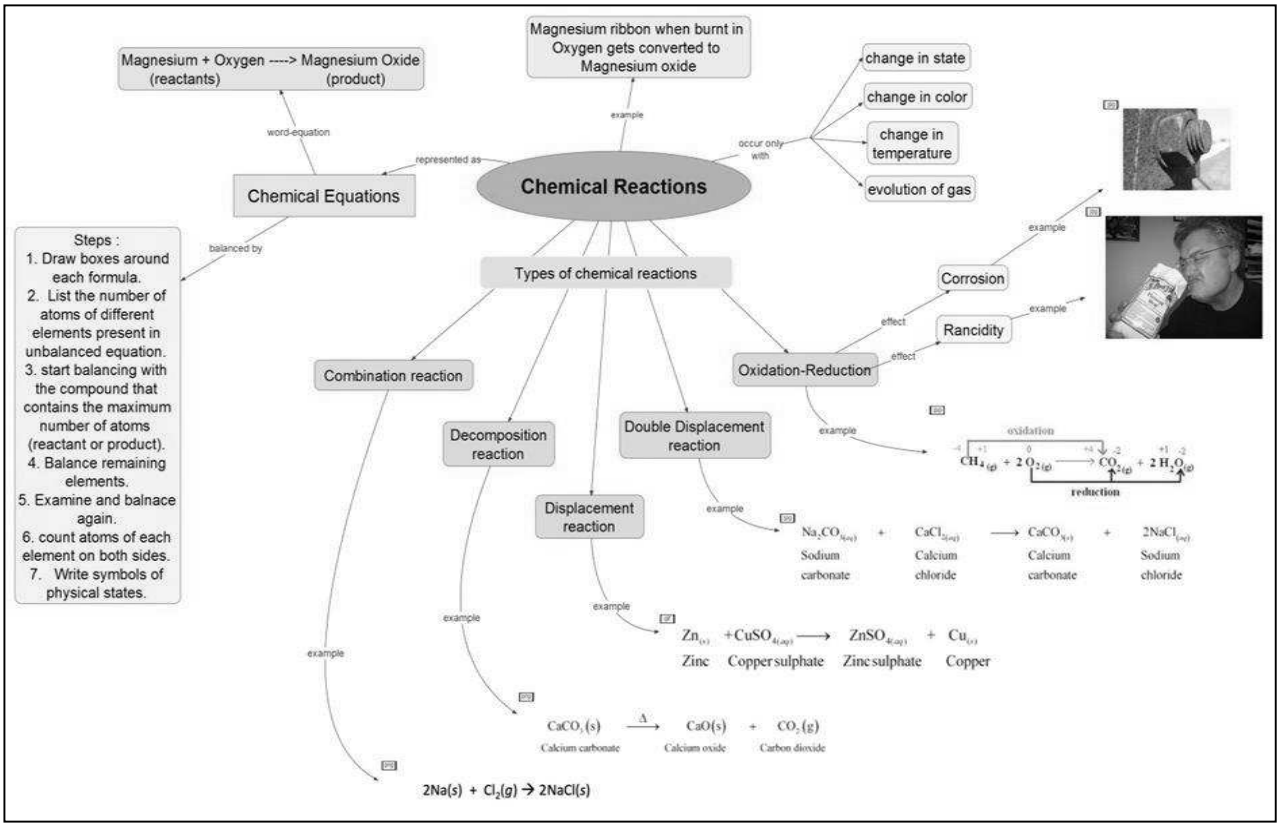
# CHAPTER 1
## CHEMICAL REACTIONS AND EQUATIONS

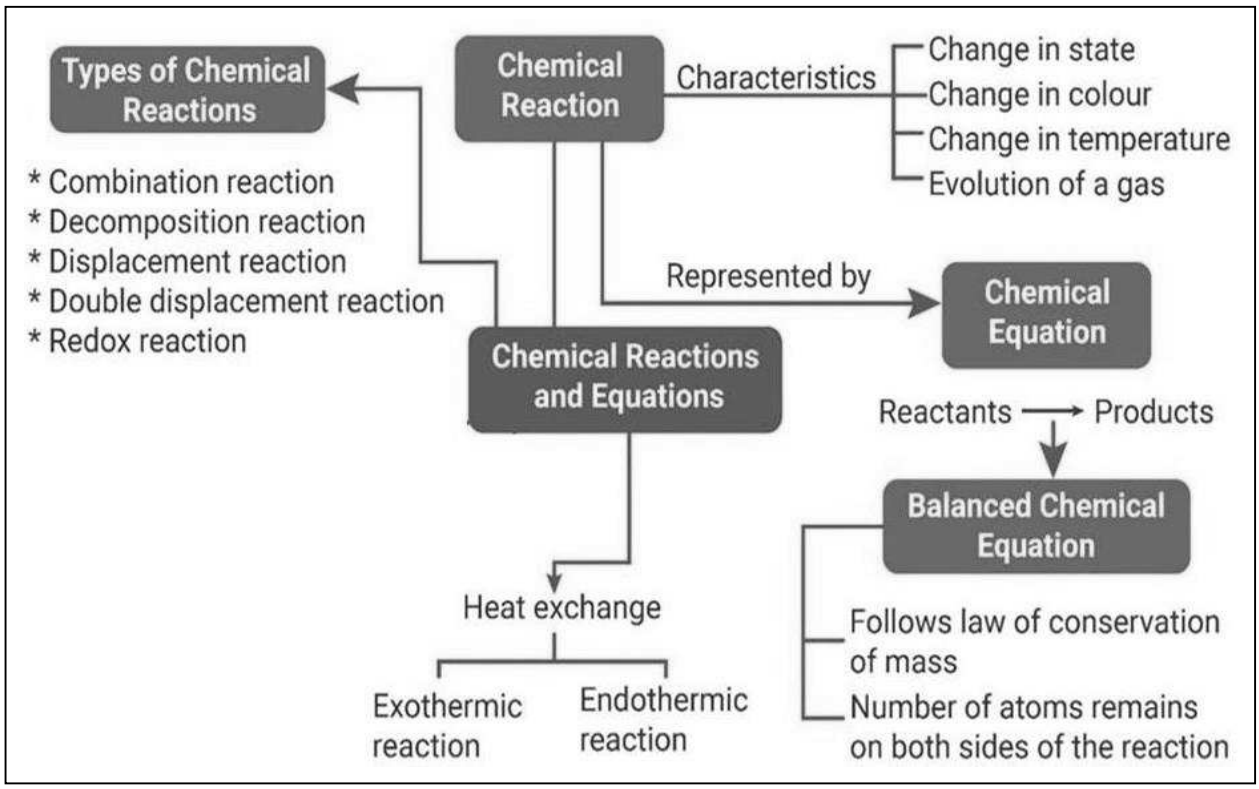
**Content**

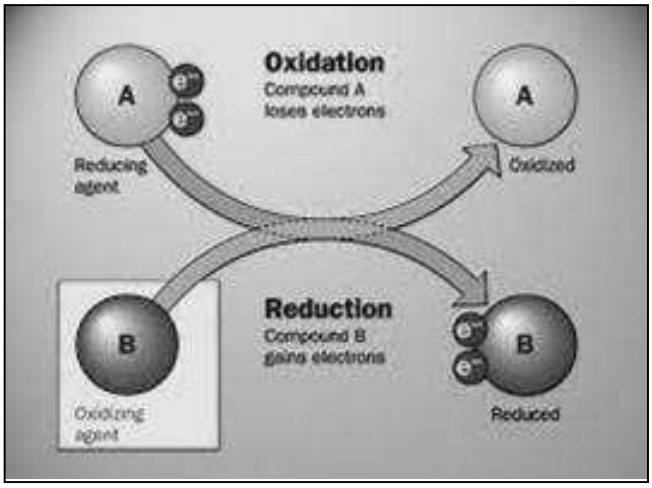
Chemical reactions: Chemical equation, Balanced chemical equation, Implications of a balanced chemical equation, types of chemical reactions: combination, decomposition, displacement, double displacement, precipitation, endothermic, exothermic reactions, oxidation and reduction.

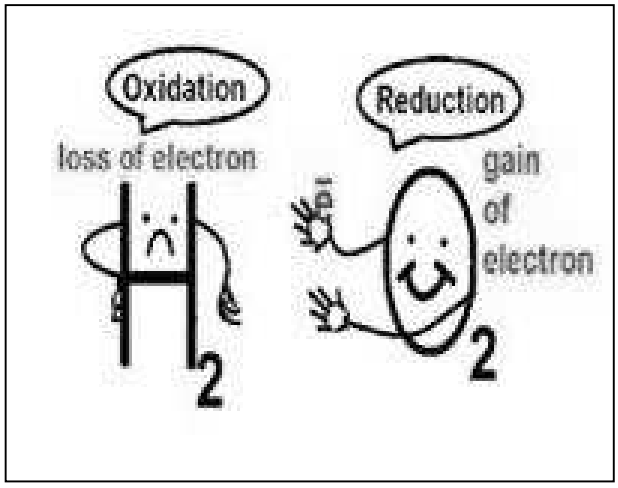





**Chemical Reaction:** A chemical reaction is a process in which one or more substances, also called reactants, are converted to one or more different substances, known as products. Substances are either chemical elements or compounds. The following activities are as given below:

1. Magnesium ribbon burns with a dazzling white flame and changes into a white powder. This powder is magnesium oxide. It is formed due to the reaction between magnesium and oxygen present in the air.
2. Take lead nitrate solution in a test tube; add potassium iodide solution to this, and then we observed that lead (II) iodide and potassium nitrate is formed.

3. Take a few zinc granules in a conical flask, add dilute hydrochloric acid or sulphuric acid to this, and then we observed that hydrogen gas is evolved.
   From the above three activities, any observation as stated below helps us to determine whether a chemical reaction has taken place-
   - Change in state
   - Change in colour
   - Evolution of gas
   - Change in temperature.

**Chemical Equations:**

Chemical equations are symbolic representations of chemical reactions in which the reactants and the products are expressed in terms of their respective chemical formulae.

**Rules for writing chemical equation:**

Certain rules have to be followed while writing a chemical equation.

1. The reactants taking part in the reaction are written in terms of their symbols or molecular formulae on the left-hand side of the equation.
2. A plus (+) sign is added between the formulae of the reactants.
3. The products of reaction are written in terms of their symbols or molecular formulae on the right-hand side of the equation.
4. A plus (+) sign is added between the formulae of the products.
5. In between the reactants and the products an arrow sign (⟶) is inserted to show which way the reaction is occurring.
   A + B ⟶ C + D
   Reactants Products

   In this hypothetical equation, A and B are the reactants, and C and D are the products. The arrow indicates that the reaction proceeds towards the formation of C and D.

**Representing the Direction of the Chemical Reaction**

The reactants and the products can be separated by one of the following four symbols:

- In order to describe a net forward reaction, the symbol → is used.
- In order to describe a net backward reaction, the symbol ← is used.
- In order to describe a reaction that occurs in both forward and backward directions, the symbol ⇄ is used.
- In order to describe a state of chemical equilibrium, the symbol ⇌ is used.

Multiple entities on either side of the reaction symbols describe above are separated from each other with the help of the + symbol in a chemical equation. It can be noted that the → symbol, when used in a chemical equation, is often read as gives rise to or yields.

**Representing the Physical States of the Reacting Entities**

These symbols may be one of the following:

- The symbol (s) describes an entity in the solid state
- The symbol (l) denotes the liquid state of an entity
- The symbol (g) implies that the entity is in the gaseous state.
- The (aq) symbol corresponding to an entity in a chemical equation denotes an aqueous solution of that entity.

In some reactions, a reactant or a product may be in the form of a precipitate which is insoluble in the solution that the reaction is taking place in. The ↓ symbol is written next to the chemical formula of these entities to describe them as precipitates.

**Representing the Input of Energy in a Chemical Equation**:

The Greek letter delta in its capitalized form (Δ) is used to state that an input of heat energy is required by the reaction.

**An example for which is represented below:**

The reaction between hydrogen gas and oxygen gas to form water.

$$2H_2 + O_2 \rightarrow 2H_2O \quad (1)$$

Reactants Products

The reacting entities are written on the left-hand side (2 molecules of hydrogen and one molecule of oxygen) whereas the products are written on the right-hand side (2 molecules of water is formed) of the chemical equation.

Equation (1) divided by 2 both sides and we get

$$H_2 + \tfrac{1}{2} O_2 \rightarrow H_2O$$

Reactant Product

The reacting entities are written on the left-hand side (1 molecules of hydrogen and half molecule of oxygen) whereas the products are written on the right-hand side (1 molecules of water) of the chemical equation.

It can also be observed that there are coefficients assigned to each of the symbols of the corresponding reactants and products. These coefficients of entities in a chemical equation are the exact value of the stoichiometric number for that entity.

## Balanced Chemical Equations:

**The law of conservation of mass** that mass can neither be created nor destroyed in a chemical reaction. The total mass of the elements present in the products of a chemical reaction has to be equal to the total mass of the elements present in the reactants.

**EXAMPLE 1:**

Write the chemical equation for the formation of magnesium oxide.

Step 1: Magnesium burns in oxygen to give magnesium oxide. Here, the reactants are magnesium and oxygen. The product is magnesium oxide.

Step 2: Thus, the word equation is

Magnesium + Oxygen ⟶ Magnesium oxide

Step 3: Replacing the names with symbols and formulae, we get the chemical equation as

$$\mathbf{Mg + O_2 \longrightarrow MgO}$$

**Reactants Products**

Step 4: The numbers of atoms of the elements are

| Element | Number of atoms in LHS | Number of atoms in RHS |
|---|---|---|
| Mg | 1 | 1 |
| O | 2 | 1 |

To balance oxygen on both sides, multiply RHS by 2, i.e.,
$Mg + O_2 \longrightarrow 2MgO$
Now, the number of oxygen atoms is balanced but the number of magnesium atoms is not. Therefore, multiply magnesium on the LHS by 2. Thus, the equation becomes
$2Mg + O_2 \longrightarrow 2MgO$
this is the balanced chemical equation.

**EXAMPLE 2:**
The word-equation represented as –
Zinc + Sulphuric acid $\longrightarrow$ Zinc sulphate + Hydrogen
The above word-equation may be represented by the following chemical equation –
$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

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 is a balanced chemical equation.

**EXAMPLE 3:**
Let us try to balance the following chemical equation –
$Fe + H_2O \longrightarrow Fe_3O_4 + H_2$

**Step I:** To balance a chemical equation, first draw boxes around each formula. Do not change anything inside the boxes while balancing the equation.
$Fe + H_2O \longrightarrow Fe_3O_4 + H_2$

**Step II:** List the number of atoms of different elements present in the unbalanced equation.

| **Element** | **Number of atoms in reactants (LHS)** | **Number of atoms in products (RHS)** |
|---|---|---|
| Fe | 1 | 3 |
| H | 2 | 2 |
| O | 1 | 4 |

**Step III:**

| Element | Number of atoms in reactants (LHS) | Number of atoms in products (RHS) |
|---|---|---|
| Fe | 1 x 3 | 3 |
| H | 2 x 4 | 2 x 4 |
| O | 1 x 4 | 4 |

Balanced equation:

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

As the number of atoms of each element is the same on both sides of the arrow is a balanced chemical equation.

**List some Examples of Chemical Equations.**

A few examples of chemical equations are listed in bulleted text below.

- $PCl_5 + H_2O \rightarrow H_3PO_4 + HCl$
- $SnO_2 + H_2 \rightarrow H_2O + Sn$
- $TiCl_4 + H_2O \rightarrow TiO_2 + HCl$
- $H_3PO_4 + KOH \rightarrow K_3PO_4 + H_2O$
- $Na_2S + AgI \rightarrow NaI + Ag_2S$
- $Fe + CuCl_2 \longrightarrow FeCl_3 + Cu$
- $CaCl_2 + AgNO_3 \rightarrow Ca(NO_3)_2 + AgCl\downarrow$

**TYPES OF CHEMICAL REACTIONS:**

1. **Combination Reaction**: A *reaction in which two or more substances combine to form a single new substance.* Combination reactions can also be called synthesis reactions.

1. $CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq)$
   (Quick lime) (Slaked lime)
2. $Ca(OH)_2(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$
   (Calcium hydroxide) (Calcium carbonate)
3. $C(s) + O_2(g) \longrightarrow CO_2(g)$
4. $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$
5. $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$
6. $C_6H_{12}O_6(aq) + 6O_2(aq) \longrightarrow 6CO_2(aq) + 6H_2O(l) + energy$
   (Glucose)

2. **Decomposition Reaction**: A reaction in which a compound breaks down into two or more simpler substances.

Most decomposition reactions require an input of energy in the form of heat, light, or electricity.

1. $2FeSO_4(s) \xrightarrow{Heat} Fe_2O_3(s) + SO_2(g) + SO_3(g)$
   (Ferrous sulphate) (Ferric oxide)
2. $CaCO_3(s) \xrightarrow{Heat} CaO(s) + CO_2(g)$
   (Limestone) (Quick lime)
3. $2AgCl(s) \xrightarrow{Sunlight} 2Ag(s) + Cl_2(g)$
4. $2Pb(NO_3)_2(s) \xrightarrow{Heat} 2PbO(s) + 4NO_2(g) + O_2(g)$

   (Lead nitrate) (Lead oxide) (Nitrogen dioxide) (Oxygen)
5. $2AgBr(s) \xrightarrow{Sunlight} 2Ag(s) + Br_2(g)$

3. **Displacement Reaction:** A chemical reaction in which a more reactive element displaces a less reactive element from its aqueous salt solution.

1. $Fe(s) + CuSO_4(aq) \longrightarrow FeSO_4(aq) + Cu(s)$
   (Copper sulphate) (Iron sulphate)
2. $Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$
   (Copper sulphate) (Zinc sulphate)
3. $Pb(s) + CuCl_2(aq) \longrightarrow PbCl_2(aq) + Cu(s)$
   (Copper chloride) (Lead chloride)

4. **Double Displacement Reaction:** A chemical reaction in which ions gets exchanged between two reactants which form a new compound is called a double displacement reaction.

1. $Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4(s) + 2NaCl(aq)$
   (Sodium sulphate) (Barium chloride) (Barium sulphate) (Sodium chloride)

5. **Precipitation reaction:** A precipitation reaction is a chemical reaction that occurs in aqueous solution and form precipitates. The insoluble salt that falls out of the solution is known as the precipitate. It can occur when two solutions containing different salts are mixed, and a cation/anion pair in the resulting combined solution forms an insoluble salt. For example,

Aqueous silver nitrate ($AgNO_3$) is added to a solution containing potassium chloride (KCl), and the precipitation of a white solid, silver chloride (AgCl), is observed:

$AgNO_3(aq) + KCl(aq) \rightarrow AgCl(s) + KNO_3(aq)$

**EXOTHERMIC AND ENDOTHERMIC CHEMICAL REACTIONS:**

**EXOTHERMIC CHEMICAL REACTIONS:** Reactions in which heat is released along with the formation of products are called exothermic reactions. For examples:

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

$C_6H_{12}O_6(aq) + 6O_2(aq) \longrightarrow 6CO_2(aq) + 6H_2O(l) + energy$
(Glucose)

**ENDOTHERMIC CHEMICAL REACTIONS:** A reaction that the system absorbs energy from its surrounding in the form of heat.
When ammonium chloride ($NH_4Cl$) is dissolved in water, an endothermic reaction takes place. The salt dissociates into ammonium ($NH_4^+$) and chloride ($Cl^-$) ions. The chemical equation can be written as follows:

**$NH_4Cl$ (s) + $H_2O$ (l) + Heat ⟶ $NH_4Cl$ (aq)**

**$N_2 + O_2 \longrightarrow 2NO$**

Other Endothermic Processes:

(i) The melting of ice to form water.
(ii) Evaporation of liquid water, forming water vapour.
(iii) Sublimation of solid $CO_2$.
(iv) The baking of bread.

**OXIDATION:** Oxidation refers to the loss of electrons by amolecule, atom, or ion.

**REDUCTION**: Reduction refers to the gain of electrons by amolecule, atom, or ion.

**REDOX REACTIONS:** A reduction-oxidation or redox reaction is a type of chemical reaction in which reduction and oxidation occur at the same time.

**OXIDATION:** If substance gains oxygen during a reaction, it is said to, be oxidised. For example:

$2Cu + O_2 \longrightarrow 2CuO$

**REDUCTION:** If substance loses oxygen during a reaction, it is said to, be reduced. For example:

$CuO + H_2 \longrightarrow Cu + H_2O$

**REDOX REACTIONS:** If one reactant gets oxidised while other gets reduced during a reaction. Such reactions are called oxidation-reduction reaction or Redox reaction.

OX

$CuO + H_2 \xrightarrow{Heat} Cu + H_2O$

RED

Some other examples of Redox reactions are:

1. $ZnO + C \longrightarrow Zn + CO$

OX

$ZnO + C \longrightarrow Zn + CO$

RED

2. $MnO_2 + HCl \longrightarrow MnCl_2 + H_2O + Cl_2$

OX

$MnO_2 + HCl \longrightarrow MnCl_2 + H_2O + Cl_2$

RED