Chemical Reactions

Definition and Characteristics

A chemical reaction is a process in which the original substance(s) loses its nature and identity and forms new substance(s) with different properties. This occurs due to breaking of chemical bonds and formation of new chemical bonds.

The substances that take part in a chemical reaction are called reactants, and the substances formed are called products.

Identification of Chemical Reactions

Chemical reactions can be identified by the following observations:

- Change in state (e.g., solid to liquid or gas)
- Change in colour
- Evolution of gas
- Change in temperature
- Formation of a precipitate (solid)

Examples of Characteristics

For example, burning candle wax changes state and colour; zinc reacting with sulfuric acid produces hydrogen gas; quicklime reacting with water produces heat; mixing sodium sulfate and barium chloride forms a white precipitate of barium sulfate.

Chemical Equations

Definition and Representation

A chemical equation is the symbolic representation of a chemical reaction using symbols and formulae. It concisely shows the reactants and products involved.

Word and Chemical Equations

Example of a word equation:

Magnesium + Oxygen → Magnesium oxide

This can be converted into a chemical equation:

$2Mg + O_2 \rightarrow 2MgO$

Writing Chemical Equations

- Write symbols and formulae of reactants on the left side separated by plus (+) signs.
- Write symbols and formulae of products on the right side separated by plus (+) signs.
- Use an arrow (→) between reactants and products.
- Mention physical states of substances (solid, liquid, gas, aqueous) in brackets.

Skeletal and Balanced Equations

A skeletal chemical equation shows only the symbols and formulae of reactants and products without balancing.

Example: $Mg + O_2 \rightarrow MgO$

A balanced chemical equation has equal numbers of atoms of each element on both sides, satisfying the Law of Conservation of Mass.

Example of balancing:

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

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

Types of Chemical Reactions

Combination Reaction

Two or more reactants combine to form a single product.

Examples:

- Burning of coal: $C(s) + O_2(g) \rightarrow CO_2(g)$
- Formation of water: $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
- Quicklime formation: $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) + Heat$

Exothermic Reactions

Reactions that release heat along with products.

Examples:

- Burning of natural gas: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) + Heat$

- Respiration: $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(aq) + 6H_2O(l) + Energy$

Decomposition Reaction

A compound splits into two or more simpler substances.

General form: A → B + C

Thermal Decomposition

Decomposition by heating.

Examples:

- Heating ferrous sulfate: $FeSO_4 \cdot 7H_2O$ (green) → Fe_2O_3 (red-brown) + SO_2 + SO_3
- Heating limestone: $CaCO_3 \rightarrow CaO + CO_2$

Electrolytic Decomposition

Decomposition by passing electricity.

Example:

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$

Photolytic Decomposition

Decomposition in presence of sunlight.

Examples:

- $2AgCl \rightarrow 2Ag + Cl_2$ (on exposure to sunlight)
- $2AgBr \rightarrow 2Ag + Br_2$ (on exposure to sunlight)

Endothermic Reaction

Reactions that require energy (heat, light, or electricity) to proceed.

Example:

$NH_4Cl(s) + H_2O(l) \rightarrow NH_4Cl(aq)$ - Heat

Displacement Reaction

A more reactive element displaces a less reactive element from its salt solution.

Examples:

- $Fe + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu$
- $Zn + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu$

Double Displacement Reaction

Mutual exchange of ions between two compounds forming new compounds.

Example:

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

The formation of $BaSO_4$ precipitate is called a precipitation reaction.

Oxidation and Reduction

Oxidation is the loss of electrons or gain of oxygen; reduction is the gain of electrons or loss of oxygen.

Example of oxidation:

$2Cu + O_2 \rightarrow 2CuO$ (with heat)

Example of reduction:

$CuO + H_2 \rightarrow Cu + H_2O$

Redox Reaction

A reaction involving simultaneous oxidation and reduction.

Example:

$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$

In this reaction, chlorine is oxidized and manganese is reduced.

Solved Examples

Example 1

Q. Balance the chemical equation: $Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Solution:

Step 1: Write unbalanced equation:

$Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Step 2: Count atoms on both sides:

- Fe: Left = 1, Right = 3
- H: Left = 2 (from H_2O), Right = 2 (from H_2)
- O: Left = 1, Right = 4

Step 3: Balance Fe by putting 3 in front of Fe:

$3Fe + H_2O \rightarrow Fe_3O_4 + H_2$

Step 4: Balance O by putting 4 in front of H_2O:

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

Step 5: Balance H by putting 4 in front of H_2:

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

Balanced equation achieved.

Example 2

Q. Write the chemical equation for the formation of water from hydrogen and oxygen.

Solution:

Step 1: Write reactants and products:

Hydrogen + Oxygen → Water

Step 2: Write word equation:

Hydrogen + Oxygen → Water

Step 3: Write chemical symbols and formulae:

$H_2 + O_2 \rightarrow H_2O$

Step 4: Balance the equation:

$2H_2 + O_2 \rightarrow 2H_2O$

Balanced chemical equation.

Practice Set

Conceptual Questions

- **Level 1:** What is a chemical reaction? List two observations that indicate a chemical reaction has occurred.
- **Level 2:** Explain the difference between a skeletal chemical equation and a balanced chemical equation.

Application-based Question

- **Level 3:** Balance the following chemical equation and identify the type of reaction: $Al + HCl \rightarrow AlCl_3 + H_2$

Answer Key

Conceptual Questions

- **Level 1:** A chemical reaction is a process where substances change to form new substances with different properties. Observations include change in colour and evolution of gas.
- **Level 2:** A skeletal equation shows reactants and products without balancing atoms. A balanced equation has equal numbers of atoms of each element on both sides.

Application-based Question

- **Level 3:** Balanced equation: $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$
  Type: Displacement reaction (aluminium displaces hydrogen from hydrochloric acid).

Quick Reference Table

Chemical Reactions: Process where reactants form products with new properties.

Chemical Equation: Symbolic representation of a chemical reaction.

Types of Reactions:

- Combination: $A + B \rightarrow AB$
- Decomposition: $AB \rightarrow A + B$
- Displacement: $A + BC \rightarrow AC + B$
- Double Displacement: $AB + CD \rightarrow AD + CB$
- Exothermic: Releases heat
- Endothermic: Absorbs heat
- Redox: Simultaneous oxidation and reduction

Balancing Equations: Equal number of atoms on both sides to satisfy conservation of mass.

Common Mistakes and Misconceptions

- Confusing decomposition with double decomposition reactions.
- Not balancing chemical equations properly.
- Mixing up names of different types of reactions.
- Ignoring physical states in chemical equations.

Glossary

- **Reactants:** Substances that undergo change in a chemical reaction.
- **Products:** New substances formed after a chemical reaction.
- **Precipitate:** Insoluble solid formed in a solution during a reaction.
- **Oxidation:** Loss of electrons or gain of oxygen.
- **Reduction:** Gain of electrons or loss of oxygen.
- **Redox Reaction:** Reaction involving both oxidation and reduction.
- **Exothermic Reaction:** Reaction releasing heat.
- **Endothermic Reaction:** Reaction absorbing heat.