Language of Chemistry

Chemical Reactions

A chemical reaction is a process in which a chemical substance is completely transformed into another substance having different properties. This process is different from the process of physical changes because in physical changes no new substance is formed or the properties of the substance after the change remain the same.

Types of Chemical Reaction

• **Simple chemical reaction:** Those chemical reactions which occur usually in one step and take lesser time to complete are known as simple chemical reactions. For example, burning of fuel and rusting of iron.

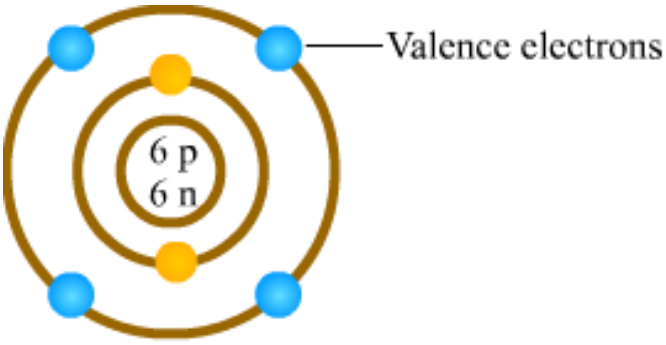
• **Complex chemical reaction:** Those chemical reactions which take longer time for their completion and occur in more than one step are known as complex chemical reactions. For example, photosynthesis reaction, digestion of food, and all biochemical reactions.

Chemical changes are very important to us as they lead to the formation of substances which help us to grow our food, make our lives more productive and comfortable, cure diseases etc.

Valence Electrons

All chemical reactions occur because the unstable atoms tend to achieve stable electronic configuration. In order to attain stable electronic configuration, an electron may get transferred from one atom to another or may be shared between two atoms.

Those electrons which take part in chemical reactions are known as **valence electrons.** The valence electrons may be in the outer most orbit or in a penultimate orbit of an atom (Penultimate orbit means before the last orbit).



Note: Atoms combine with each other in order to complete their octet. All atoms try to achieve the nearest noble gas configuration, and in doing so they may lose electrons, gain electrons or share electrons. For example, sodium has a total of 11 electrons and its electronic configuration is 2, 8, 1. In order to attain the nearest stable noble gas configuration (Ne = 2,8), sodium losses 1 electron to form Na^+ ion with electronic configuration 2,8.

How do you know whether a chemical reaction has taken place or not?

Some changes that are observed during a chemical reaction are:

Evolution of gas: In many chemical reactions, gas is evolved sometimes with an effervescence. For, example when zinc metal reacts with hydrogen chloride, hydrogen gas is evolved.

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

Change of colour: Sometimes, a colour change occurs during a chemical reaction due to the formation of a new product. For example, when silver chloride is exposed to sunlight it produces black metallic coloured silver with the evolution of chlorine gas.

$2AgCl \rightarrow 2Ag + Cl_2$

Formation of precipitate: In certain chemical reactions, an insoluble solid substance called **precipitate** is formed. For example, silver nitrate reacts with sodium bromide to form a yellow precipitate of silver bromide.

$AgNO_3 + NaBr \rightarrow NaNO_3 + AgBr \downarrow$

Change of state: In some reactions, the change of state is observed in the formation of products from reactants. For example, sodium chloride (aqueous) when reacts with silver nitrate (aqueous) forms sodium nitrate (aqueous) and silver chloride (solid white precipitate).

$NaCl\ (aq) + AgNO_3\ (aq) \rightarrow NaNO_3\ (aq) + AgCl$ (white ppt)

Conditions for Chemical Change

For a chemical reaction to proceed, certain physical conditions are required. These conditions are:

- **Close contact**

Some chemical reactions proceed only when the reactant molecule are brought together in close contact with each other.

The intimate contact can be brought by

- grinding the reactants together
- dissolving the reactants in water

Example: Potassium iodide reacts with mercury chloride when they are thoroughly grinded together.

$$2KI + HgCl_2 \rightarrow HgI_2 + 2KCl$$

- **Heat**

Certain chemical reactions proceed only when reactants are heated together.

Example: The given reaction occurs only when reactant is heated.

$$KClO_3 \xrightarrow{Heat} 2KCl + 3O_2$$

- **Light**

Certain chemical reactions proceed when reactants are exposed to sunlight or diffused sunlight.

Example: The given reaction occurs only when reactants are exposed to sunlight.

$$H_2 + Cl_2 \xrightarrow{sunlight} 2HCl$$

- **Pressure**

Certain chemical reactions proceed when reactants are subjected to a pressure higher than atmospheric pressure.

Example: Nitrogen and hydrogen react in the presence of catalyst when subjected to a pressure between 200- 900 atms.

$$N_2 + 3H_2 \xrightarrow{200-900\ atms} 2NH_3$$

- **Catalytic agent**

Certain chemical reactions proceed in forward direction when brought in contact with a catalyst.

Example: Sulphur dioxide and oxygen react in the presence of asbestos, which acts as a catalyst.

$$SO_2 + O_2 \xleftrightarrow[450°C]{\text{Pt-Asbestos}} 2\,SO_3$$

- **Electric Current**

Certain chemical reactions proceed only when an electric current is passed through reactants in fused state or in aqueous solution.

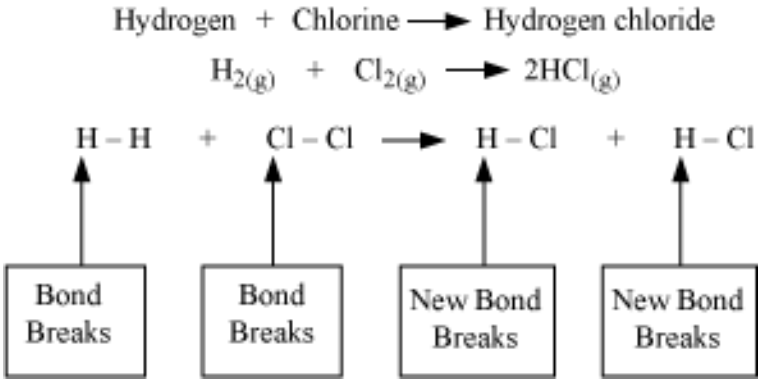
Example: Acidulated water decomposes into hydrogen and oxygen only when electric current is passed.

$$2\,H_2O \xleftrightarrow[\text{Current}]{\text{Electric}} 2\,H_2 + O_2$$

Energy change in chemical reactions

During a chemical reaction, old bonds are broken and new bonds are formed. Energy is required to break the old bonds between the molecules of reactants; this energy is commonly called **activation energy.**

Also, energy is liberated when new bonds are formed. Thus, a chemical change is associated with absorption or release of energy. This energy can be in the form of **heat, sound, or electricity.**



Every substance is associated with a certain amount of energy stored in it in the form of latent energy. This stored energy is called **chemical energy or internal energy.** It is denoted by E.

The internal energy of a substance is the sum total of kinetic energy and potential energy.

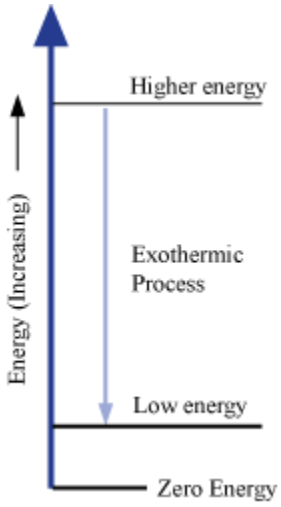
E = K.E. + P.E.

The internal energy is different for different substances. Hence, internal energy for reactants is different for internal energy of products.

The difference between chemical energy of reactants and chemical energy of products is called **energy change of a chemical reaction.**

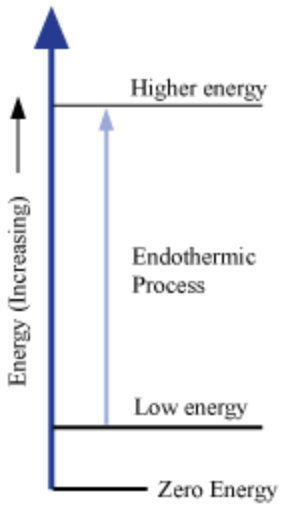
In an **exothermic reaction**, internal energy of reactants is greater than internal energy of the products and therefore, change in the energy will be negative. It is represented as:

Reactants + Energy → Products



In **an endothermic reaction**, the internal energy of reactants is less than the internal energy of the products. It is represented as:

Reactants → Products + Energy

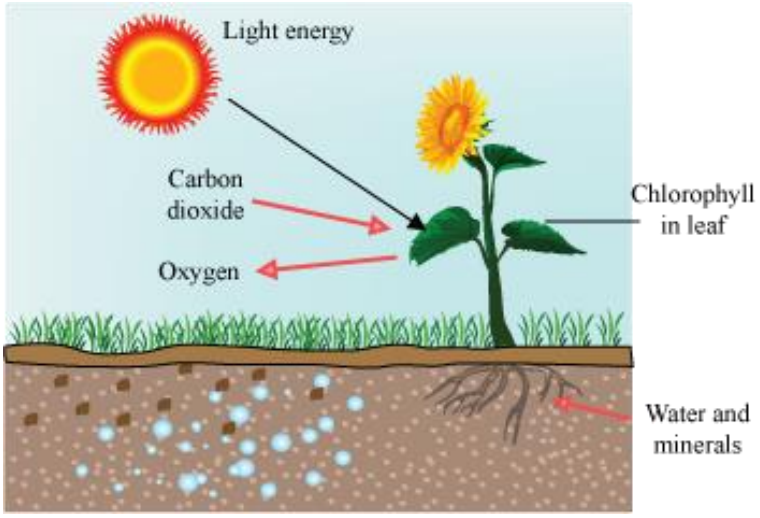


Energy released or absorbed is measured in kilocalories or kilojoules.

Endothermic reactions are the reactions, which absorb energy in the form of heat. The opposite of an endothermic process is an **exothermic process**, one that releases energy in the form of heat.

Photosynthesis is an example of an endothermic chemical reaction. In this process, plants use the energy from the sun to convert carbon dioxide and water into glucose and oxygen.

$$6\,CO_2 + 6\,H_2 \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} 6\,O_2 + C_6H_{12}O_6$$



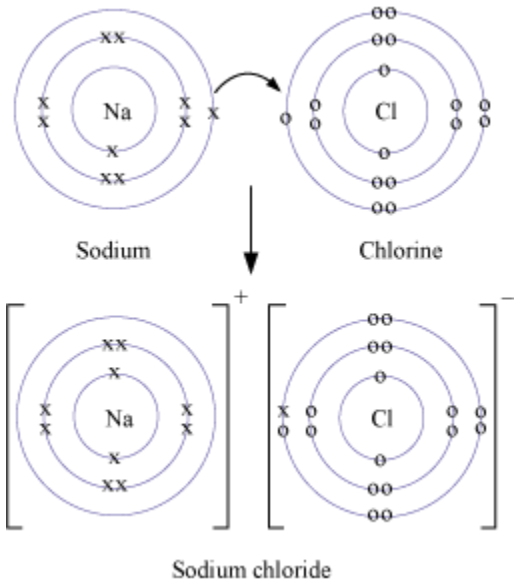
Some other examples of endothermic processes are:

- Depressurising a pressure can

- A chemical cold pack consisting primarily of ammonium nitrate and water
- Melting of solids
- Vaporisation, evaporation, fusion

An example of an exothermic reaction is the mixture of sodium and chlorine to yield table salt. This reaction produces 411 kJ of energy for each mole of salt that is produced.

$$Na_{(s)} + 0.5\ Cl_{2(s)} \longrightarrow NaCl_{(s)}$$



Some examples of exothermic processes are:

- Condensation of rain from water vapour
- Combustion of fuels such as petrol, wood, coal, and oil
- Hydration processes

Balanced Chemical Equations

To describe a chemical reaction more concisely, equations of the reactions are written.

Chemical equation

A chemical equation is a concise form which uses symbols and formulae of the chemical compounds or elements involved in the reaction. It also indicates the number of atoms of each element involved in a reaction.

In a chemical reaction, the total mass of the reactants should be equal to the total mass of the products. This means that the total number of atoms of each element should be equal on both sides of a chemical equation. Such an equation is called a **balanced chemical equation**, and the method by which it is obtained is called the balancing of chemical equations.

Another example of a balanced chemical equation is the reaction of limewater with carbon dioxide, that results in the formation of a precipitate of calcium carbonate and water is represented as:

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \rightarrow \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O\,(l)}$$

In this reaction, calcium hydroxide is present in the form of a solution in water, carbon dioxide is present as a gas, calcium carbonate is produced as a precipitate i.e. in the solid state, and water is formed in the liquid state.

The energy changes involved in a reaction are denoted by writing the changes involved in the equation itself.

If energy is used in the reaction, then it will be written on the left-hand side. If it is released in the process, then it is written on the right-hand side.

For example, combustion of butane (or any other hydrocarbon i.e., the compounds made up of carbon and hydrogen) is accompanied by the evolution of heat and light energy along with the production of carbon dioxide and water. Therefore, the equation for the same will be written as:

$$2C_4H_{10} + 13O_2 \rightarrow 10H_2O + 8CO_2 + \text{Heat} + \text{Light}$$

The reaction conditions (such as temperature, pressure, catalyst etc.) for a reaction are indicated above or below the forward arrow in a reaction.

Below are some balanced chemical equations:

$$\underset{\text{Carbon monoxide}}{(1)\ CO_{(g)}} + \underset{\text{Hydrogen}}{2H_{2(g)}} \xrightarrow[ZnO+CrO_3]{300\text{ atm, }300^\circ C} \underset{\text{Methyl alcohol}}{CH_3OH_{(aq)}}$$

(2) $2KClO_{3(s)} \xrightarrow[MnO_2]{\Delta} 2KCl_{(s)} + 3O_{2(g)}$

Potasium chlorate Potassium chloride Oxygen

Chemical Reaction	Chemical Equation
One reactant or two or more products	$CaCO_3 \rightarrow CaO + CO_2$
Two reactants and one product	$N_2 + H_2 \rightarrow 2\ NH_3$
Two reactants and two products	$Na_2SO_4 + BaCl_2 \rightarrow BaSO_4 + 2\ NaCl$
Two reactants and three or more products	$Cu + 2\ H_2SO_4 \rightarrow CuSO_4 + 2H_2O + SO_2$

Write the balanced equations for the following chemical reactions.

1. Barium chloride + Sodium sulphate → Barium sulphate + Sodium chloride.

2. Sodium + Water → Sodium hydroxide + Hydrogen

Other questions asked in previous years' board examinations

Ques. On what basis is a chemical equation balanced?

(**1 mark)**

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Sol: Law of conservation of mass forms the basis of balancing chemical equations. In a balanced chemical equation, the number of atoms of each element is equal on both sides of the equation.

Ques. Balance the following chemical equation:

$Pb(NO_3)_2\ (s) \xrightarrow{heat} PbO\ (s) + NO_2\ (g) + O_2\ (g)$

(**1 mark)**

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Sol: The balanced chemical equation for the given reaction is:

$$2Pb(NO_3)_2(s) \xrightarrow{Heat} 2\,PbO(s) + 4NO_2(g) + O_2(g)$$

Information conveyed by balanced chemical equations

- Result of the chemical change
- Number of molecules of reactants being consumed and products being formed
- Chemical composition of reactants and product species
- Molecular mass of reactants and products
- Proves the law of conservation of mass

Limitation of a chemical equation
A chemical equation does not provide some other important chacteristics of a chemical reaction, such as:

- time needed to complete the reaction
- physical state of reactants and products
- concentration of each reactant and product
- rate of the reaction

Making a chemical reaction more informative

- Providing the information about catalyst used, temperature and pressure of the reaction above or below the arrow.

$$N_2\ (g) + H_2\ (g) \xrightarrow[450^\circ\ C,\ 200-900\ atm]{Fe + Mo} 2\ NH_3\ (g)$$

- Stating whether heat is being evolved or absorbed in a chemical reaction

  $C(s) + O_2(g) \rightarrow CO_2(g) + Heat$

- Mentioning the physical state of reactants and products.

  $C(s) + O_2\,(g) \rightarrow CO_2\,(g)$

- Adding concentration of acids and bases

  $Mg\ (s) + H_2SO_4\ (aq) \rightarrow MgSO_4\ (aq) + H_2\ (g)$