Chemical Changes and Reactions

A chemical reaction is the process of breaking the chemical bonds of the reacting substances (reactants) and making new bonds to form new substances (products).

A chemical bond is the force which holds the atoms of a molecule together, as in a compound.

Conditions Necessary for a Chemical Change

The following conditions are necessary for a chemical change:

Close physical contact (*Mixing*)	A chemical reaction occurs when two substances are mixed in their solid state. Iodine and sulphur react explosively when brought into close contact.
Solution	A chemical reaction occurs when two substances are mixed in the solution form. Sodium carbonate and tartaric acid vigorously react only in the solution state.
Heat	Some chemical reactions occur only on heating. $CuCO_3 \xrightarrow{\text{Heat}} CuO + CO_2$
Light	Reactions which occur by the action of light are called **photochemical reactions** or **photolysis**. Molecules of the reactants absorb light energy, get activated and then react rapidly. Photosynthesis: $6CO_2 + 6H_2O \xrightarrow{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$ (Glucose)
Electricity	Chemical reactions such as decomposition of compounds occur only when electricity is passed through the substance. $2H_2O \xrightarrow{\text{Electric Current}} 2H_2\uparrow + O_2\uparrow$
Pressure	Some reactions occur only when substances are subjected to high pressure. $N_2 + 3H_2 \rightleftharpoons 2NH_3$
Catalyst	Some chemical reactions need a catalyst to accelerate or decelerate their rates of reaction. Catalysts themselves do not take part in the reaction. A catalyst such as Pt or MnO_2 initiates a change in the rate of the reaction without undergoing any change in its chemical composition. $4NH_3 + 5O_2 \xrightarrow[800\,^\circ C]{\text{Pt}} 4NO + 6H_2O$ **Positive catalyst**: A positive catalyst accelerates a reaction. **Negative catalyst:** A negative catalyst retards a reaction.

Sound	Some chemical reactions proceed only by absorption of sound energy. Sound energy speeds up the reacting molecules, atoms or ions causing a reaction to occur. $C_2H_2 \xrightarrow{\text{Sound Energy}} 2C + H_2$

Characteristics of a Chemical Reaction

1. Evolution of gas	In a chemical reaction, a gas may be one of the products. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$
2. Change of colour	Some chemical reactions are characterised by a change in the colour of the reactants. $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$
3. Formation of precipitate	Some chemical reactions are characterised by the formation of a precipitate. The precipitate is an insoluble solid substance. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
4. Change of state	In some reactions, a change of a state is observed. The reaction starts with solid or liquid reactants and ends up with gaseous products and *vice versa*. $NH_{3(g)} + HCl_{(g)} \rightleftharpoons NH_4Cl_{(s)}$

Types of Chemical Changes or Chemical Reactions

A chemical reaction is the process of breaking chemical bonds of the reacting substances (reactants) and making new bonds to form new substances (products).

1. Direct combination or synthesis	A chemical reaction in which **<u>two or more substances</u> combine to form a <u>single product</u>**. 1) Combination of two elements: $2Fe_{(s)} + S_{(s)} \rightarrow FeS_{(s)}$ Iron Sulphur Iron sulphide 2) Combination of an element and a compound: $2CO_{(g)} + O_{2(g)} \xrightarrow{\text{heat}} 2CO_{2(g)}$ 3) Combination of two or more compounds: $PbO_{2(s)} + SO_{2(s)} \rightarrow PbSO_{4(s)}$ Lead dioxide Sulphur dioxide Lead sulphate

2. Decomposition reaction	A chemical reaction in which a single compound splits into two or more simple substances. $2HgO_{(s)} \rightarrow 2Hg_{(s)} + O_2\uparrow$ Mercuric oxide Mercury Oxygen Decomposition occurs by application of heat or light or by the passage of electric current.
	Electrolysis of acidulated water: On passing electric current through acidulated water, water produces two volumes of hydrogen gas and one volume of oxygen gas. $2H_2O_{(l)} \xrightarrow{\text{Electric Current}} 2H_{2(g)} + O_{2(g)}$
	Thermal decomposition: A decomposition reaction brought about by heat. $2\ KClO_3 \xrightarrow{\text{Heat}} 2KCl + 3O_2$
	In a decomposition reaction: 1) A compound can break up into two or more elements. (a) $2HgO_{(s)} \xrightarrow{\Delta} 2Hg_{(l)} + O_{2(g)}$ (b) $2H_2O_{(l)} \xrightarrow[\text{current}]{\text{electric}} 2H_{2(g)} + O_{2(g)}$ 2) A compound can break up to form both elements and compounds. $2\ KNO_3 \xrightarrow{\text{Heat}} 2KNO_2 + 3O_2$ 3) A compound can break up to form two or more new compounds. $CaCO_{3(s)} \xrightarrow[1000^\circ]{\text{heat}} CaO_{(s)} + CO_{2(g)}$

Thermal decomposition of a metal compound:

(i) Metal hydroxide

Hydroxides

K, Na	Metal hydroxides are stable to heat
Ca, Mg, Al	Decompose on heating to form metal oxide and water vapour
Zn	$Ca(OH)_2 \longrightarrow CaO + H_2O$ $Zn(OH)_2 \longrightarrow ZnO + H_2O$
Fe, Pb, Cu	$Pb(OH)_2 \longrightarrow PbO + H_2O$ $Cu(OH)_2 \longrightarrow CuO + H_2O$
Hg	Yeilds metal, oxygen and water vapour
Ag	$4AgOH \longrightarrow 4Ag + O_2 + 2H_2O$

(ii) Metal carbonates

Carbonates

K, Na	Stable to heat and Soluble in water
Ca, Mg, Al	Decompose on heating with decreasing vigour to form the metal oxide and carbon dioxide
Zn	$Mg\ CO_3 \longrightarrow MgO + CO_2$
Fe, Pb, Cu	$ZnCO_3 \longrightarrow ZnO + CO_2$ $CuCO_3 \longrightarrow CuO + CO_2$
Hg	Forms the metal, oxygen and carbon dioxide
Ag	$2Ag_2CO_3 \longrightarrow 4Ag + O_2 + 2CO_2$

(iii) Metal bicarbonates

Metal bicarbonates or metal hydrogen carbonates decompose to give metal carbonate, water vapour and carbon dioxide.

$$NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + H_2O + CO_2$$

sodium hydrogen carbonate — sodium carbonte

(iv) Metal nitrates

Nitrates

K, Na	On heating they melt and decompose to give metal nitrite and oxygen. $2KNO_3 \longrightarrow 2KNO_2 + O_2$
Ca, Mg, Al	Decompose on heating to form the metal oxide, nitrogen dioxide and oxygen
Zn	$2Ca(NO_3)_2 \longrightarrow 2CaO + 4NO_2 + O_2$
Fe, Pb, Cu	$2Zn(NO_3)_2 \longrightarrow 2ZnO + 4NO_2 + O_2$ $2Pb(NO_3)_2 \longrightarrow 2PbO + 4NO_2 + O_2$ $2Cu(NO_3)_2 \longrightarrow 2CuO + 4NO_2 + O_2$
Hg	Forms metal, nitrogen dioxide and oxygen
Ag	$2Ag_2NO_3 \xrightarrow{\Delta} 2Ag + 2NO_2 + O_2$

3. Reversible reaction

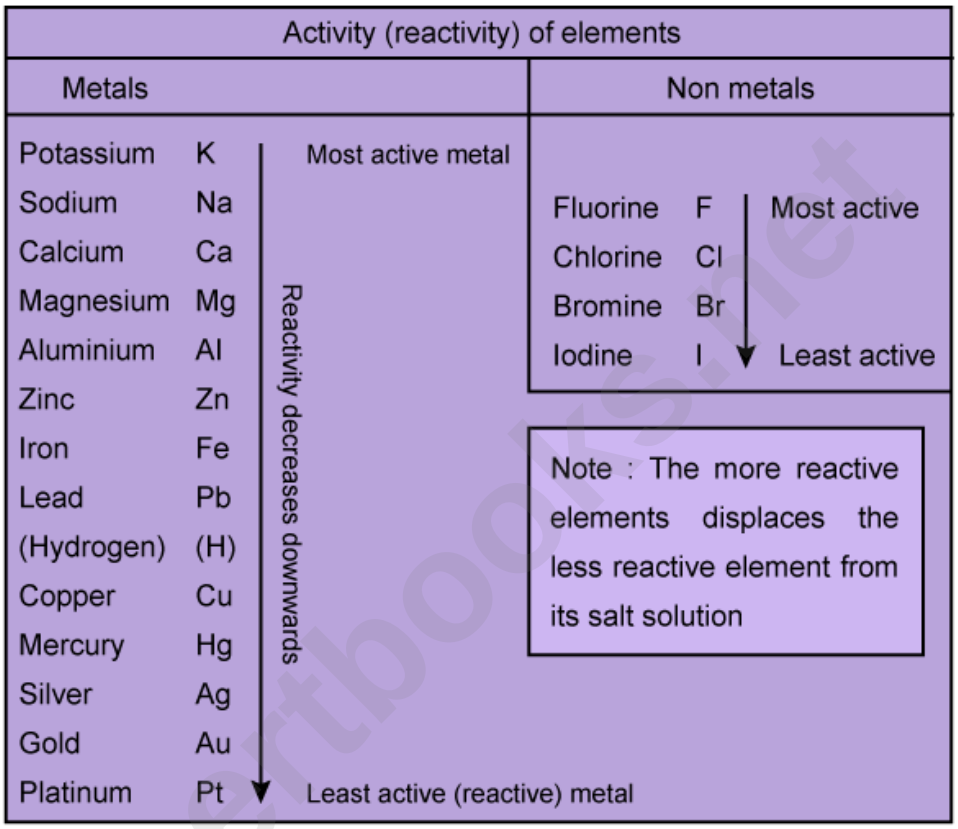
A reaction in which the direction of a chemical change can be easily reversed by changing the conditions under which the reaction is taking place.

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

Thermal dissociation

A reaction in which a substance dissociates into two or more simpler substances on the application of heat is called a thermal dissociation reaction. It is a reversible reaction.

$$NH_4Cl_{(s)} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} NH_3 + HCl_{(g)}$$

4. Displacement reaction	A reaction in which the more reactive element displaces the less reactive element from its compound. Zinc displaces copper in copper sulphate to form zinc sulphate. 
5. Double displacement	A reaction in which ions of the reactants exchange places to form two new compounds. $NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$
6. Double decomposition	A type of chemical change in which two compounds in a solution react to form two new compounds by the mutual exchange of radicals. These reactions are of two types—precipitation reaction and neutralisation reaction.
	Precipitation reaction The insoluble solid formed during a double displacement reaction is called a precipitate. $Na_2SO_{4(aq)} + BaCl_2 \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$

	Neutralisation reaction The reaction between an acid and a base to form a salt and water is called a neutralisation reaction. $NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$ Uses of neutralisation reaction in everyday life: a) Venom of honey bee contains formic acid. When someone is stung by a bee, formic acid enters the skin and produces pain which can be relieved by rubbing the spot with slaked lime or baking soda both of which are bases. b) Acidity is caused by excess secretion of HCl by stomach glands. It can be relieved by taking milk of magnesia or sodium hydrogen carbonate, both of which are bases. On the other hand, deficiency of HCl is covered up by taking any suitable acid in the dilute form.
	Hydrolysis It is the process in which a salt and water react to form an acidic or a basic solution. 1) Hydrolysis of a salt formed by the reaction of a strong base and a weak acid forms a basic solution which turns red litmus blue. 2) Hydrolysis of a salt formed by the reaction of a strong acid and a weak base forms an acidic solution which turns blue litmus red.

Energy Changes in Chemical Reactions

Each substance has a fixed amount of stored energy, which is in the form of potential energy. This energy is called its chemical energy.

The formation of gas bubbles in a liquid during a reaction is called effervescence.

Exothermic change

A chemical change which takes place with the release of heat energy is called an exothermic change.

$C + O_2 \rightarrow CO_2 + Heat$

Endothermic change

A chemical change which takes place with the absorption of heat energy is called an endothermic change.

$C + 2S + Heat \rightarrow CS_2$

Photochemical reaction

A chemical reaction which proceeds with the absorption of light energy.

$$6CO_2 + 6H_2O \xrightarrow{\text{Sunlight}} C_6H_{12}O_2$$

Electrochemical reaction

A chemical reaction which proceeds with the absorption of electric energy.

$$2KCl \xrightarrow{\text{Electric Current}} K^+ + Cl^-$$