Introduction to Chemical Reactions and Equations

Children recall physical and chemical change you studied in class 9th

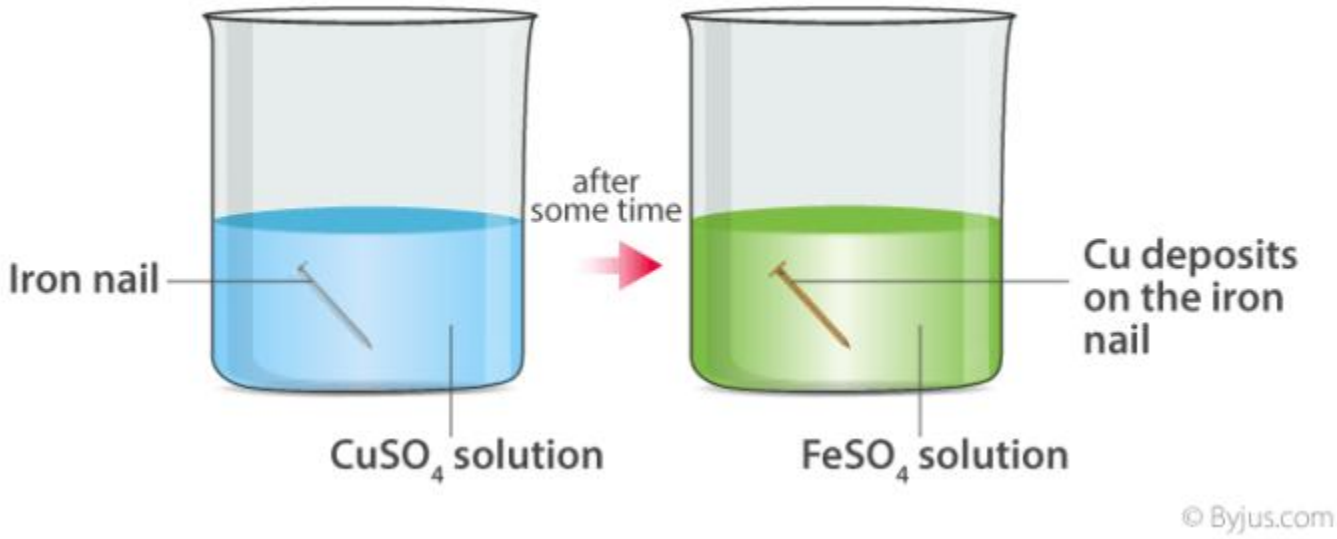
Physical and chemical changes

Chemical change – one or more new substances with new physical and chemical properties are formed.

Example: $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

(Blue) (Green)

Here, when copper sulphate reacts with iron, two new substances, i.e., ferrous sulphate and copper are formed.



Example 2: Digestion of food(carbohydrate turn into CO2 and energy)

Example 3: Rusting of iron (iron turn into iron oxide)

Physical change – change in colour or state occurs but no new substance is formed.
Example: Water changes to steam on boiling but no new substance is formed(Even though steam and water look different when they are made to react with a piece of Na, they react the same way and give the exact same products). This involves only a change in state (liquid to vapour).

" A process which involves chemical change is called a chemical reaction"

Observations that help determine a chemical reaction or characterstics of a chemical reaction:

A chemical reaction can be determined with the help of any of the following observations:
a) Evolution of a gas
b) Change in temperature
c) Formation of a precipitate
d) Change in colour
e) Change of state

Chemical reaction : Definition:

Chemical reactions are chemical changes in which one or more substance(reactants) transform into one or more substance (products) by making or breaking of bonds(or both) between different atoms.

Examples of chemical reactions showing particular characterstics:

1. Evolution of a gas:

$$Zn(s) + H_2SO_4 \rightarrow ZnSO_{4(aq)} + H_{2(g)}$$

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

2. **Formation of precipitate:** The chemical reaction between sulphuric acid and barium chloride solution is characterised by the formation of a white precipitate of barium sulphate .

   $BaCl_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s)\ (ppt) + 2HCl(aq)$

3. **Change in Temperature**: There are two types of reaction i.e Exothermic and Endothermic Reaction.

Exothermic Reactions: Those reactions in which energy is released in the form of heat are called **Exothermic Reactions**.

Examples -

(1) All combustion reactions e.g.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + Heat$$

(2) Thermite reactions e.g.

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3 + Heat$$

Combinations are generally exothermic in nature. The decomposition of organic matters into compost is an example of exothermic reaction.

Endothermic Reactions: Those reactions in which energy is absorbed are called **Endothermic Reactions**.

Examples -

$$CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2$$

also, the reaction of photosynthesis -

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2$$

4. Change in colour: The chemical reaction between sulphur dioxide gas and acidified potassium dichromate solution is characterized by a change in colour from orange to green.
5. **Change in state of substance:** The combustion reaction of candle wax is characterised by a change in state from solid to liquid and gas (because the wax is a solid, water formed by the combustion of wax is a liquid at room temperature whereas, carbon dioxide produced by the combustion of wax is a gas). There are some chemical reactions which can show more than one characteristics.

Chemical Equation

The symbolic representation of chemical reaction using symbols and formulae is known as **Chemical Equation**. For this, reactants are written in left hand side whereas products are written on the right.

Word equation

A word equation is a chemical reaction expressed in words rather than chemical formulas. It helps identify the reactants and products in a chemical reaction.
For example,
Sodium + Chlorine → Sodium chloride
The above equation means: “Sodium reacts with chlorine to form sodium chloride.”

Symbols of elements and their valencies

A symbol is the chemical code for an element. Each element has one or two-letter atomic symbol, which is the abbreviated form of its name.
Valency is the combining capacity of an element. It can be considered as the number of electrons lost, gain or shared by an atom when it combines with another atom to form a molecule.

Writing chemical equations

Representation of a chemical reaction in terms of symbols and chemical formulae of the reactants and products is known as a chemical equation.

$$Zn(s) + dil.\ H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(\uparrow)$$

(Reactants) (Products)

- For solids, the symbol is “(s)”.
- For liquids, it is “(l)”.
- For gases, it is “(g)”.
- For aqueous solutions, it is “(aq)”.
- For gas produced in the reaction, it is represented by “(↑)”.
- For precipitate formed in the reaction, it is represented by “(↓)”.

Balancing of a Chemical Reaction

Conservation of mass

According to the law of conservation of mass, no atoms can be created or destroyed in a chemical reaction, so the number of atoms for each element in the reactants side has to balance the number of atoms that are present in the products side.
In other words, the total mass of the products formed in a chemical reaction is equal to the total mass of the reactants participated in a chemical reaction.

Balanced chemical equation

The chemical equation in which the number of atoms of each element in the reactants side is equal to that of the products side is called a balanced chemical equation.

Steps for balancing chemical equations

Hit and trial method: While balancing the equation, change the coefficients (the numbers in front of the compound or molecule) so that the number of atoms of each element is same on each side of the chemical equation.

To balance the given or any chemical equation, follow these steps:
$Fe + H_2O \rightarrow Fe_3O_4 + H_2$
Write the number of atoms of elements present in reactants and in products in a table as shown here.

Name of atom	No. of atoms in the reactant	No. of atoms in the product
Iron	1	3

Hydrogen	2	2
Oxygen	1	4

Balance the atom which is maximum in number on either side of a chemical equation.
In this equation, the number of oxygen atom is the maximum on the RHS.
To balance the oxygen, one needs to multiply the oxygen on the LHS by 4, so that, the number of oxygen atoms becomes equal on both sides.
$Fe + 4 \times H_2O \rightarrow Fe_3O_4 + H_2$
Now, the number of hydrogen atoms becomes 8 on the LHS, which is more than that on the RHS. To balance it, one needs to multiply the hydrogen on the RHS by 4.
$Fe + 4 \times H_2O \rightarrow Fe_3O_4 + 4 \times H_2$
After that, the number of oxygen and hydrogen atoms becomes equal on both sides.
The number of iron is one on the LHS, while it is three on the RHS. To balance it, multiply the iron on the LHS by 3.
$3 \times Fe + 4 \times H_2O \rightarrow Fe_3O_4 + 4 \times H_2$
Now the number of atoms of each element becomes equal on both sides. Thus, this equation becomes a balanced equation.

I. Combination reaction

In a combination reaction, two elements or one element and one compound or two compounds combine to give one single product.

$H_2 + Cl_2 \rightarrow 2HCl$

element + element → compound

$2CO + O_2 \rightarrow 2CO_2$

compound + element → compound

$NH_3 + HCl \rightarrow NH_4Cl$

compound + compound → compound

Combination reactions are also called synthesis reactions as a new compound is formed from its constituents .

When magnesium is burnt in the air (oxygen), magnesium oxide is formed. In this reaction, magnesium is combined with oxygen.

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

Magnesium + Oxygen → Magnesium Oxide

II. Decomposition reaction

A single reactant decomposes on the application of heat or light or electricity to give two or more products.

Types of decomposition reactions:

a.) Thermal Decomposition reactions: which require heat are called thermolytic decomposition or thermolysis.

Examples:

When calcium carbonate is heated, it decomposes into calcium oxide and carbon dioxide.

$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$

Calcium carbonate → Calcium oxide + Carbon dioxide

When ferric hydroxide is heated, it decomposes into ferric oxide and water

$2Fe(OH)_3(s) \xrightarrow{\triangle} Fe_2O_3(s) + 3H_2O(l)$

Thermal Decomposition of HgO

2HgO--------- 2Hg + O2

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

Thermal decomposition of HgO

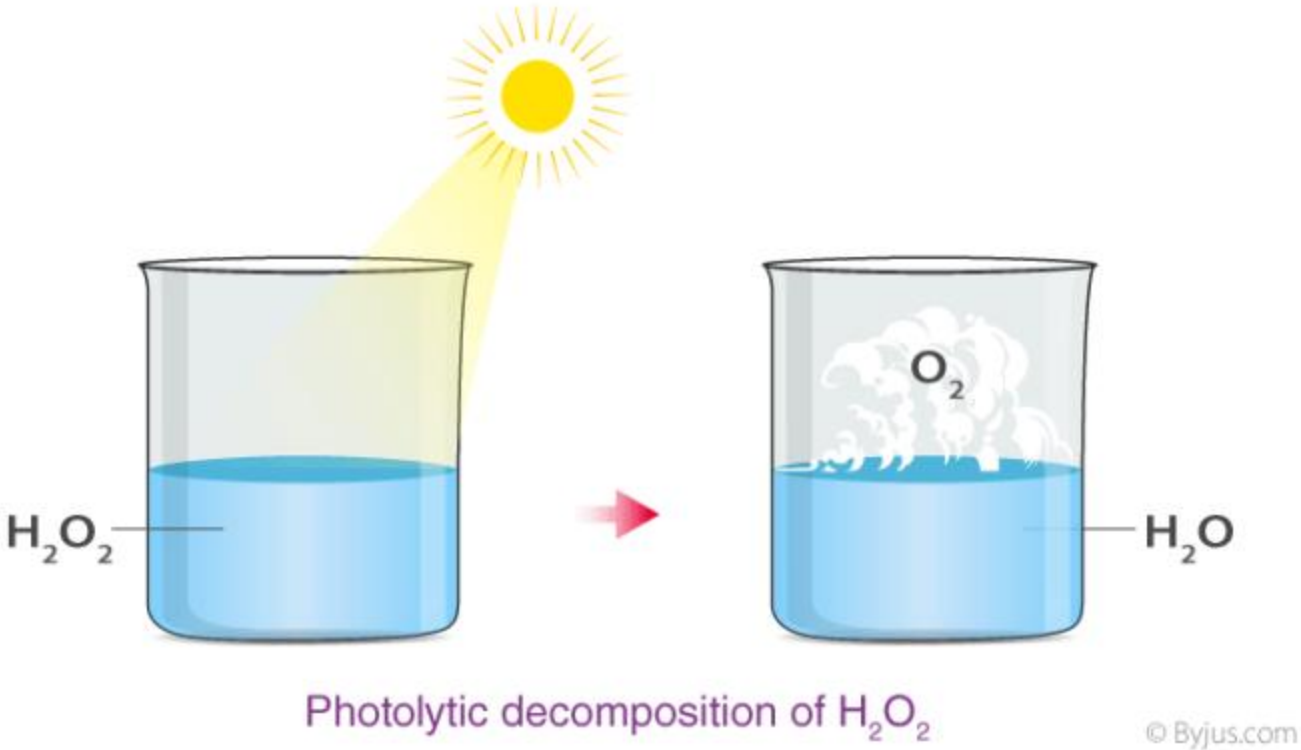
b.) **Photolysis or Photo Decomposition Reaction:** Reactions in which a compound decomposes because of sunlight are known as Photolysis or Photo Decomposition Reaction.

Example: When silver chloride is put in sunlight, it decomposes into silver metal and chlorine gas.

$2AgCl(s)\ (white) \xrightarrow{Sunlight} 2Ag(s)\ (grey) + Cl_2(g)$

Photographic paper has a coat of silver chloride, which turns into grey when exposed to sunlight. It happens because silver chloride is colourless while silver is a grey metal

$2AgBr(s)\ (white) \xrightarrow{Sunlight} 2Ag(s)\ (grey) + Br_2(g)$



Photolytic decomposition of H_2O_2

c) . **Electrolytic Decomposition:** Reactions in which compounds decompose into simpler compounds because of passing of electricity, are known as Electrolytic Decomposition. This is also known as Electrolysis.
Example: When electricity is passed in water, it decomposes into hydrogen and oxygen.

$$2H_2O(l) \xrightarrow[Electrolysis]{Electric\ \ Current} 2H_2(g) + O_2(g)$$

III. **Displacement Reaction:** The chemical reactions in which a more reactive element displaces a less reactive element from a compound is known as Displacement Reactions. Displacement reactions are also known as Substitution Reaction or Single Displacement/ replacement reactions.
A general displacement reaction can be represented by using a chemical equation as follows :
$A + BC \rightarrow AC + B$
Displacement reaction takes place only when 'A' is more reactive than B. If 'B' is more reactive than 'A', then 'A' will not displace 'C' from 'BC' and reaction will not be taking place.
Examples:
When zinc reacts with hydrochloric acid, it gives hydrogen gas and zinc chloride.
$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

More reactive element displaces a less reactive element from its compound or solution.

i) $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$
ii) $Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$

IV. **Double Displacement Reaction:** Reactions in which ions are exchanged between two reactants forming new compounds are called Double Displacement Reactions.
AB + CD → AC + BD
Examples:
When the solution of barium chloride reacts with the solution of sodium sulphate, white precipitate of barium sulphate is formed along with sodium chloride.
$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s)$ (Precipitate) + 2NaCl(aq)

When sodium hydroxide (a base) reacts with hydrochloric acid, sodium chloride and water are formed.
$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Note: Double Displacement Reaction, in which precipitate is formed, is also known as precipitation reaction. Neutralisation reactions are also examples of double displacement reaction.

Precipitation Reaction: The reaction in which precipitate is formed by the mixing of the aqueous solution of two salts is called Precipitation Reaction.
Example:

$$\underset{\substack{\text{Silver}\\\text{Nitrate}}}{AgNO_3(aq)} + \underset{\substack{\text{Sodium}\\\text{Chloride}}}{NaCl(aq)} \longrightarrow \underset{\substack{\text{Silver}\\\text{Chloride}\\\text{(Precipitate)}}}{AgCl(s)} + \underset{\substack{\text{Sodium}\\\text{Nitrate}}}{NaNO_3(aq)}$$

An insoluble compound called precipitate forms when two solutions containing soluble salts are combined.

For example, $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow 2KNO_3(aq) + PbI_2(\downarrow)(s)(yellow)$

Neutralization Reaction: The reaction in which an acid reacts with a base to form salt and water by an exchange of ions is called Neutralization Reaction.

Example:

$$\underset{\text{Sodium hydroxide}}{NaOH(aq)} + \underset{\text{Hydrochloric Acid}}{HCl(aq)} \longrightarrow \underset{\text{Sodium Chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)}$$

When zinc reacts with copper sulphate, it forms zinc sulphate and copper metal.
$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

V. Redox reaction

Oxidation and reduction take place simultaneously.
Oxidation: Substance loses electrons or gains oxygen or loses hydrogen.
Reduction: Substance gains electrons or loses oxygen or gains hydrogen.
Oxidising agent – a substance that oxidises another substance and self-gets reduced.
Reducing agent – a substance that reduces another substance and self-gets oxidised.

Examples:

1. $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$
   (Blue) (Green)

$Fe \rightarrow Fe^{+2} + 2e-$ $(oxidation)$; Fe - reducing agent.

$Cu^{+2} + 2e- \rightarrow Cu(s)$ $(reduction)$; Cu - oxidising agent.

2. $ZnO + C \rightarrow Zn + CO$

ZnO reduces to Zn → reduction

C oxidises to CO → oxidation

ZnO - Oxidising agent

C - Reducing agent

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

Cuo reduces to Cu

H2 oxidises to H2O

CuO – oxidizing agent

H2 – reducing agent

(vi) Exothermic and Endothermic Reactions:

Exothermic Reaction: Reaction which produces energy is called Exothermic Reaction. Most of the decomposition reactions are exothermic.

Example:

Respiration is a decomposition reaction in which energy is released.

$$\underset{\text{glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{oxygen}}{6O_2(g)} \longrightarrow \underset{\text{carbondioxide}}{6CO_2(g)} + \underset{\text{water}}{6H_2O(l)} + \text{Energy}$$

When quick lime (CaO) is added to water, it releases energy.

$$\underset{\substack{\text{Quick lime}\\ \text{(Calcium oxide)}}}{CaO(s)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\substack{\text{Calcium}\\ \text{hydroxide}\\ \text{(Slaked lime)}}}{Ca(OH)_2(aq)} + \text{Energy}$$

Endothermic Reaction: A chemical reaction in which heat energy is absorbed is called Endothermic Reaction.

Example: Decomposition of calcium carbonate.

$$\underset{\substack{\text{Calcium}\\ \text{carbonate}}}{CaCO_3(s)} \xrightarrow{\text{heat}} \underset{\substack{\text{Calcium}\\ \text{oxide}}}{CaO(s)} + \underset{\substack{\text{Carbon}\\ \text{dioxide}}}{CO_2(g)}$$

Corrosion: The process of slow conversion of metals into their undesirable compounds due to their reaction with oxygen, water, acids, gases etc. present in the atmosphere is called Corrosion.

Example: Rusting of iron.

Rusting: Iron when reacts with oxygen and moisture forms red substance hydrated iron oxide which is called Rust.

$$4Fe(s) + 3O_2(g) + H_2O(l) \longrightarrow \underset{\substack{\text{Rust}\\ \text{(Hydrated ferric oxide)}}}{2Fe_2O_3 \cdot xH_2O\ (s)}$$

The rusting of iron is a redox reaction.

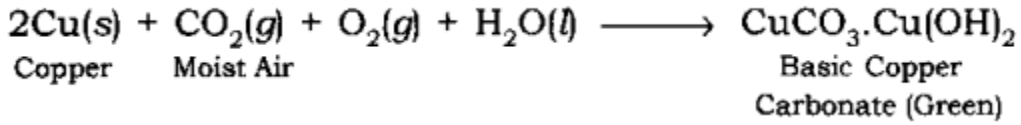
Corrosion (rusting) weakens the iron and steel objects and structures such as railings, car bodies, bridges and ships etc. and cuts short their life.

Methods to Prevent Rusting

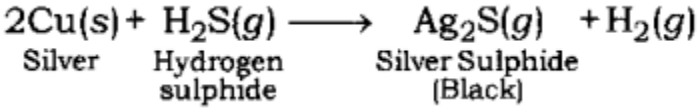
- By painting.
- By greasing and oiling.
- By galvanisation.

- By anodizing
- By alloying

Corrosion of Copper: Copper objects lose their lustre and shine after some time because the surface of these objects acquires a green coating of basic copper carbonate, $CuCO_3.Cu(OH)_2$ when exposed to air.



Corrosion of Silver Metal: The surface of silver metal gets tarnished (becomes dull) on exposure to air, due to the formation of a coating of black silver sulphide(Ag_2S) on its surface by the action of H_2S gas present in the air.



Rancidity: The taste and odour of food materials containing fat and oil changes when they are left exposed to air for a long time. This is called Rancidity. It is caused due to the oxidation of fat and oil present in food materials.

Methods to prevent rancidity:

- Store cooking oils from direct sunlight.
- Food should be placed at low temperature in air tight containers.
- By adding antioxidants such as BHT and BHA, food can be protected from rancidity.
- Packing material should replace the air with nitrogen.
- Minimize the use of salts in fried foods.

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