Chapter 1

Chemical Reactions

A chemical reaction occurs when one or more reactants (also known as reactants) are changed into one or more products (also known as products). The constituent atoms of the reactants are rearranged in a chemical reaction, resulting in the formation of various substances as products.

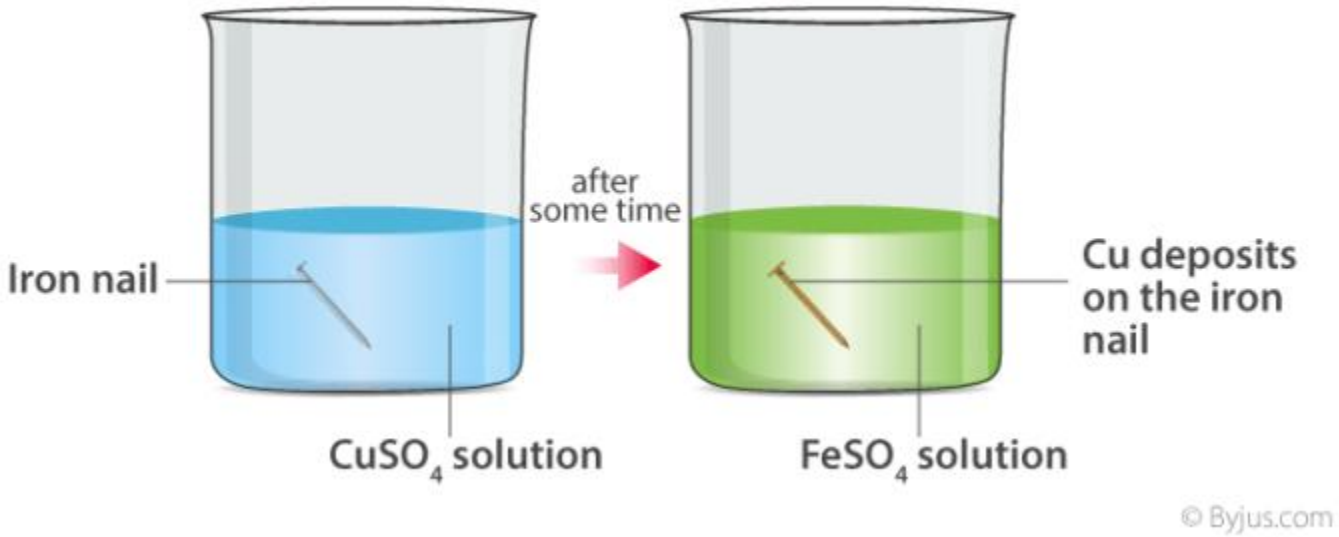
Physical and chemical changes

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.



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)..

Students can refer to the short notes and MCQ questions along with separate solution pdf of this chapter for quick revision from the links below:

Observations that help determine 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

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

A chemical reaction is a process that causes one set of chemical components to change into another. Chemical reactions are defined as changes in the locations of electrons in the formation and breaking of chemical bonds between atoms, with no change in the nuclei, and are described using a chemical equation. At a given temperature and chemical concentration, chemical reactions occur at a predictable rate. Reaction speeds often increase as temperature rises because more thermal energy is available to attain the activation energy required to break bonds between atoms.

Types of chemical reactions

Taking into consideration different factors, chemical reactions are grouped into multiple categories.
Few examples are:
- Combination
- Decomposition
- Single Displacement
- Double displacement
- Redox
- Endothermic
- Exothermic
- Precipitation
- Neutralisation

Chemical Reactions and Equations I

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.

A chemical reaction is described using a word equation, which is a shorthand manner of expressing it. The names of the reactants are shown on the left side of a word equation. If there are more than one reactant, the names of the reactants are separated by a plus sign (+). Products are shown on the right side of a word equation. If there are more than one product, the names of the products are separated by a plus sign (+).

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.

$$\underset{\text{(Reactants)}}{Zn(s) + dil.\,H_2SO_4(aq)} \rightarrow \underset{\text{(Products)}}{ZnSO_4(aq) + H_2(\uparrow)}$$

• 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

Law of 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

The changes that occur during a chemical reaction are represented by a chemical equation.

Reactants → Products.

The equilibrium of all chemical equations must be maintained. This means that on both sides of the arrow, the number of each sort of atom must be the same.

Chemical equations are balanced using coefficients. A coefficient is a numerical value that is added to the front of a chemical symbol or formula. It indicates the number of atoms or molecules of the material involved in the process.

Place coefficients in front of symbols or formulas as needed to balance a chemical equation so that the same number of each type of atom appears in both reactants and products.

For example,

$Zn + HCl \rightarrow ZnCl_2 + H_2$

Balanced Equation is

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

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.

Short-cut technique for balancing a chemical equation

Example:

$a CaCO_3 + b H_3PO_4 \rightarrow c Ca_3(PO_4)_2 + d H_2CO_3$

Set up a series of simultaneous equations, one for each element.

Ca: a=3c

C: a=d

O: 3a+4b=8c+3d

H: 3b=2d

P: b=2c

Let's set c=1

Then a=3 and

d = a = 3

b = 2c = 2

So a=3; b=2; c=1; d=3

The balanced equation is

$3CaCO_3 + 2H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 3H_2CO_3$

Chemical Reactions and Equations II

Types of chemical reactions

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Few examples are:

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- Single Displacement
- Double displacement
- Redox
- Endothermic
- Exothermic
- Precipitation
- Neutralisation

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

When quicklime or calcium oxide (CaO) reacts with water, slaked lime [$Ca(OH)_2$] is formed. During this reaction, a large amount of heat is released. So, this reaction is an exothermic Reaction.

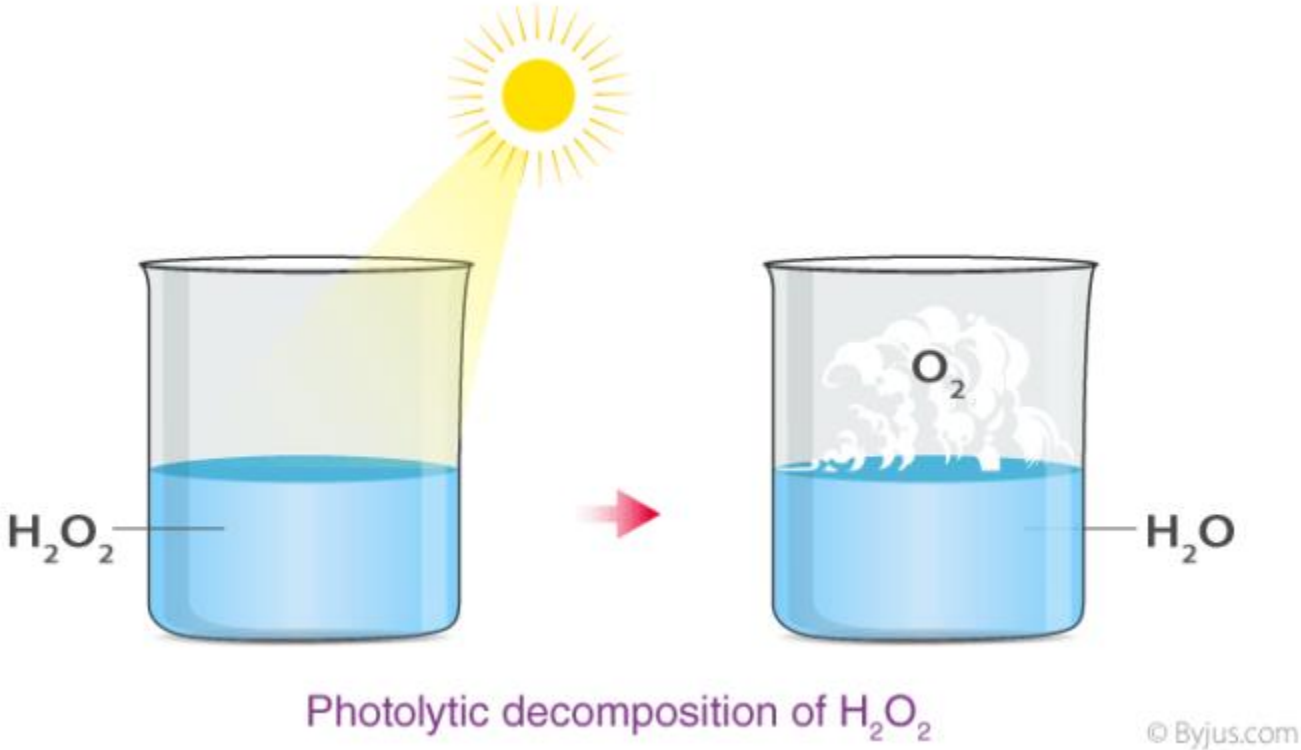
$CaO + H_2O \rightarrow Ca(OH)_2$

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. Decomposition reactions which require heat – thermolytic decomposition or thermolysis.

Thermal decomposition of HgO

b. Decomposition reactions which require light – photolytic decomposition or photolysis.



Photolytic decomposition of H_2O_2

c. Decomposition reactions which require electricity – electrolytic decomposition or electrolysis.

Electrolytic decomposition of H_2O

Displacement reaction

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) $Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$

Double displacement reaction or Precipitation reaction

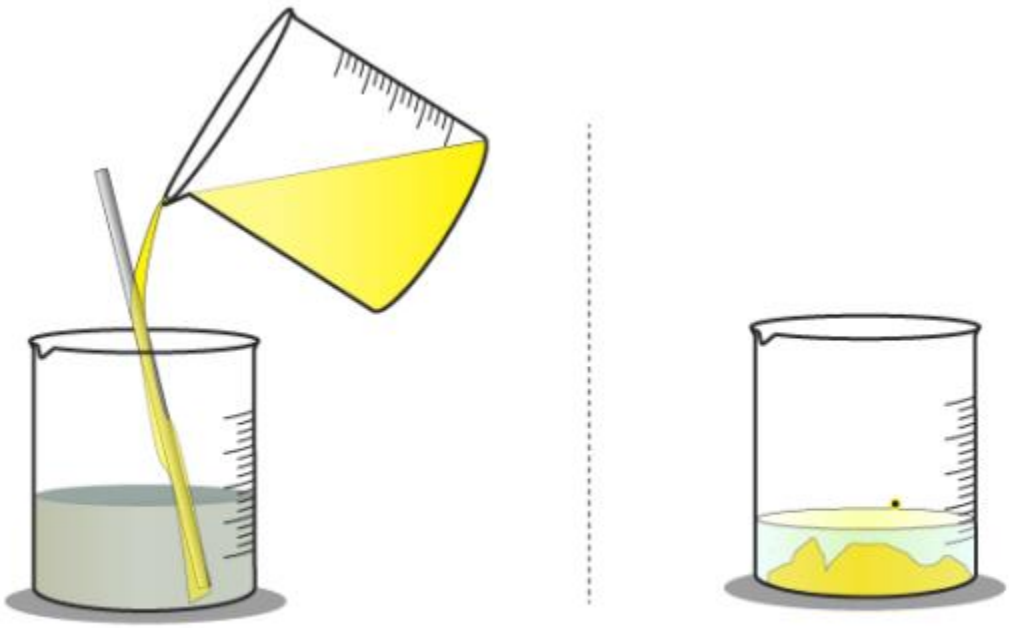
An exchange of ions between the reactants takes place to give new products.

$$Al_2(SO_4)_3(aq) + 3Ca(OH)_2(aq) \rightarrow 2Al(OH)_3(aq) + 3CaSO_4(s)$$

For example,

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

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



Precipitation reaction

One of the best examples of precipitation reactions is the chemical reaction between potassium chloride and silver nitrate, in which solid silver chloride is precipitated out. This is the insoluble salt formed as a product of the precipitation reaction. The chemical equation for this precipitation reaction is provided below.

$AgNO_3$(aqueous) + KCl(aqueous) ⟶ AgCl(precipitate) + KNO_3(aqueous)

Redox reaction

A redox reaction occurs when the oxidation states of the substrate change. The loss of electrons or an increase in the oxidation state of a chemical or its atoms is referred to as oxidation. The gain of electrons or a decrease in the oxidation state of a chemical or its atoms is referred to as reduction.

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

Endothermic and exothermic reaction

Exothermic reaction – heat is evolved during a reaction. Most of the combination reactions are exothermic.

$Al + Fe_2O_3 \rightarrow Al_2O_3 + Fe$ + heat
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat

Effect of oxidation reaction in everyday life

Endothermic – Heat is required to carry out the reaction.

$6CO_2 + 6H_2O$ + Sunlight → $C_6H_{12}O_6 + 6O_2$

Glucose
Most of the decomposition reactions are endothermic.

Corrosion

Gradual deterioration of a material, usually a metal, by the action of moisture, air or chemicals in the surrounding environment.

Rusting:

$4Fe(s) + 3O_2(\text{from air}) + xH_2O(\text{moisture}) \rightarrow 2Fe_2O_3.xH_2O(\text{rust})$
Corrosion of copper:
$Cu(s) + H_2O(\text{moisture}) + CO_2(\text{from air}) \rightarrow CuCO_3.Cu(OH)_2(\text{green})$
Corrosion of silver:
$Ag(s) + H_2S\ (\text{from air}) \rightarrow Ag_2S(\text{black}) + H_2(g)$

Rancidity

It refers to the oxidation of fats and oils in food that is kept for a long time. It gives foul smell and bad taste to food. Rancid food causes stomach infection on consumption.
Prevention:
(i) Use of air-tight containers
(ii) Packaging with nitrogen
(iii) Refrigeration
(iv) Addition of antioxidants or preservatives