THE RADIANT EDUCATION POINT
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Chemical Reactions and Equations

SYLLABUS:- Chemical reactions: Chemical equation, Balanced chemical equation, implications of a balanced chemical equation, types of chemical reactions: combination, decomposition, displacement, double displacement, precipitation, endothermic and exothermic reactions, oxidation and reduction.

Chemical Reaction – The transformation of chemical substance into another chemical substance is known as Chemical Reaction. For example: rusting of iron, burning of coal, burning of candle, burning of paper.
In chemical reaction new substance is formed which is completely different in properties from the original substance, so in a chemical reaction chemical change takes place.

Experiment 1 –
The burning of magnesium in air to form magnesium oxide is an example of a chemical reaction.

$$Mg + O_2 \longrightarrow MgO$$

- Take about 2cm long magnesium ribbon and clean it by rubbing its surface with sand paper.
- Hold it with a pair of tongs. Burn it using a burner.
- The magnesium ribbon starts burning with a dazzling white flame.
- Hold the burning magnesium ribbon over a watch glass so that the magnesium oxide powder being formed collects in the watch glass.

Note: *Before burning in air, the magnesium ribbon is cleaned by rubbing with a sand paper. This is done to remove the protective layer of gases from the surface of magnesium ribbon so that it may readily combine with the oxygen of air.*

Experiment 2 –
Formation of a precipitate:
Some chemical reactions are characterized by the formation of precipitate. A precipitate is a 'solid product' which separates out from the solution during a chemical reaction.

The chemical between potassium iodide and lead nitrate is characterized by the formation of a yellow precipitate of lead iodide.
The reaction between lead nitrate and potassium iodide is a type of precipitation and double displacement reaction. The lead nitrate [$Pb(NO_3)_2$] reacts with potassium iodide (Kl) leading to the formation of potassium nitrate (KNO_3) and a yellow precipitate of lead iodide (PbI_2). The reaction involved is given below:

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

- Take some lead nitrate solution in test tube.
- Add potassium iodide solution to it.
- A yellow precipitate of lead iodide is formed at once.
- A change in colour also takes place in this chemical reaction.

Experiment 3 –
Evolution of a Gas:
Some chemical reactions are characterized by the evolution of a gas.
The chemical reaction between zinc and dilute sulphuric acid is characterized by the evolution of hydrogen gas.
When zinc granules are added to dilute hydrochloric acid taken in a test tube, the zinc metal displaces the hydrogen from the acid and hydrogen gas comes out in the form of small bubbles. This is a displacement reaction.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

- Take some zinc granules in a conical flask.
- Add dilute sulphuric acid over zinc granules.
- We will see the bubbles of hydrogen gas being formed around zinc granules.

Experiment 4 –

Change in colour:

Some chemical reactions are characterized by a change in colour.

The chemical reaction between citric acid and purple coloured potassium permanganate solution is characterized by a change in colour from purple to colourless.

- Take some dilute potassium permanganate solution in a test tube. It has purple colour.
- Add some lemon juice (it contains citric acid) to it with the help of a dropper and shake the test tube.
- The purple colour of potassium permanganate solution goes on fading and ultimately it becomes colourless.

Experiment 5 –

Change in temperature:

Some chemical reactions are characterized by a change in temperature.

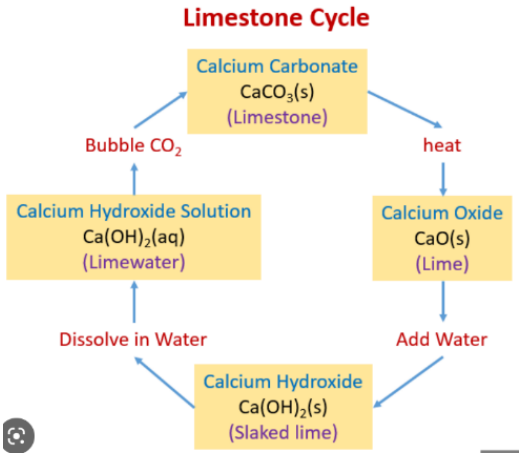
The chemical reaction between quicklime and water to form slaked lime is characterized by a change in temperature.

When quicklime (CaO) reacts with water H_2O, Calcium hydroxide $Ca(OH)_2$ is formed along with the liberation of heat. Thus it is considered an Exothermic reaction.

The chemical reaction can be depicted as:

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) + HEAT$$

- Take a little of quicklime in a hard-glass beaker.
- Add water to it slowly.
- Touch the beaker.
- The beaker feels to be quite hot.



Rice, potatoes and bread contain carbohydrates. These carbohydrates are broken down to form glucose. This glucose combines with oxygen in the cells of our body and provides energy. The special name of this reaction is respiration.

$$C_6H_{12}O_6\ (aq) + 6O_2\ (aq) \rightarrow 6CO_2\ (aq) + 6H_2O\ (l) + \text{energy}$$

Experiment 6 –

Change in state:

Some chemical reactions are characterized by a change in state.

- When wax is burned (in the form of wax candle,) then water and carbon dioxide are formed.
- Now, wax is a liquid whereas carbon dioxide is a gas. This means that during the combustion reaction of wax, the physical state changes from solid to liquid and gas.

Common observations in a chemical reaction –

1. Change of state of substance.
2. Change in colour of substance.
3. Evolution of gas.
4. Change in temperature.

DID YOU KNOW:-

A solution of slaked lime ($Ca(OH)_2$) is used for white washing walls. Calcium hydroxide reacts slowly with the carbon dioxide in air to form a thin layer of calcium carbonate on the walls. Calcium carbonate is formed after two to three days of white washing and gives a shiny finish to the walls.

$$Ca(OH)_2\ (aq) + CO_2\ (g) \rightarrow CaCO_3\ (s) + H_2O(l)$$

In a Chemical Equation –

Reactant: Substances which take part in a chemical reaction are called reactants.

Product: New substance formed after a chemical reaction is called product.

Balanced Chemical Equation – A balanced chemical equation has number of atoms of each element equal on both sides.

Example:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$.

According to Law of Conservation of Mass, mass can neither be created nor destroyed in a chemical reaction. To obey this law, the total mass of elements present in reactants must be equal to the total mass of elements present in products.

Unbalanced Chemical Equation – If the number of atoms of each element in reactants is not equal to the number of atoms of each element present in product, then the chemical equation is called unbalanced chemical equation.

Making Chemical Equation More Informative –

1.By writing the physical states of substances a chemical equation becomes more informative –
Gaseous state is represented by symbol 'g'.
Liquid state is represented by symbol 'l'.
Solid state is written by symbol 's'.
Aqueous solution (substance dissolved in water) is written by symbol 'aq'.

2.Exothermic and Endothermic Reaction –
Reactions which produce energy are called exothermic reaction.
Reactions which absorb/require energy are called endothermic reaction.
Respiration is a exothermic reaction as in respiration process energy is released.
When quick lime (calcium oxide) is added to water, it decomposes and releases energy. So, it is also an example of exothermic reaction.

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) + HEAT$$

Cooking involves chemical reactions which are endothermic as cooking is possible because of heating. Similarly in process of photosynthesis, sunlight is required so it is also an example of endothermic reaction.

3.Writing the condition in which reaction takes place –
The condition is generally written above and/or below the arrow of a chemical equation.

$$CO_2(g) + 2H_2(g) \xrightarrow{340\ atm.} CH_3OH(l)$$

Catalyst is a chemical substance which is neither a reactant nor a product but the reactions takes place only in its presence or the reaction speeds up in its presence.

$$CO + 2H_2 \xrightarrow[ZnO + CrO_2]{300\ atm.,\ 300^oC} CH_3OH$$

Thus, by writing the symbols of the physical state of substances and condition under which reaction takes place, a chemical equation can be made more informative.

Oxidation and Reduction Reactions
Oxidation: Addition of oxygen or removal of hydrogen from a compound is known as oxidation.
Oxidizing agent: Compounds which can add oxygen or remove hydrogen are known as oxidizing agents.
Reduction: Addition of hydrogen or removal of oxygen from a compound is called reduction.
Reducing agent: Compounds or elements which can cause reduction are called reducing agents.
In a chemical reaction oxidation and reduction both take place simultaneously and such reactions are also known as REDOX REACTIONS. In the word REDOX, 'Red' stands for reduction and 'Ox' stands for oxidation.

Example:
If the Copper powder is heated in a china dish, it reacts with oxygen present in the air to form Copper (II) oxide which is black in colour.
The black colour is produced due to the oxidation of Copper.

$$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$$

If hydrogen gas is passed over this heated material (CuO), the black coating on the surface turns brown as the reverse reaction takes place and copper is obtained.

$$CuO + H_2 \rightarrow Cu + H_2O$$

In this reaction, oxygen is removed from copper and oxygen is added to hydrogen. So, cupric oxide is reduced to copper and hydrogen is oxidized to water. Cupric oxide is oxidizing agent and hydrogen is reducing agent.

Effects of Oxidation –

1. Respiration is oxidation reaction in which food is oxidized to produce energy.
2. Iron gets oxidized to form rust; which leads to corrosion of iron in the long run.
3. Most of the metals react with atmospheric oxygen and it leads to formation of a layer on the metal article. The metal gets corroded in the long run.
4. Rusting of iron can be prevented by painting the iron article. This can also be prevented by applying a layer of zinc over iron article. This process is known as galvanization.
5. Fried food gets oxidized when exposed to air. This spoils the taste of the food and the food becomes unfit for consumption. The spoiling of fried food because of oxidation is called rancidity. Fried food is often packed in airtight packets to prevent rancidity.
6. We are able to utilize various types of fuel because of oxidation. Oxidation of fuel helps in producing energy.

Types of Chemical Reaction –

Chemical reactions can be classified in following types:-

a. Combination Reactions
b. Decomposition Reactions
c. Displacement Reactions
d. Double Displacement Reactions

a. Combination Reaction – Reactions in which two or more reactants combine to form one product are called combination reactions.

Example:

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

$$\mathbf{Mg + O_2 \longrightarrow MgO}$$

When calcium oxide reacts with water, calcium hydroxide is formed

$$\mathbf{CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)}$$

When carbon monoxide reacts with oxygen, carbon dioxide is formed.

b. Decomposition Reaction – Reactions in which one compound decomposes in two or more compounds or element are known as decomposition reaction. Decomposition reaction is just opposite of combination reaction.

Example:

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

$$\underset{\text{(Limestone)}}{CaCO_3(s)} \xrightarrow{\text{Heat}} \underset{\text{(Quick lime)}}{CaO(s)} + CO_2(g)$$

Heating of ferrous sulphate is also a decomposition reaction

$$\underset{\text{(Ferrous sulphate)}}{2FeSO_4(s)} \xrightarrow{\text{Heat}} \underset{\text{(Ferric oxide)}}{Fe_2O_3(s)} + SO_2(g) + SO_3(g) \qquad (1.19)$$

Thermal Decomposition:

When lead nitrate is heated, it decomposes into lead oxide, nitrogen dioxide and oxygen.

$$\underset{\text{(Lead nitrate)}}{2Pb(NO_3)_2(s)} \xrightarrow{\text{Heat}} \underset{\text{(Lead oxide)}}{2PbO(s)} + \underset{\text{(Nitrogen dioxide)}}{4NO_2(g)} + \underset{\text{(Oxygen)}}{O_2(g)} \qquad (1.21)$$

In the above examples, compound is decomposed because of heating, so, these reactions are called **thermal decomposition**.

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:

1. The reaction for electrolytic decomposition of water is

$$\mathbf{2H_2O(l) \rightarrow 2H_2(g) + O2(g)}$$

2. It is clear from the reaction that two volumes of hydrogen gas and one volume of oxygen gas are generated when water is electrolytically decomposed. i.e. ratio of hydrogen to oxygen is 2:1by volume.

When electricity is passed in water, it decomposes into hydrogen and oxygen.

Photolysis or Photo Decomposition:

Reactions in which a compound decomposes because of sunlight are known as **photolysis** or **photo decomposition**.

Example:

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

Silver chloride in presence of sunlight breaks down into silver and chlorine gas, and this reaction is used in white and black photography.

The chemical reaction is as follows:

$$2AgCl(s) \rightarrow 2Ag(s) + Cl_2(g)$$

Similarly, when silver bromide is put under sunlight, it decomposes into silver metal and bromine gas.

c. Displacement Reaction – Reactions in which atoms or ions move from one compound to other to form new compound are known as **displacement reaction**. Displacement reaction is also known as **Substitution Reaction** or **Single displacement /Replacement Reaction**.

Example:

When an iron nail is dipped in copper sulphate solution, a brown coating of copper is formed on the surface of iron and the colour of copper sulphate solution changes from blue to light green. This reaction shows that iron is more reactive than copper as it displaces copper from its solution and iron passes into solution as Fe (II) ions and ferrous sulphate solution is formed.

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

Zinc (Zn) is more reactive than copper (Cu), therefore it can displace Cu from aqueous copper sulphate (CuSO4) solution. In this process, the blue colour of (CuSO4) changes to a colourless $ZnSO_4$ solution.

Balanced reaction

$Zn\ (s) + CuSO_4\ (aq) \rightarrow ZnSO_4\ (aq) + Cu\ (s)$

This reaction is also known as a single displacement reaction.

When a strip of lead metal is placed in a solution of copper chloride, then lead chloride solution and copper metal are formed. The green colour of copper chloride fades and the solution becomes colourless.

$$Pb(s) + CuCl_2(aq) \rightarrow PbCl_2(aq) + Cu(s)$$

d. Double Displacement Reaction – Reactions in which ions are exchanged between two reactants forming new compounds are called double displacement reactions.

A general double displacement reaction can be represented using the following general chemical equation.

Example:

When the solution of barium chloride reacts with the solution of sodium sulphate, white precipitate of barium sulphate is formed along with sodium chloride.

Barium chloride(solution) + Sodium sulphate(solution) → Barium sulphate (white ppt.)↓ + Sodium chloride(solution)

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

The reaction between lead nitrate and potassium iodide is a type of precipitation and double displacement reaction. The lead nitrate [$Pb(NO_3)_2$] reacts with potassium iodide (Kl) causing exchange of ions between the reactants leading to the formation of potassium nitrate (KNO_3) and a yellow precipitate of lead iodide (PbI_2). The reaction involved is given below:

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

When sodium hydroxide (a base) reacts with hydrochloric acid, sodium chloride and water are formed.

The reaction of sodium hydroxide with hydrochloric acid results in salt and water. The balanced chemical equation is

$$NaOH + HCl \rightarrow NaCl + H_2O$$

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