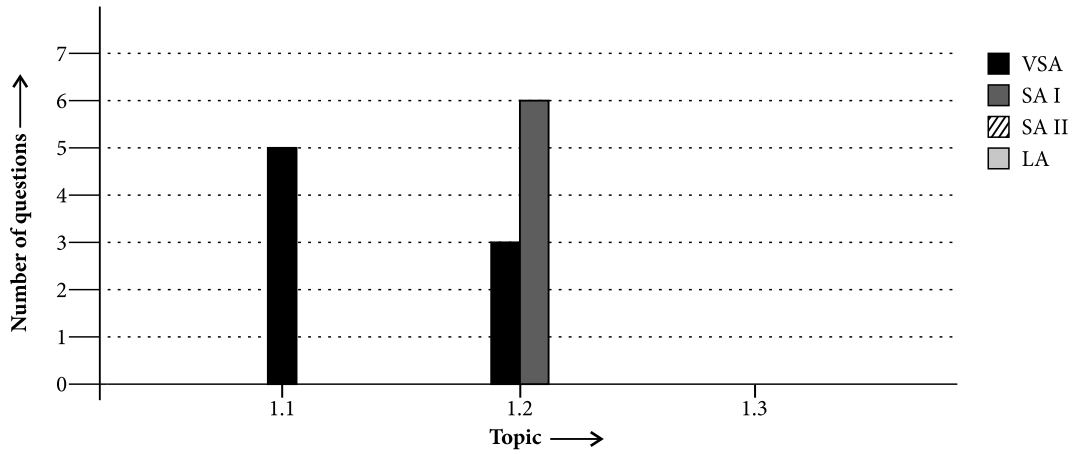
Chapter

1

Chemical Reactions and Equations

Topicwise Analysis of 2010-2008 Years' CBSE Board Questions



- Maximum weightage is of *Types of Chemical Reactions.*
- Maximum VSA type questions were asked from *Chemical Equations.*
- Maximum SA I type questions were asked from *Types of Chemical Reactions.*

QUICK RECAP

- **Physical changes :** Those changes which are accompanied with change in physical properties of the substances but no new substance is formed are called *physical changes e.g.*, melting of ice, boiling of water, etc.
- **Chemical changes :** Those changes in which the original substances lose their nature and identity to form new chemical substances with different properties are called *chemical changes e.g.,* burning of candle, cooking food, etc.
- **Chemical reactions :** The process involving a chemical change is known as a *chemical reaction*. The chemical substances taken initially are called *reactants* and the chemical substances which are formed during a chemical reaction are called *products*. Thus, chemical reaction is a process in which breaking of chemical bonds (present in the reactant molecules) and making of new chemical bonds (in the product molecules) occur *e.g.*, burning of magnesium ribbon in air.

$$\underbrace{Mg + O_2}_{\text{Reactants}} \longrightarrow \underbrace{MgO}_{\text{Product}}$$

Characteristics of chemical reactions : The following observations help us to determine whether a chemical reaction has taken place or not :

- **Change in state :** Certain chemical reactions are accompanied with the change of state *e.g.*, when a mixture of hydrogen gas and oxygen gas is ignited with an electric spark at room temperature, liquid water is formed.

$$\underset{\text{Hydrogen}}{2H_{2(g)}} + \underset{\text{Oxygen}}{O_{2(g)}} \xrightarrow[\text{room temp.}]{\text{electric spark}} \underset{\text{Water}}{2H_2O_{(l)}}$$

- **Change in colour :** Certain chemical reactions are accompanied with the change of colour *e.g.,* when red lead oxide is heated yellow lead monoxide is formed.

$$\underset{\substack{\text{Lead oxide}\\\text{(red colour)}}}{2Pb_3O_{4(s)}} \xrightarrow{\text{heat}} \underset{\substack{\text{Lead monoxide}\\\text{(yellow colour)}}}{6PbO_{(s)}} + \underset{\text{Oxygen}}{O_{2(g)}\uparrow}$$

- **Evolution of a gas :** Some chemical reactions are accompanied with the evolution of a gas *e.g.,* reaction between a metal (like zinc, magnesium or iron) and dilute sulphuric acid produces hydrogen gas.

$$\underset{\text{Zinc}}{Zn_{(s)}} + \underset{\text{Sulphuric acid}}{H_2SO_4\,(\text{dil.})} \longrightarrow \underset{\substack{\text{Zinc}\\\text{sulphate}}}{ZnSO_{4(aq)}} + \underset{\text{Hydrogen}}{H_{2(g)}\uparrow}$$

- **Change in temperature :** Some chemical reactions occur with change in heat energy or with change in temperature.
  - Reactions which result in rise in temperature *i.e.* in which heat is evolved are called *exothermic reactions*.

$$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(l)} + \text{Heat}$$

  - Reactions which result in fall in temperature *i.e.* in which heat is absorbed are called *endothermic reactions*.

$$\underset{\text{Lime stone}}{CaCO_{3(s)}} + \text{Heat} \longrightarrow \underset{\substack{\text{Quick lime}\\\text{or lime}}}{CaO_{(s)}} + \underset{\substack{\text{Carbon}\\\text{dioxide}}}{CO_{2(g)}}$$

Chemical equation : A method of representing a chemical reaction in terms of symbols and formulae of the substances participated is known as *chemical equation*. There are two ways to represent a chemical equation :

- **In terms of words :** When a chemical equation is written in terms of words, it is called a *word equation*. The chemical reaction between granulated zinc and hydrochloric acid can be written in terms of words as

$$\underbrace{\text{Zinc} + \text{Hydrochloric acid}}_{\text{Reactants}} \longrightarrow \underbrace{\text{Zinc chloride} + \text{Hydrogen}}_{\text{Products}}$$

- **In terms of symbols and formulae :** Chemical reaction between granulated zinc and hydrochloric acid can be written in terms of symbols and formulae as

$$\underbrace{Zn + 2HCl}_{\text{Reactants}} \longrightarrow \underbrace{ZnCl_2 + H_2}_{\text{Products}}$$

- **Conventions used in chemical equations :**
  - The reactants are written on the left hand side along with plus (+) sign between them.
  - Similarly, products are written on the right hand side along with plus (+) sign between them.
  - An arrow (⟶) separates the reactants from the products.
  - The arrowhead points towards the products and tells about the direction of the reaction.

Balanced and unbalanced chemical equations :

- **Balanced chemical equation :** The equation which contains an equal number of atoms of each element on both sides of the arrow is called a *balanced chemical equation*.

$$2Mg + O_2 \longrightarrow 2MgO$$

A balanced chemical equation must obeys the law of conservation of mass.

- **Unbalanced chemical equation:** The equation in which the number of atoms of each element on both sides of the arrow is not equal.

$$H_2 + O_2 \longrightarrow H_2O$$

Balancing a chemical equation : Balancing of a chemical equation means to equalise the number of atoms of each element on both sides of the equation.

Consider the following steps for balancing the chemical equation :

For example, iron reacts with water (steam) to form iron(II, III) oxide and hydrogen.

Step-I : Write the chemical equation in the form of a word equation. Keep the reactants on the left hand side and the products on the right hand side. Separate them by an arrow (⟶) with head pointing from the reactants to products.

Iron + Steam ⟶ Iron (II, III) oxide + Hydrogen

Step-II : Write down the symbols and formulae of the various reactants and products which gives skeletal chemical equation.

$$Fe + H_2O \longrightarrow Fe_3O_4 + H_2$$

Step-III : Listing number of atoms of different elements.

Elements	Number of atoms on LHS	Number of atoms on RHS
Fe	1	3
H	2	2
O	1	4

Step-IV : Select the compound with maximum number of atoms to start balancing. In that compound, balance the element with maximum number of atoms (*e.g.*, oxygen in the given equation). It may be a reactant or a product.

Atoms of oxygen	In reactants	In products
(i) Initial	1 (in H_2O)	4 (in Fe_3O_4)
(ii) To balance	1 × 4	4

$$Fe + 4H_2O \longrightarrow Fe_3O_4 + H_2$$

Step-V : To balance the atoms of an element, put a whole number coefficient before the formula of the compound. If selection of the biggest formula appears inconvenient, balance the atoms of that element which occurs at minimum number of places on both sides of the equation. Atoms of the element which occur at maximum places are balanced at last.

To balance H-atoms on both sides :

Atoms of hydrogen	In reactants	In products
(i) Initial	8 in ($4H_2O$)	2 (in H_2)
(ii) To balance	8	2 × 4

$$Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$$

To balance Fe-atoms on both sides :

Atoms of iron	In reactants	In products
(i) Initial	1 (in Fe)	3 (in Fe_3O_4)
(ii) To balance	1 × 3	3

So, the equation would be

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

Step VI : For checking the correct balanced equation, we count atoms of each element on both sides of the equation.

Elements	Number of atoms on LHS	Number of atoms on RHS
Fe	3	3
H	8	8
O	4	4

As the number of atoms of each element on both sides of the equation are equal, the equation is balanced.

$$3Fe_{(s)} + 4H_2O_{(g)} \longrightarrow Fe_3O_{4(s)} + 4H_{2(g)}$$

How can a chemical equation be made more informative?

A chemical equation can be made more informative by adding some extra information to the chemical equation which may be summarised as :

- Write the state symbols for the reactants and products taking part in a chemical reaction. Use symbols (*g*) for gases, (*s*) for solids, (*l*) for liquids and (*aq*) for aqueous solutions.
- Indicate the gas evolved in the reaction by (↑).
- Indicate the precipitate obtained in the reaction by (↓).
- Mention the heat evolved by (+) sign and heat absorbed by (–) sign on the product side.

- Mention the reaction conditions, temperature as *t*°C or K, pressure as atm, catalyst, etc. above or below the arrow.
- When reactants are converted into products and products cannot be converted back to reactants then the reaction is called an *irreversible reaction* and is represented by ($\longrightarrow$). On the other hand, if in a chemical reaction, reactants are converted into products in forward direction and again products are converted back into reactants in backward direction then, it is called a *reversible reaction* and is represented by ($\rightleftharpoons$).

Types of chemical reactions : As we know, in chemical reactions, bonds present in reactants break and new bonds form in the products. This exchange of species can take place in a number of ways resulting in different types of reactions, which can be explained as follows :

- **Combination reactions :** The reactions in which two or more substances combine to form a single substance under suitable conditions.

  Examples :

  – Combustion of coal

  $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

  – Combination of nitric oxide with oxygen to form nitrogen dioxide.

  $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$

  Nitric oxide — Nitrogen dioxide (brown gas)

  – Combination of ammonia with hydrogen chloride gas to form a white solid mass of ammonium chloride.

  $NH_{3(g)} + HCl_{(g)} \longrightarrow NH_4Cl_{(s)}$

  Ammonium chloride (white)

- **Decomposition reactions :** Those reactions in which a single substance breaks down to give two or more smaller substances under suitable conditions. Three types of decomposition reactions are as follows :

  – **Thermal decomposition reactions :** These reactions occur in presence of heat.

  $2FeSO_{4(s)} \xrightarrow{heat} Fe_2O_{3(s)} + SO_{2(g)}\uparrow + SO_{3(g)}\uparrow$

  Ferrous sulphate (green) — Ferric oxide (reddish brown) — Sulphur dioxide (smell of burning sulphur) — Sulphur trioxide

  – **Electrolytic decomposition reactions :** These reactions occur in presence of electric current.

  $2H_2O_{(l)} \xrightarrow[current]{electric} 2H_{2(g)} + O_{2(g)}$

  – **Photodecomposition reactions :** These reactions occur in presence of sunlight.

  $2AgBr_{(s)} \xrightarrow{sunlight} 2Ag_{(s)} + Br_{2(g)}$

  Silver bromide — Silver — Bromine

- **Displacement reactions :** Those chemical reactions in which one element takes the position of another element present in the compound.

  Examples :

  $Zn_{(s)} + CuSO_{4(aq)} \longrightarrow ZnSO_{4(aq)} + Cu_{(s)}$

  $Pb_{(s)} + CuCl_{2(aq)} \longrightarrow PbCl_{2(aq)} + Cu_{(s)}$

  Note : All displacement reactions are exothermic reactions.

- **Double displacement reactions :** Those reactions in which two compounds react by exchange of ions to form two new compounds, are called *double displacement reactions*.

  Example :

  $AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow AgCl_{(s)}\downarrow + NaNO_{3(aq)}$

  Silver nitrate — Sodium chloride — Silver chloride — Sodium nitrate

  There are two types of double displacement reactions :

  – **Precipitation reactions :** Those reactions in which aqueous solution of two compounds on mixing react to form an insoluble compound which further separates out as a precipitate are called *precipitation reactions*.

  Examples :

  $FeCl_{2(aq)} + 2NaOH_{(aq)} \longrightarrow Fe(OH)_{2(s)}\downarrow + 2NaCl_{(aq)}$

  Ferrous hydroxide (dirty green ppt.)

  $Na_2SO_{4(aq)} + BaCl_{2(aq)} \longrightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$

  (Barium sulphate) (white ppt.)

  – **Neutralisation reactions :** Those reactions of acids and bases in which product formed is neutral to litmus are known as *neutralisation reactions*.

Examples :

$$\underset{\text{Base}}{NaOH_{(aq)}} + \underset{\text{Acid}}{HCl_{(aq)}} \longrightarrow \underset{\text{Salt}}{NaCl_{(aq)}} + H_2O$$

$$\underset{\text{Base}}{CuO_{(s)}} + 2\underset{\text{Acid}}{HCl_{(aq)}} \longrightarrow \underset{\text{Salt}}{CuCl_{2(aq)}} + H_2O$$

- **Redox reactions :** Reactions in which oxidation and reduction take place simultaneously are called *redox reactions*.
  - **Oxidation :** Those reactions in which the addition of oxygen to a substance or removal of hydrogen from a substance takes place are called *oxidation reactions*.

  On the other hand, the substance which either gives oxygen or removes hydrogen in an oxidation reaction is known as an *oxidising agent*.
  - **Reduction :** Those reactions in which addition of hydrogen to a substance or removal of oxygen from a substance takes place are called *reduction reactions*.

  On the other hand, the substance which either gives hydrogen or removes oxygen in a reduction reaction is known as *reducing agent*.

Examples :

$$\overset{\text{Oxidation}}{ZnO + C \xrightarrow{\Delta} Zn + CO}$$
$$\text{Reduction}$$

Here, ZnO : Oxidising agent
C : Reducing agent

$$\overset{\text{Reduction}}{2H_2S + SO_2 \xrightarrow{\Delta} 3S + 2H_2O}$$
$$\text{Oxidation}$$

Here, SO_2 : Oxidising agent
H_2S : Reducing agent

Effect of oxidation reactions in everyday life : As oxygen is the most essential element for sustaining life, it is involved in variety of reactions which has wide range of effects on our daily life. The two effects are discussed below :

- **Corrosion :** It is a process in which metals are decayed gradually by the action of air, moisture and acids on their surface. Basically, it is caused by oxidation of metals by oxygen present in the air.

  Example : Rusting of iron,

$$\underset{\text{Iron}}{4Fe_{(s)}} + \underset{\text{Air}}{3O_{2(g)}} + \underset{\text{Moisture}}{2xH_2O_{(l)}} \longrightarrow \underset{\substack{\text{Hydrated}\\ \text{Iron(III) oxide}}}{2Fe_2O_3{\cdot}xH_2O_{(s)}}$$

$$2Cu_{(s)} + \underbrace{CO_{2(g)} + O_{2(g)}}_{\text{Air}} + \underset{\text{Moisture}}{H_2O_{(l)}} \longrightarrow$$

$$\underset{\substack{\text{Basic copper carbonate}\\ \text{(green)}}}{CuCO_3{\cdot}Cu(OH)_2}$$

  Corrosion causes damage to car bodies, iron railings, ships and to all objects made up of metals, specially those of iron.
  - **Prevention of corrosion :** Corrosion can be prevented
    - by coating the surface by a layer of another metal which does not corrode *e.g.*, coating of iron with zinc.
    - by coating surface with grease, paint or oil, etc.
- **Rancidity :** The slow oxidation of oils and fats present in food materials resulting in compounds with unpleasant smell is known as *rancidity*. Vacuum packing, refrigeration of food materials, placing of food materials away from direct sunlight will slow down the process of rancidity.

Previous Years' CBSE Board Questions

1.1 Chemical Equations

VSA (1 mark)

1. Write a balanced chemical equation for the reaction between sodium carbonate and hydrochloric acid indicating the physical state of the reactants and the products. *(Foreign 2010)*

2. Balance the following chemical equation :
$Pb(NO_3)_{2(s)} \xrightarrow{heat} PbO_{(s)} + NO_{2(g)} + O_{2(g)}$ *(Delhi 2009)*

3. Balance the following chemical equation :
$Fe_{(s)} + H_2O_{(g)} \longrightarrow Fe_3O_{4(s)} + H_{2(g)}$ *(AI 2008)*

4. Balance the following chemical equation :
$FeSO_4 \xrightarrow{heat} Fe_2O_3 + SO_2 + SO_3$ *(AI 2008)*

5. Balance the following chemical reaction :
$MnO_2 + HCl \longrightarrow MnCl_2 + Cl_2 + H_2O$ *(AI 2008)*

1.2 Types of Chemical Reactions

VSA (1 mark)

6. In electrolysis of water, why is the volume of gas collected over one electrode double than that of gas collected over the other electrode? *(AI 2009)*

7. What change in colour is observed when white silver chloride is left exposed to sunlight? What type of chemical reaction is this? *(Foreign 2009)*

8. What happens chemically when quick lime is added to water? *(Delhi 2008)*

SA I (2 marks)

9. What happens when an aqueous solution of sodium sulphate reacts with an aqueous solution of barium chloride? State the physical conditions of reactants in which the reaction between them will not take place. Write the balanced chemical equation for the reaction and name the type of reaction. *(Delhi 2010)*

10. What is a redox reaction? When a magnesium ribbon burns in air with a dazzling flame and forms a white ash, is magnesium oxidised or reduced? Why? *(Delhi 2009)*

11. (a) What is the colour of ferrous sulphate crystals? How does this colour change after heating?
(b) Name the products formed on strongly heating ferrous sulphate crystals. What type of chemical reaction occurs in this change? *(Delhi 2009)*

12. (i) What is observed when a solution of potassium iodide is added to a solution of lead nitrate taken in a test tube?
(ii) What type of reaction is this?
(iii) Write a balanced chemical equation to represent the above reaction. *(AI 2009)*

13. What is an oxidation reaction? Identify in the following reaction : $ZnO + C \rightarrow Zn + CO$
(i) the substance oxidised and
(ii) the substance reduced. *(Delhi 2008)*

14. Give an example of decomposition reaction. Describe an activity to illustrate such a reaction by heating. *(AI 2008)*

Detailed Solutions

1. $Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2\,(g)}$
Sodium carbonate; Hydrochloric acid; Sodium chloride

2. $2Pb(NO_3)_{2(s)} \xrightarrow{heat} 2PbO_{(s)} + 4NO_{2(g)} + O_{2(g)}$

3. $3Fe_{(s)} + 4H_2O_{(g)} \longrightarrow Fe_3O_{4(s)} + 4H_{2(g)}$

4. $2FeSO_4 \xrightarrow{heat} Fe_2O_3 + SO_2 + SO_3$

5. $MnO_2 + 4HCl \longrightarrow MnCl_2 + Cl_2 + 2H_2O$

6. In electrolysis of water, hydrogen (H_2) gas is liberated at cathode while oxygen (O_2) gas is liberated at anode. The overall reaction is

$$2H_2O_{(l)} \xrightarrow{\text{Electric current}} 2H_{2(g)} + O_{2(g)}$$

From the above reaction, it is clear that amount of H_2 liberated is twice that of O_2.

7. When white silver chloride is left exposed to sunlight, its colour changes to grey due to the formation of silver.

$$\underset{\text{White}}{2AgCl_{(s)}} \xrightarrow{sunlight} \underset{\text{Grey}}{2Ag_{(s)}} + Cl_{2(g)}$$

This type of reaction is called photodecomposition reaction.

8. Quick lime reacts vigorously with water to produce calcium hydroxide (slaked lime) releasing a large amount of heat (exothermic reaction).

$$\underset{\text{(Quick lime)}}{CaO_{(s)}} + H_2O_{(l)} \longrightarrow \underset{\text{(Slaked lime)}}{Ca(OH)_{2(aq)}} + \text{heat}$$

9. When an aqueous solution of sodium sulphate reacts with an aqueous solution of barium chloride then, white precipitate of barium sulphate ($BaSO_4$) is formed.

$$Na_2SO_{4(aq)} + BaCl_{2(aq)} \longrightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$$

If the reactants are present in solid state then no reaction will take place between them. This type of reaction is called double displacement reaction or precipitation reaction.

10. A reaction in which oxidation and reduction take place simultaneously is called redox reaction. On heating in oxygen/air, magnesium burns with a dazzling white light to give magnesium oxide.

$$2Mg + O_2 \xrightarrow{heat} 2MgO$$

Here, magnesium is oxidised as addition of oxygen has taken place.

11. (a) Ferrous sulphate crystals ($FeSO_4.7H_2O$) are light green in colour.
When it is heated, white colour solid is formed.

$$\underset{\text{(Light green)}}{FeSO_4.7H_2O} \xrightarrow{heat} \underset{\text{(White)}}{FeSO_4} + 7H_2O$$

(b) When anhydrous ferrous sulphate is further heated strongly, it decomposes to give ferrous oxide (Fe_2O_3) and oxides of sulphur.

$$\underset{\text{White}}{2FeSO_{4(s)}} \xrightarrow[\text{strongly}]{\text{heated}} \underset{\text{Reddish brown}}{Fe_2O_{3(s)}} + SO_{2(g)} + SO_{3(g)}$$

This type of chemical reaction is known as decomposition reaction.

12. (i) When lead nitrate is added to potassium iodide then yellow precipitate of lead iodide is formed along with potassium nitrate.
(ii) This type of reaction is called precipitation reaction in which one of the products formed is an insoluble substance.
(iii) Chemical reaction will be as follows :

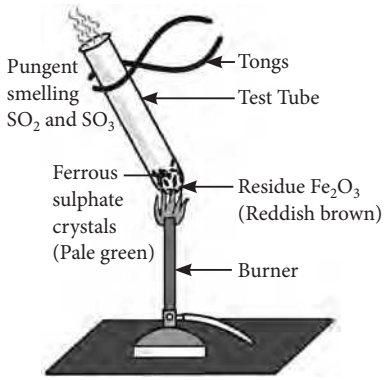
$$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \longrightarrow \underset{\text{(Yellow ppt.)}}{PbI_{2(s)}\downarrow} + 2KNO_{3(aq)}$$

13. The reaction in which oxygen is added or hydrogen is removed or loss of electrons takes place is called an oxidation reaction.
In the reaction,

$$\overset{\text{Reduction}}{ZnO} + C \longrightarrow Zn + \overset{\text{Oxidation}}{CO}$$

(i) Carbon is getting oxidised to carbon monoxide.
(ii) Zinc oxide is getting reduced to zinc.

14. Those reactions in which a compound breaks down into two or more simpler substances are known as decomposition reactions.
Aim : To show thermal decomposition reaction of ferrous sulphate.
Material required : Ferrous sulphate crystals, dry test tube, burner



Procedure : 1. Take 2 g of ferrous sulphate crystals in a dry test tube.

2. Observe the colour of ferrous sulphate crystals.

3. Heat the crystals of ferrous sulphate over the flame of a burner for some time.

4. Observe the crystals after heating for 5 minutes.

$$\underset{\substack{\text{Ferrous sulphate crystal}\\\text{(Pale green)}}}{FeSO_4 \cdot 7H_2O} \xrightarrow{\text{Heat}} \underset{\substack{\text{Anhydrous ferrous sulphate}\\\text{(White)}}}{FeSO_{4(s)}} + \underset{}{7H_2O_{(g)}}$$

$$\underset{\substack{\text{Ferrous sulphate}\\\text{(white)}}}{2FeSO_{4(s)}} \xrightarrow{\text{Heat}} \underset{\substack{\text{Ferric oxide}\\\text{(Reddish brown)}}}{Fe_2O_{3(s)}} + \underset{\substack{\text{Sulphur dioxide}\\\text{(Colourless)}}}{SO_{2(g)}} + \underset{\substack{\text{Sulphur trioxide}\\\text{(Colourless)}}}{SO_{3(g)}}$$

Observation : The pale green colour of ferrous sulphate crystals changes to reddish brown ferric oxide and smell of burning sulphur is observed.