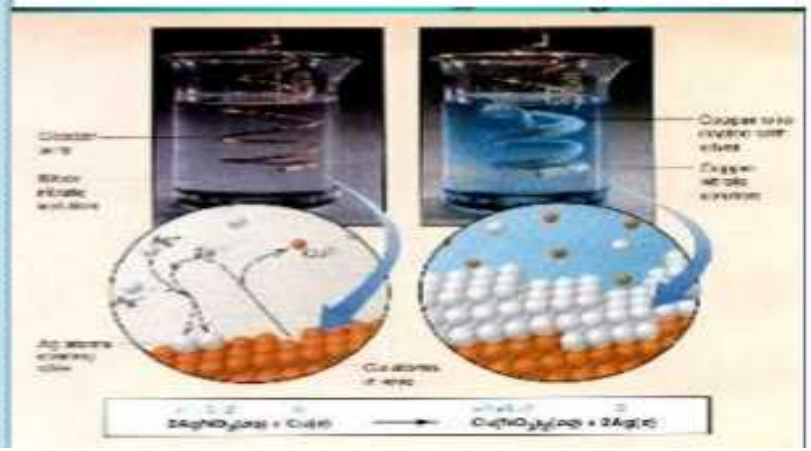
CHAPTER-1

Chemical Reactions and Equations



CLASS-X

- **Whenever a chemical change occurs, we can say that a chemical reaction has taken place.**

Figure 1.1
Burning of a magnesium ribbon in air and collection of magnesium oxide in a watch-glass

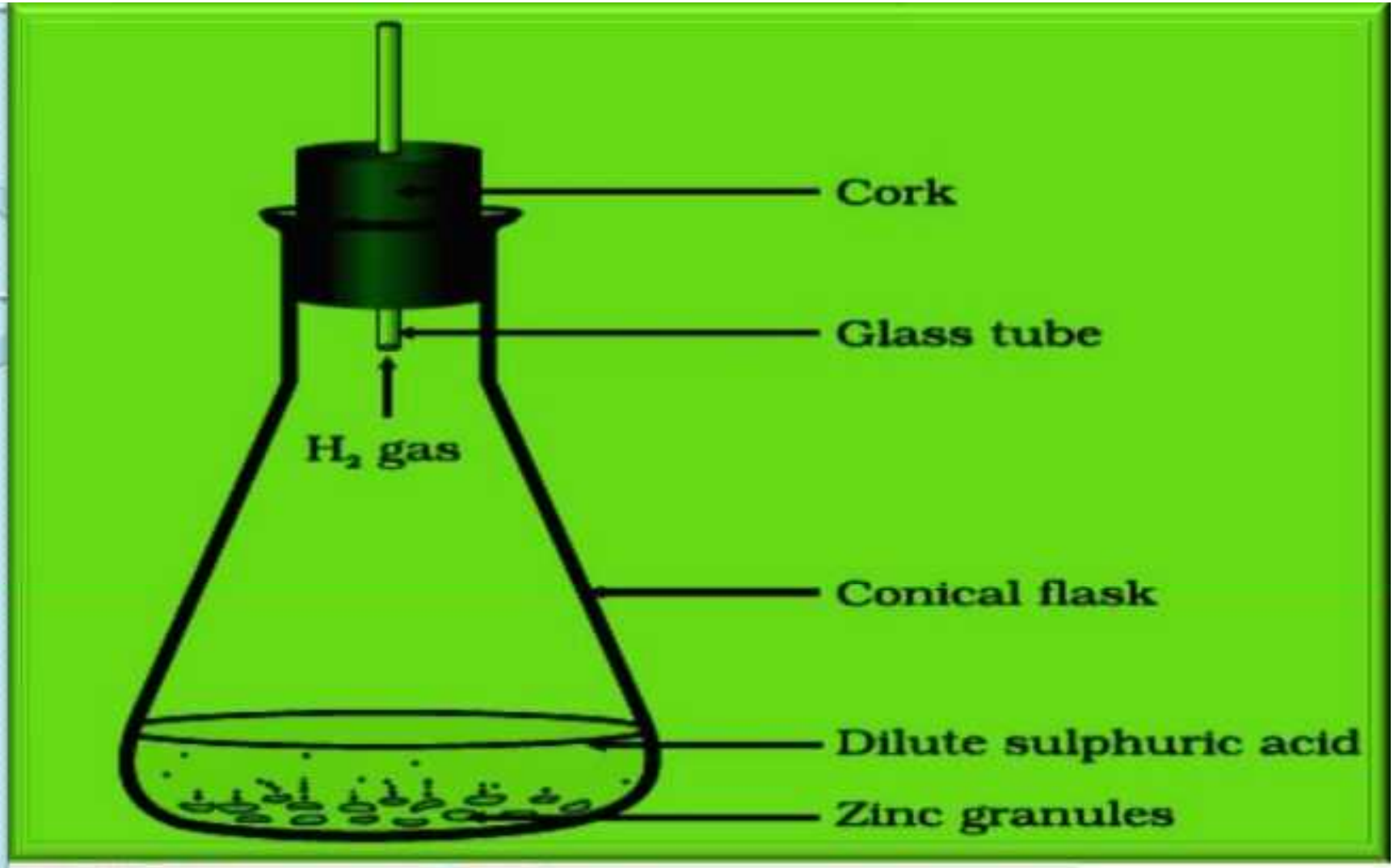


Figure 1.2
Formation of hydrogen gas by the action of dilute sulphuric acid on zinc

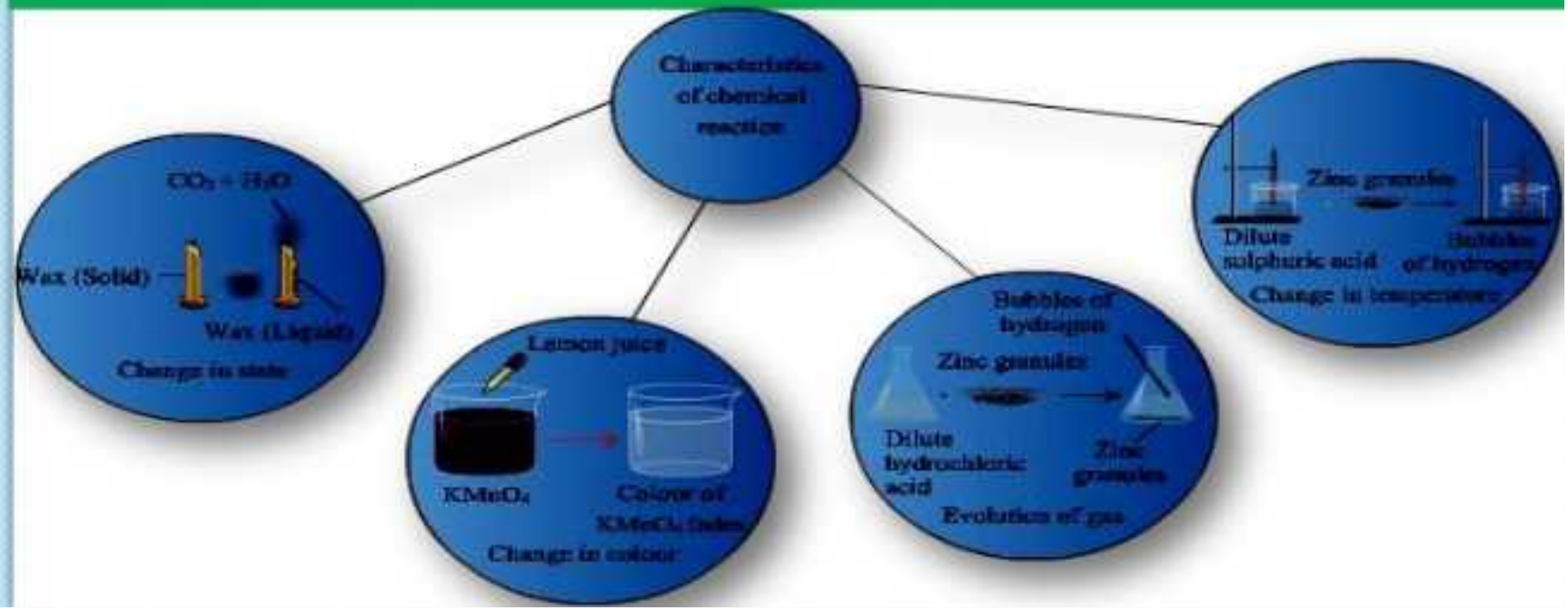
❖**The following observations helps us to determine whether a chemical reaction has taken place –**

1. change in state

2. change in colour

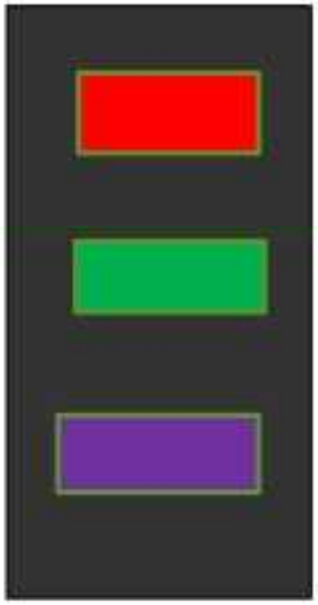
3. evolution of a gas

4. change in temperature.

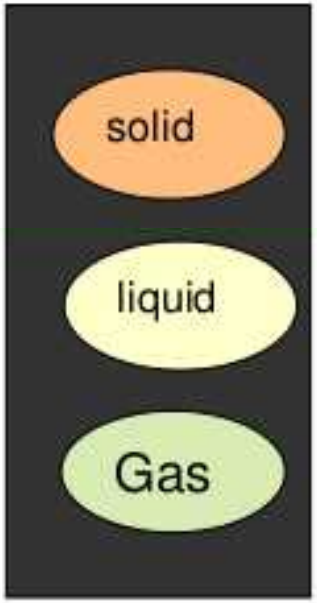


Signs of Chemical Reactions

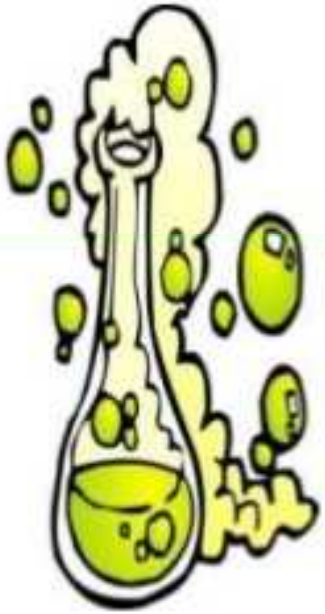
There are four main signs that indicate a chemical reaction has taken place:



change in color



change in state



Evolution of gas

change in temperature

❖CHEMICAL EQUATIONS

- when a magnesium ribbon is burnt in oxygen, it gets converted to magnesium oxide. This description of a chemical reaction in a sentence form is quite long. It can be written in a shorter form. The simplest way to do this is to write it in the form of a word-equation.
- The word-equation for the above burning of magnesium ribbon reaction would be –

Magnesium + Oxygen → Magnesium oxide

❖CHEMICAL EQUATIONS

- **Reactants – the substances that exist before a chemical change (or reaction) takes place.**
- **Products – the new substance(s) that are formed during the chemical changes.**
- **CHEMICAL EQUATION indicates the reactants and products of a reaction.**

REACTANTS → PRODUCTS

- A word-equation shows change of reactants to products through an arrow placed between them.

- The reactants are written on the left-hand side (LHS) with a plus sign (+) between them. Similarly, products are written on the right-hand side (RHS) with a plus sign (+) between them.

- The arrowhead points towards the products, and shows the direction of the reaction.

❖ Writing a Chemical Equation

$$Mg + O_2 \rightarrow MgO$$

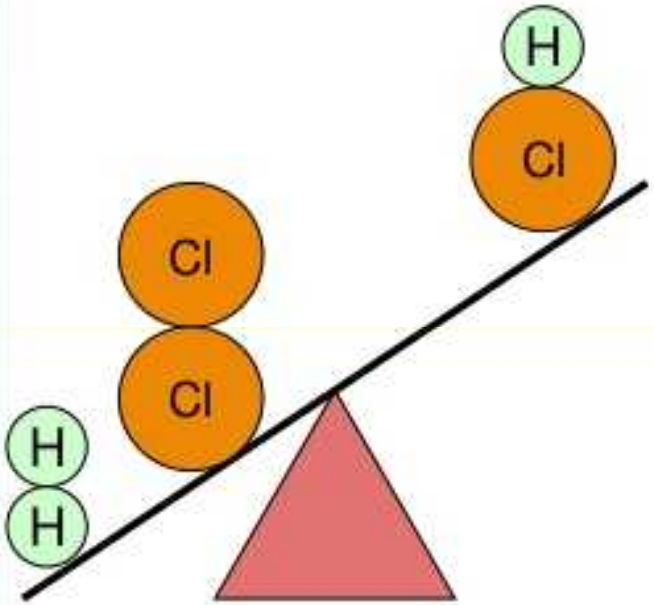
Count and compare the number of atoms of each element on the LHS and RHS of the arrow. Is the number of atoms of each element the same on both the sides? If not, then the equation is unbalanced because the mass is not the same on both sides of the equation. Such a chemical equation is a skeletal chemical equation for a reaction. Equation is a skeletal chemical equation for the burning of magnesium in air.

❖Balanced Chemical Equations

Mass can neither be created nor destroyed in a chemical reaction. That is, the total mass of the elements present in the products of a chemical reaction has to be equal to the total mass of the elements present in the reactants.

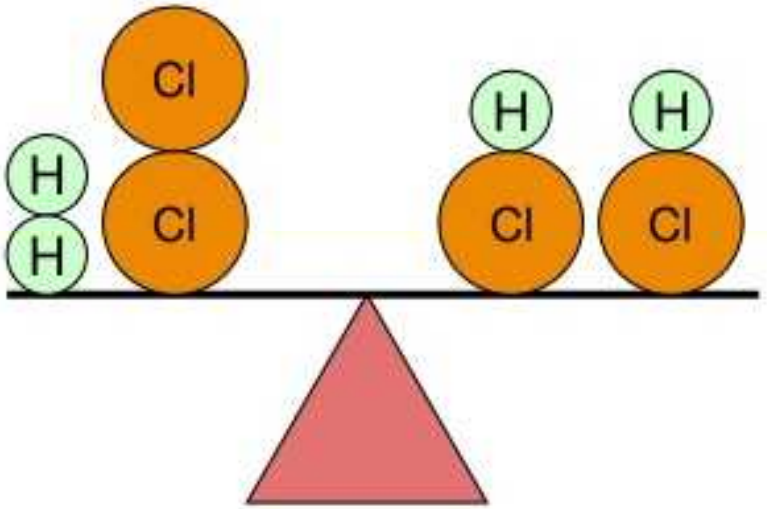
In other words, the number of atoms of each element remains the same, before and after a chemical reaction Hence, we need to balance a skeletal chemical equation.

Unbalanced and Balanced Equations



$H_2 + Cl_2 \rightarrow HCl$ (unbalanced)

	reactants	products
H	2	1
Cl	2	1



$H_2 + Cl_2 \rightarrow 2\ HCl$ (balanced)

	reactants	products
H	2	2
Cl	2	2

❑Let us try to balance the following chemical equation –

$$Fe + H_2O \rightarrow Fe_3O_4 + H_2$$

➢Step 1: **To balance a chemical equation, first draw boxes around each formula. Do not change anything inside the boxes while balancing the equation.**

$$\boxed{Fe} + \boxed{H_2O} \rightarrow \boxed{Fe_3O_4} + \boxed{H_2}$$

$$\boxed{Fe} + \boxed{H_2O} \rightarrow \boxed{Fe_3O_4} + \boxed{H_2}$$

Step II: List the number of atoms of different elements present in the unbalanced equation

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Fe	1	3
H	2	2
O	1	4

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Fe	1	3
H	2	2
O	1	4

➢**Step III:** **It is often convenient to start balancing with the compound that contains the maximum number of atoms. It may be a reactant or a product. In that compound, select the element which has the maximum number of atoms. Using these criteria, we select Fe_3O_4 and the element oxygen in it. There are four oxygen atoms on the RHS and only one on the LHS.**

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
Fe	1	3
H	2	2
O	1	4

To balance the oxygen atoms –

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

To equalise the number of atoms, it must be remembered that we cannot alter the formulae of the compounds or elements involved in the reactions. For example, to balance oxygen atoms we can put coefficient '4' as 4 H_2O and not H_2O_4 or $(H_2O)_4$. Now the partly balanced equation becomes –

$$\boxed{Fe} + 4\boxed{H_2O} \rightarrow \boxed{Fe_3O_4} + \boxed{H_2}$$

(partly balanced equation)

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

Step IV: Fe and H atoms are still not balanced. Pick any of these elements to proceed further. Let us balance hydrogen atoms in the partly balanced equation. To equalise the number of H atoms, make the number of molecules of hydrogen as four on the RHS.

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

The equation would be –

$$Fe + 4\,H_2O \rightarrow Fe_3O_4 + 4\,H_2$$

or

Step V: Examine the above equation and pick up the third element which is not balanced. You find that only one element is left to be balanced, that is, iron.

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

To equalise Fe, we take three atoms of Fe on the LHS.

$$3\,Fe + 4\,H_2O \rightarrow Fe_3O_4 + 4\,H_2$$

Step VI: Finally, to check the correctness of the balanced equation, we count atoms of each element on both sides of the equation.

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

(balanced equation

The numbers of atoms of elements on both sides are equal. This equation is now balanced. This method of balancing chemical equations is called hit-and-trial method as we make trials to balance the equation by using the smallest whole number coefficient.

Step VII: *Writing Symbols of Physical*

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

balanced Does this equation tell us anything about the physical state of each reactant and product? No information has been given in this equation about their physical states. To make a chemical equation more informative, the physical states of the reactants and products are mentioned along with their chemical formulae. The gaseous, liquid, aqueous and solid states of reactants and products are represented by the notations (g), (l), (aq) and (s), respectively. The word aqueous (aq) is written if the reactant or

The balanced Eq. becomes

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

*Usually physical states are not included in a chemical equation unless it is necessary to specify them.
*Sometimes the reaction conditions, such as temperature, pressure, catalyst, etc., for the reaction are indicated above and/or below the arrow in the equation. For example –

$$CO(g) + 2H_2(g) \xrightarrow{340\,atm} CH_3OH(l)$$

$$6CO_2(aq) + 6H_2O(l) \xrightarrow[Chlorophyll]{Sunlight} \underset{(Glucose)}{C_6H_{12}O_6(aq)} + 6O_2(aq)$$

❖QUESTIONS:-

Q1. WHY SHOULD A MAGNESIUM RIBBON BE CLEANED BEFORE BURNING IN AIR?

ANS-Magnesium is an extremely reactive metal. When stored, it reacts with oxygen to form a layer of magnesium oxide on its surface. This layer of magnesium oxide is quite stable and prevents further reaction of magnesium with oxygen. The magnesium ribbon is cleaned by sand paper for removing this layer so that the

Q2. Write the balanced equation for the following chemical reactions.

(I) Hydrogen + Chlorine → Hydrogen chloride

(II) Barium chloride + Aluminium sulphate → Barium sulphate + Aluminium chloride

(III) Sodium + Water → Sodium hydroxide + Hydrogen

ANS-1 $H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$

2- $3BaCl_{2(s)} + Al_2(SO_4)_{3(s)} \longrightarrow 3BaSO_{4(s)} + 2AlCl_{3(s)}$

3- $2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$

Q3. WRITE A BALANCED CHEMICAL EQUATION WITH STATE SYMBOLS FOR THE FOLLOWING REACTIONS.
(I) SOLUTIONS OF BARIUM CHLORIDE AND SODIUM SULPHATE IN WATER REACT TO GIVE INSOLUBLE BARIUM SULPHATE AND THE SOLUTION OF SODIUM CHLORIDE.
(II) SODIUM HYDROXIDE SOLUTION (IN WATER) REACTS WITH HYDROCHLORIC ACID SOLUTION (IN WATER) TO PRODUCE SODIUM CHLORIDE SOLUTION AND WATER.

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

(ii) $NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$

❖TYPES OF CHEMICAL REACTION

During a chemical reaction atoms of one element do not change into those of another element. Nor do atoms disappear from the mixture or appear from elsewhere. Actually, chemical reactions involve the breaking and making of bonds between atoms to produce new substances.

Types of Reactions

Combination:

Two or more reactants join together to make products that are fewer in number but larger in atom count.

Decomposition:

A reactant breaks apart to form products that are greater in number but smaller in atom count. Combination and Decomposition are the reverse of one another.

Single Displacement:

An element reacts with a compound to form a new element and a different compound. The reactant element "displaces" an element in the compound that is the most chemically similar. For example, a metal will replace a different metal.

Double Displacement:

Two compounds react to form two new compounds. The reactant elements "displace" a chemically similar element twice. For ionic compounds the positive ion reactant combines with the negative ion of the other reactant. The negative ion of the first reactant combines with the positive ion of the second.

1. Combination Reaction

- **Definition-A reaction in which a single product is formed from two or more reactants is known as a combination reaction.**
- **For ex-Calcium oxide reacts vigorously with water to produce slaked lime (calcium**

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

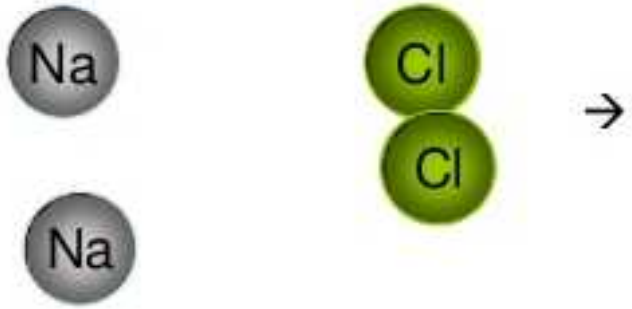
(Quick lime) (Slaked lime)

In this reaction, calcium oxide and water combine to form a single product, calcium hydroxide.

Combination Reaction

combination reaction (Synthesis)

$2\ Na + Cl_2 \rightarrow 2\ NaCl$



General form: A + B → AB

element or compound + element or compound → compound

➢Example of combination Reactions:-

Photosynthesis

$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

Formation of water

$$2\ H_2 + O_2 \longrightarrow 2\ H_2O$$

Formation of salt

$$2Na + Cl_2 \longrightarrow 2\ NaCl$$

General Form

$$A + B \longrightarrow C$$

Do You Know?

A solution of slaked lime produced by the reaction 1.13 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. It is interesting to note that the chemical formula for marble is also $CaCO_3$.

$$\underset{\text{(Calcium hydroxide)}}{Ca(OH)_2(aq)} + CO_2(g) \rightarrow \underset{\text{(Calcium carbonate)}}{CaCO_3(s)} + H_2O(l)$$

Let us discuss some more examples of combination reactions.

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

(ii) Formation of water from H2(g) and O2(g)

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

In simple language we can say that when two or more substances (elements or compounds) combine to form a single product, the reactions are called combination reactions.

Reactions in which heat is released along with the formation of products are called exothermic chemical reactions. Other examples of exothermic reactions are –

(i) Burning of natural gas

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

(ii) Do you know that respiration is an exothermic process?

We all know that we need energy to stay alive. We get this energy from the food we eat. During digestion, food is broken down into simpler substances. For example, 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.

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

(Glucose)

iii) The decomposition of vegetable matter into compost is also an example of an exothermic reaction.

2. Decomposition Reaction

- Definition-A reaction in which a single reactant is break down to give simpler product.
- For example-Ferrous sulphate crystals ($FeSO_4$, $7H_2O$) lose water when heated and the colour of the crystals changes. It then decomposes to ferric oxide (Fe_2O_3),sulphur dioxide (SO_2) and sulphur trioxide (SO_3). Ferric oxide is a solid, while SO_2 and SO_3 are gases

$$2FeSO_4(s) \xrightarrow{\text{Heat}} Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

(Ferrous sulphate) (Ferric oxide)

➢Example of Decomposition Reactions:-

Hydrogen Peroxide

$$2\ H_2O_2 \longrightarrow 2\ H_2O + O_2$$

Electrolysis of water

$$2\ H_2O \xrightarrow{electricity} H_2 + 2\ O_2$$

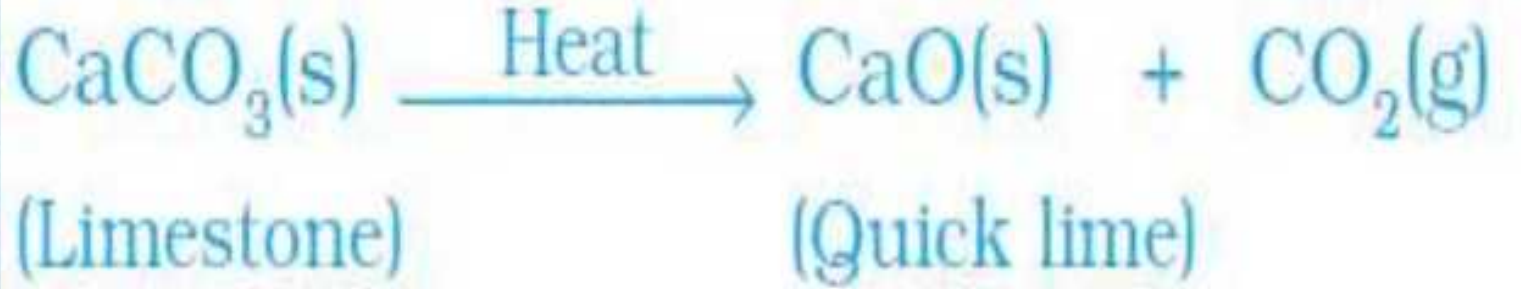
Nitrogen triiodide

$$2\ NI_3 \longrightarrow N_2 + 3\ I_2$$

General Form

$$AB \longrightarrow A + B$$

Decomposition of calcium carbonate to calcium oxide and carbon dioxide on heating is an important decomposition reaction used in various industries. Calcium oxide is called lime or quick lime. It has many uses – one is in the manufacture of cement. When a decomposition reaction is carried out by heating, it is called thermal decomposition.



Other example of thermal decomposition reaction are:-

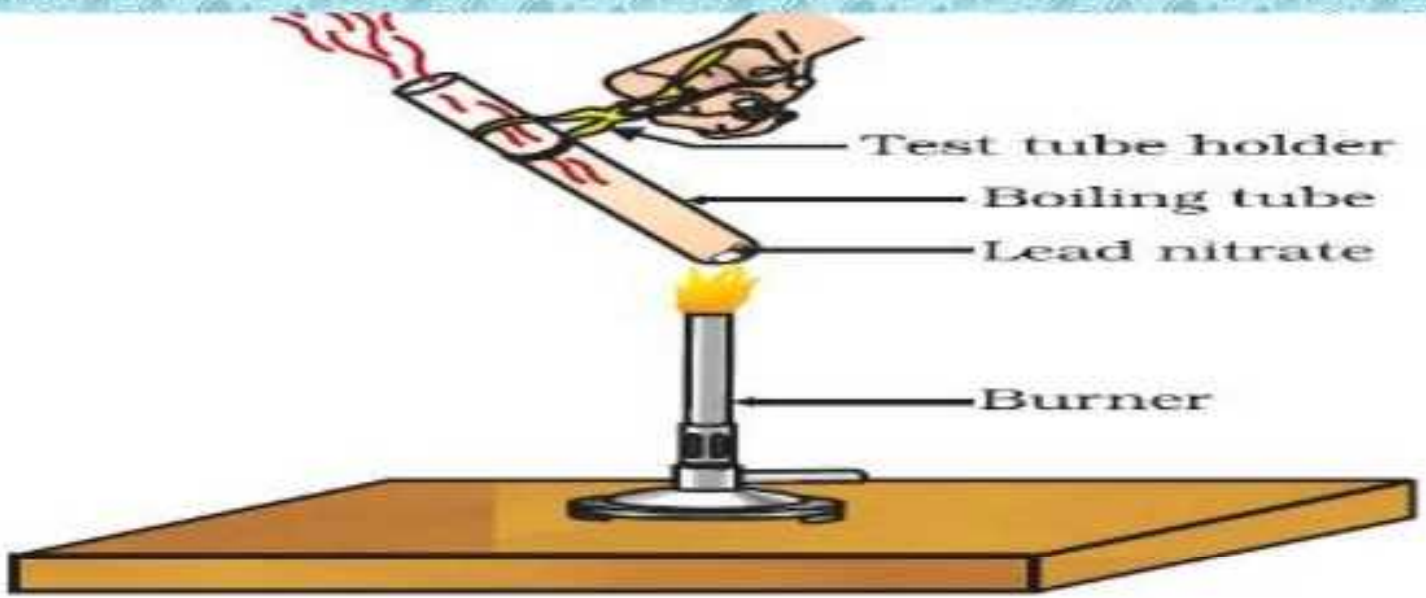


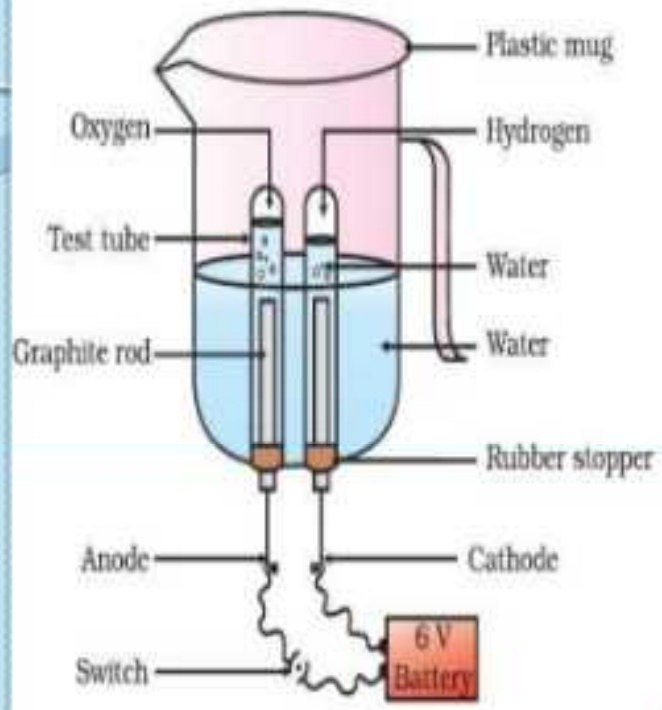
Figure 1.5
Heating of lead nitrate and emission of nitrogen dioxide

You will observe the emission of brown fumes. These fumes are of nitrogen dioxide (NO2). The reaction that takes place is –

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

(Lead nitrate) (Lead oxide) (Nitrogen dioxide) (Oxygen)

Let us perform some more decomposition reactions;



Electrolysis of water

Silver chloride turns grey in sunlight to form silver metal

You will see that white silver chloride turns grey in sunlight. This is due to the decomposition of silver chloride into silver and chlorine by light.

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

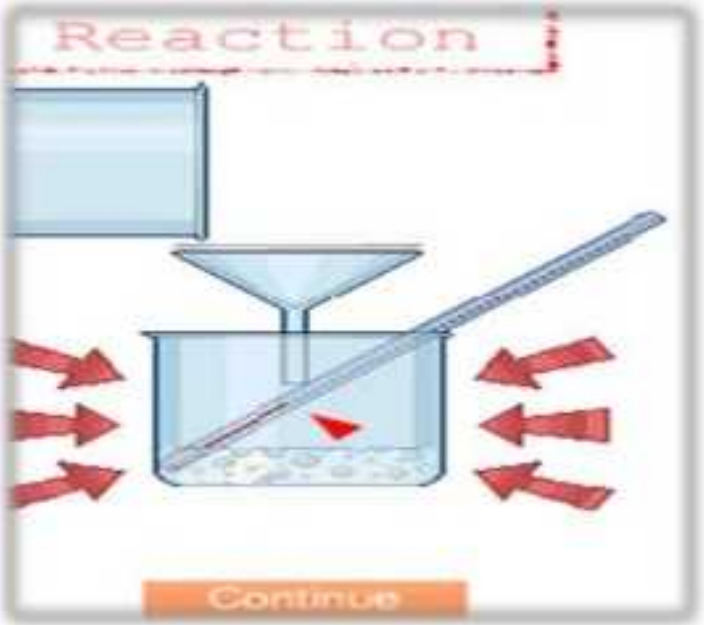
Silver bromide also behaves in the same way.

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

The above reactions are used in black and white photography.

Let's find out! click on this video

We have seen that the decomposition reactions require energy either in the form of heat, light or electricity for breaking down the reactants.Reactions in which energy is absorbed are known as **endothermic reactions.**



❖QUESTIONS:-

Q1. A SOLUTION OF A SUBSTANCE 'X' IS USED FOR WHITE WASHING.

(I) NAME THE SUBSTANCE 'X' AND WRITE ITS FORMULA.

(II) WRITE THE REACTION OF THE SUBSTANCE 'X' NAMED IN (I) ABOVE WITH WATER.

ANS-(i) The substance 'X' is calcium oxide.Its chemical formula is CaO.

(ii) Calcium oxide reacts vigorously with water to form calcium hydroxide (slaked lime)

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)}$$

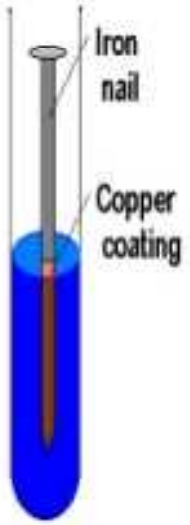
Calcium oxide (Quick lime) + Water → Calcium hydroxide (Slaked lime)

Q2. WHY IS THE AMOUNT OF GAS COLLECTED IN ONE OF THE TEST TUBES IN ACTIVITY 1.7 DOUBLE OF THE AMOUNT COLLECTED IN THE OTHER? NAME THIS GAS.

ANS-2Water (H_2O) contains two parts hydrogen and one part oxygen. Therefore, the amount of hydrogen and oxygen produced during electrolysis of water is in a 2:1 ratio. During electrolysis, since hydrogen goes to one test tube and oxygen goes to another, the amount of gas collected in one of the test tubes is double of the amount collected in the other.

3.Disaplacement Reaction

- Definition-A reaction in which a one element displaced or replaced or removed another element, is known as a displacement reaction.
- For example-The reaction between iror copper sulphate.



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

(Copper sulphate) (Iron sulphate)

In this reaction, iron has displaced or removed another element,copper, from copper sulphate solution

❑Other examples of displacement reactions are

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

(Copper sulphate) (Zinc sulphate)

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

(Copper chloride) (Lead chloride)

Zinc and lead are more reactive elements than copper. They displace copper from its compounds.

4.Double Displacement Reaction

- **Definition-A reactions in which there is an exchange of ions between the reactants are called double displacement reactions.**
- **For example-Formation of barium sulphate and sodium chloride from sodium sulphate and barium chloride.**

$$\underset{\text{(Sodium sulphate)}}{Na_2SO_4(aq)} + \underset{\text{(Barium chloride)}}{BaCl_2(aq)} \rightarrow \underset{\text{(Barium sulphate)}}{BaSO_4(s)} + \underset{\text{(Sodium chloride)}}{2NaCl(aq)}$$

Any reaction that produces a precipitate can be called a precipitation reaction.

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

(Sodium sulphate) (Barium chloride) (Barium sulphate) (Sodium chloride)

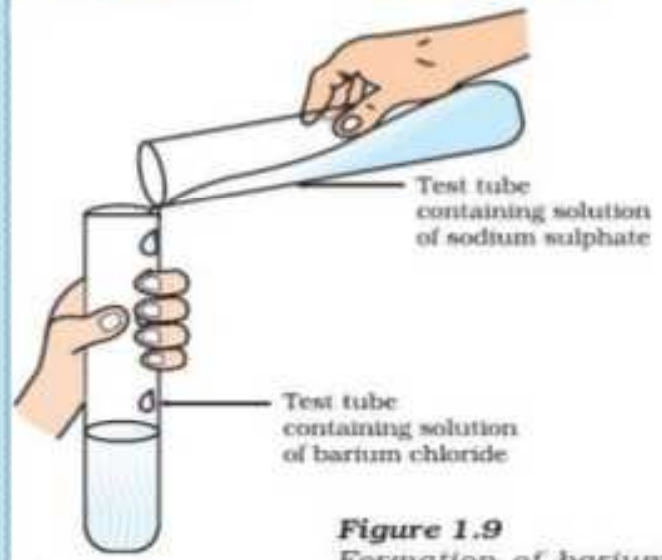
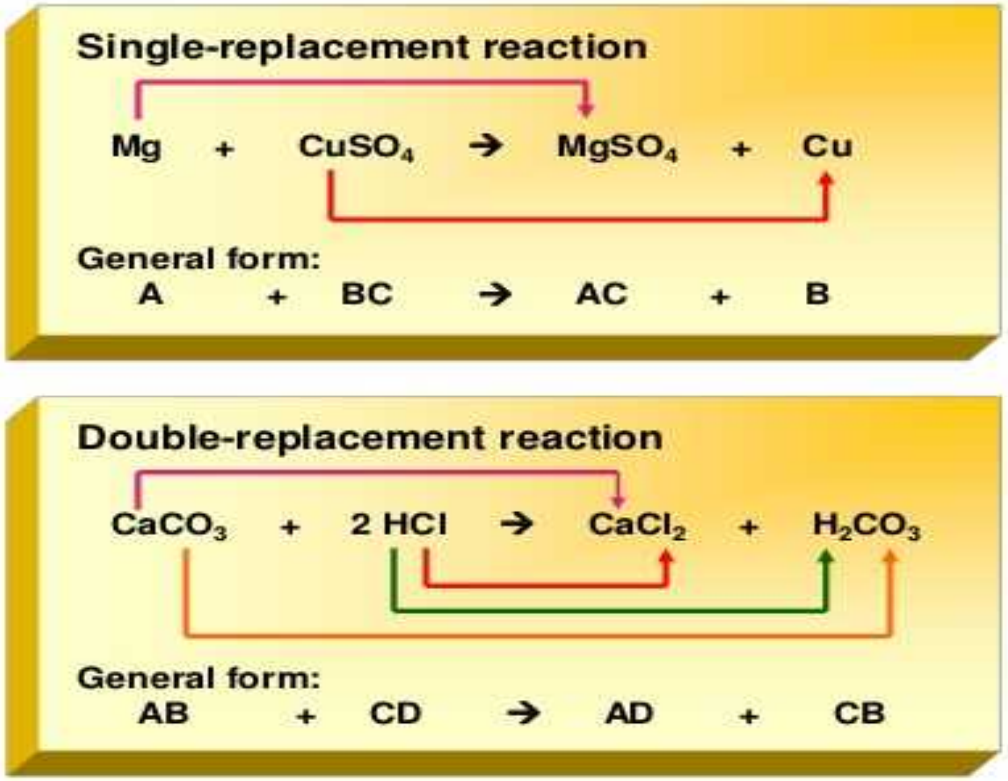


Figure 1.9
Formation of barium sulphate and sodium chloride

The white precipitate of $BaSO_4$ is formed by the reaction of SO_4^{2-} and Ba^{2+}. The other product formed is sodium chloride which remains in the solution.

Single and Double displacement Reactions



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Oxidation and Reduction

- The surface of copper powder becomes coated with black copper(II) oxide. Why has this black substance formed? This is because oxygen is added to copper and

$$2Cu + O_2 \xrightarrow{Heat} 2CuO$$

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

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

➢If a substance gains oxygen during a reaction, it is said to be oxidised. If a substance loses oxygen during a reaction, it is said to be reduced. During this reaction,the copper(II) oxide is losing oxygen and is being reduced. The hydrogen is gaining oxygen and is being oxidised.In other words, one reactant gets oxidised while the other gets reduced during a reaction. Such reactions are called oxidation-reduction reactions or redox reactions.