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# Chapter 1 Chemical Reactions and Equations

- What happens when-

(1) Milk is left at room temperature during the summer.
(2) An iron nail is left exposed to humid atmosphere.
(3) Grapes get fermented.
(4) Food is cooked.
(5) Food gets digested in our body.
(6) We respire.

- All these cases involve a chemical change where, the nature and the identity of the initial substance gets changed.
- Whenever a chemical change occurs, it involves a chemical reaction to take place.

- What is actually meant by a chemical reaction ?
- How do we know that a chemical reaction has taken place ?
- Any of the following observations helps us to determine whether a chemical reaction has taken place or not-

(1) Change in state
(2) Change in colour
(3) Evolution of a gas
(4) Change in temperature.

## Activity 1.1

- **Caution-**This Activity needs the teacher's assistance. It would be better if the students wear suitable eyeglasses during the activity.
- Clean a magnesium ribbon about 3-4 cm long by rubbing it with sandpaper.
- Hold it with a pair of tongs.
- Burn it using a spirit lamp or burner, keeping it away as far as possible from your eyes and collect the ash so formed in a watch-glass as shown in Figure.
- What do you observe ?

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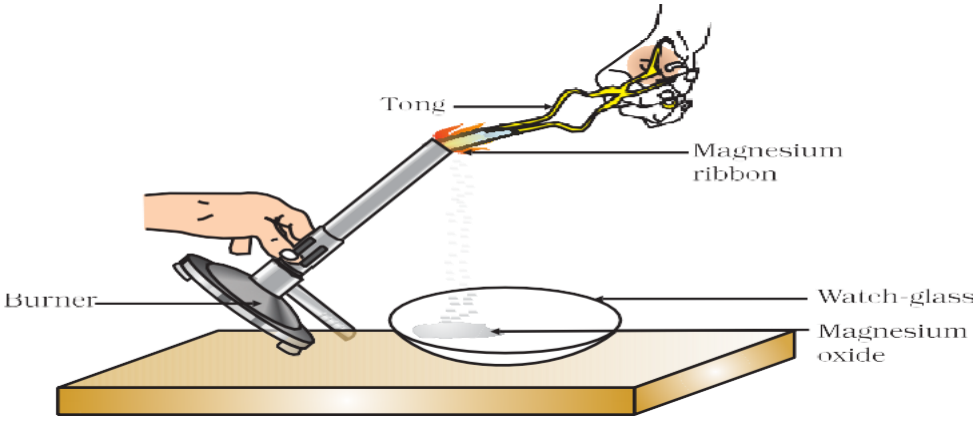



**Fig.-Burning of a magnesium ribbon in air**

Here, magnesium ribbon burns with a dazzling white flame and changes into a white powder. This powder is magnesium oxide. It is formed due to the reaction between magnesium and oxygen present in the air.

## Activity 1.2

- Take lead nitrate solution in a test tube.
- Add potassium iodide solution to this solution.
- What do you observe ?

## Activity 1.3

- Take a few zinc granules in a conical flask.
- Add dilute hydrochloric acid or sulphuric acid to the flask.
- Do you observe anything happening around the zinc granules ?
- Touch the conical flask.
- Is there any change in its temperature ?

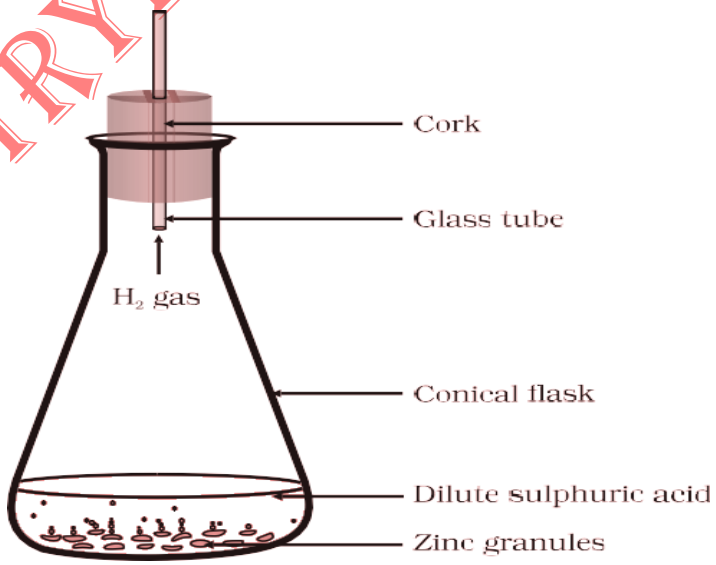



**Fig.-Action of dilute sulphuric acid on zinc granules**

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## Chemical Equations

When a chemical reaction is written in word or symbolic form, then it is called a chemical equation.

For example, when a magnesium ribbon is burnt in oxygen, it gets converted into magnesium oxide. This description of a chemical reaction in a sentence form is quite long. It can be written in a shorter form using a word-equation as under-

Magnesium + Oxygen → Magnesium oxide

(Reactants) (Product)

Here, the substances which undergo chemical change in the reaction i.e. magnesium and oxygen are called the reactants, while, the new substance formed during the reaction i.e. magnesium oxide is called the product.

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

Chemical equations can be made more concise and useful using the chemical formulae of the reactants and products instead of the words. For example, the reaction between magnesium and oxygen to form magnesium oxide can be written as under-

$$2Mg + O_2 \rightarrow 2MgO$$

Here, if the number of atoms of each element on both the sides is same, then the equation is said to be balanced equation. But, if it is not same, then the equation is said to be unbalanced equation, as the mass is not the same on both sides of the equation. Such a chemical equation is called the skeletal chemical equation for the reaction. For example, the skeletal chemical equation for the burning of magnesium in air is as under-

$$Mg + O_2 \rightarrow MgO$$

## Balanced Chemical Equations

As per the law of conservation of mass, the matter can neither be created nor destroyed during a chemical reaction. Thus, the total mass of the elements present in the products of a chemical reaction must be equal to the total mass of the elements present in the reactants. In other words, the number of atoms of each element must be the same before and after a chemical reaction.

The word-equation for the reaction between zinc and sulphuric acid is as under-

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Zinc + Sulphuric acid $\rightarrow$ Zinc sulphate + Hydrogen

This word-equation is represented by the following chemical equation-

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

Let us examine the number of atoms of different elements on both sides of the arrow.

| Element | Number of atoms in Reactants (LHS) | Number of atoms in Products (RHS) |
|---|---|---|
| Zn | 1 | 1 |
| H | 2 | 2 |
| S | 1 | 1 |
| O | 4 | 4 |

As the number of atoms of each element is the same on both sides of the reaction, this is a balanced chemical equation.

**Q.-**Balance the following chemical equation-

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

**Ans.-**

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

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

**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 |

**Step III-** It is often convenient to start balancing of equation with the compound containing the maximum number of atoms. It may be a reactant or a product. In this compound, we also select the element having the maximum number of atoms for balancing. Here, we have to select $Fe_3O_4$ and the element oxygen first for balancing. There are four oxygen atoms on the RHS and only one on the LHS.

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To balance the oxygen atoms, $H_2O$ molecule present in reactant should be multiplied by 4.

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

**Step IV-**To balance hydrogen atoms, $H_2$ molecule present in product should be multiplied by 4.

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

**Step V-**To balance iron atoms, Fe present in reactant should be multiplied by 3.

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

**Step VI-**To balance iron atoms, Fe present in reactant should be multiplied by 3.

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

Now, the numbers of atoms of all the elements on both sides of this equation are equal. Hence, 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-** To make a chemical equation more informative, some times physical states of the reactants and products are also 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 product is present as a solution in water.

Representing physical state of reactants and products, the above equation can be written as under-

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

The symbol (g) used with $H_2O$ indicates that, in this reaction water is used in the form of steam.

Usually physical states are not included in a chemical equation, unless it is necessary to specify them.

**Questions-**

Q.1. Why should a magnesium ribbon be cleaned before burning in air ?

Q.2. Write the balanced equation for the following chemical reactions-

(a) Hydrogen + Chlorine → Hydrogen chloride

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

(c) Sodium + Water → Sodium hydroxide + Hydrogen

Q.3.Write a balanced chemical equation with state symbols for the following reactions.

(a) Solutions of barium chloride and sodium sulphate in water react to give insoluble barium sulphate and the solution of sodium chloride.

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(b) Sodium hydroxide solution (in water) reacts with hydrochloric acid solution (in water) to produce sodium chloride solution and water.

## Types of Chemical Reactions

During a chemical reaction atoms of one element do not change into those of another element. Also they do not disappear from the mixture or appear from elsewhere. Actually, chemical reactions involve the breaking and making of bonds between atoms to produce new substances.

## (1) Combination Reaction

Such a reaction in two or more substances (elements or compounds) combine together to form a single product is known as a combination reaction.

For example, calcium oxide (quick lime) reacts vigorously with water to produce slaked lime (calcium hydroxide) releasing a large amount of heat.

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

(Quick lime) (Slaked lime)

Some more examples of combination reactions are as under-

(1) Burning of coal

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

(2) Formation of water from $H_2(g)$ and $O_2(g)$

$$2H_2(g) + O_2(g) \rightarrow CO_2(g)$$

## Activity 1.4

- Take a small amount of calcium oxide or quick lime in a beaker.
- Slowly add water to this.
- Touch the beaker as shown in Fig.
- Do you feel any change in temperature ?

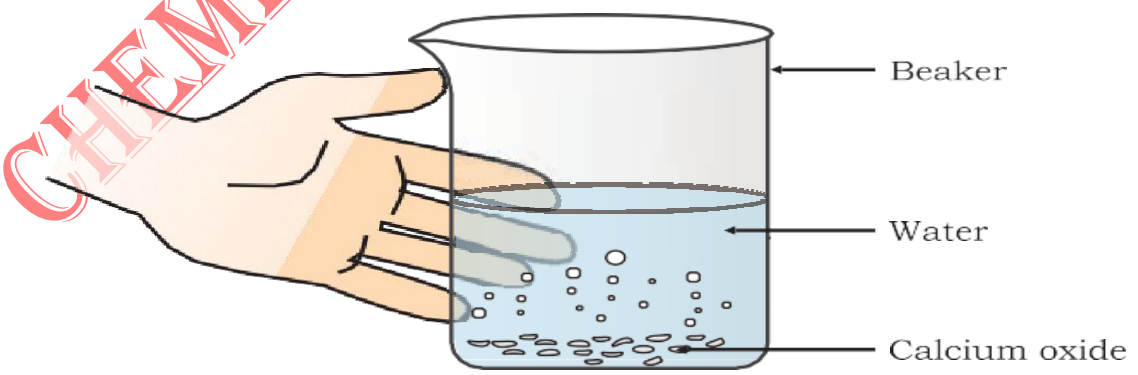



**Fig.-Formation of slaked lime by the reaction of calcium oxide with water**

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## Do You Know

- A solution of slaked lime is used for whitewashing 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 whitewashing and gives a shiny finish to the walls.

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

Calcium hydroxide  Calcium carbonate

**Exothermic Reactions-**Reactions in which heat is released along with the formation of products are called exothermic chemical reactions.

For examples-

(1) Reaction of quick lime with water

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

(Quick lime)  (Slaked lime)

(2) Burning of natural gas

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

(3) Respiration

(4) The decomposition of vegetable matter into

## What is Respiration ?

We all need energy to stay alive. This energy is obtained 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 and the reaction involved in respiration is as under-

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

(Glucose)

**(2)Decomposition Reaction-** Such reactions in which a single reactant breaks down to give two or more simpler products are called decomposition reactions. For example, when calcium carbonate is heated, it gets decomposed to give calcium oxide and carbon dioxide.

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

Lime stone  Quick lime

Calcium oxide is called lime or quick lime. It is used in the manufacture of cement.

Here, since the decomposition reaction is being carried out by heating, it is

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called thermal decomposition.

Similarly, ferrous sulphate ($FeSO_4$) on heating undergoes thermal decomposition to form ferric oxide ($Fe_2O_3$), sulphur dioxide ($SO_2$) and sulphur trioxide ($SO_3$).

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

In fact, when green coloured crystals of ferrous sulphate are heated, they lose their crystallization water to give anhydrous ferrous sulphate which is colourless. On further heating anhydrous ferrous sulphate decomposes to form ferric oxide ($Fe_2O_3$), sulphur dioxide ($SO_2$) and sulphur trioxide ($SO_3$). Here, characteristic odour of burning sulphur is produced due to formation of oxides of sulphur.

## ➢ Activity 1.5

- Take about 2 g ferrous sulphate crystals in a dry boiling tube.
- Note the colour of the ferrous sulphate crystals.
- Heat the boiling tube over the flame of a burner or spirit lamp as shown in Fig.
- Observe the colour of the crystals after heating.




**Fig.- Heating the crystals of ferrous sulphate**

In the same way, lead nitrate undergoes thermal decomposition on heating to form lead oxide (PbO), nitrogen dioxide ($NO_2$) and oxygen ($O_2$).

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

Here, brown fumes of nitrogen dioxide ($NO_2$) is emitted.

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## Activity 1.6

- Take about 2 g lead nitrate powder in a boiling tube.
- Hold the boiling tube with a pair of tongs and heat it over a flame, as shown in Fig.
- What do you observe ? Note down the change, if any.

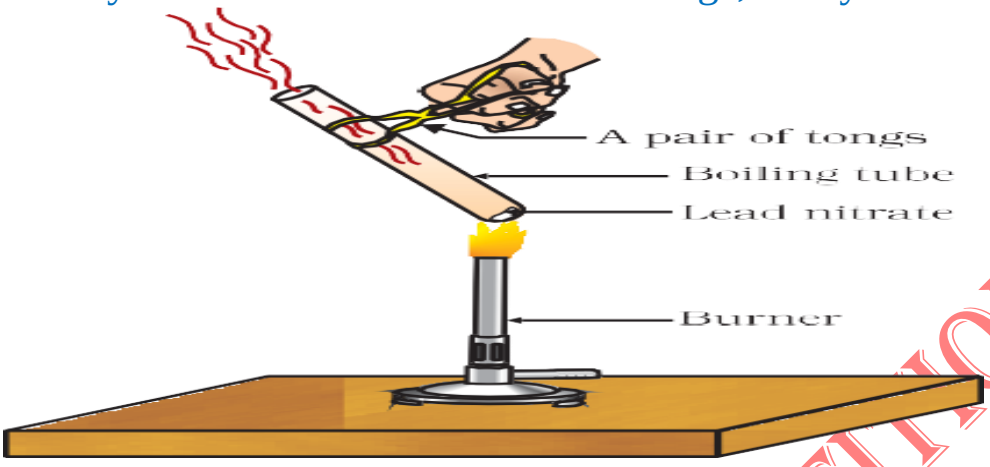



**Fig.-Heating of lead nitrate and emission of nitrogen dioxide**

## Activity 1.7

- Take a plastic mug. Drill two holes at its base and fit rubber stoppers in these holes. Insert carbon electrodes in these rubber stoppers as shown in Fig.
- Connect these electrodes to a 6 volt battery.
- Fill the mug with water such that the electrodes are immersed. Add a few drops of dilute sulphuric acid to the water.
- Take two test tubes filled with water and invert them over the two carbon electrodes.
- Switch on the current and leave the apparatus undisturbed for some time.
- Observe the formation of bubbles at both the electrodes. These bubbles displace water in the test tubes.
- Is the volume of the gas collected the same in both the test tubes?
- Once the test tubes are filled with the respective gases, remove them carefully.
- Test these gases one by one by bringing a burning candle close to the mouth of the test tubes.
  - **Caution-** This step must be performed carefully by the teacher.
- What happens in each case ?
- Which gas is present in each test tube ?
- Why is the amount of gas collected in one of the test tubes double of the amount collected in the other ? Name this gas.

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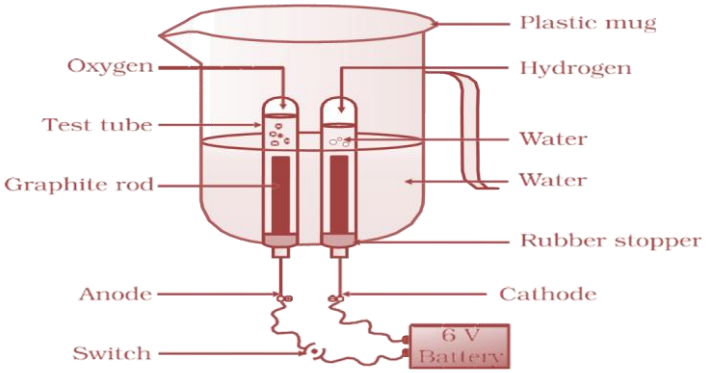



**Fig.- Electrolysis of Water**

White silver chloride turns grey in sunlight. This is due to the decomposition of silver chloride into silver and chlorine by light.

$$2AgCl(s) \xrightarrow{Sun\ light} 2Ag(s) + Cl_2(g)$$

White Grey

## Activity 1.8

- Take about 2 g silver chloride in a china dish.
- What is its colour ?
- Place this china dish in sunlight for some time.
- Observe the colour of the silver chloride after some time.

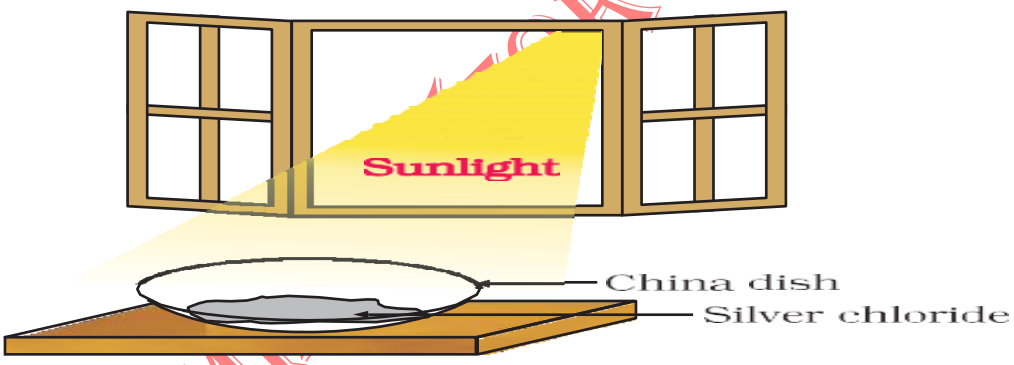



Fig.- Silver chloride turns grey in sunlight to form silver metal

Silver bromide also behaves in the same way.

$$2AgBr(s) \xrightarrow{Sun\ light} 2Ag(s) + Br_2(g)$$

These reactions are used in black and white photography.

Thus, 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.

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Take about 2 g barium hydroxide in a test tube. Add 1 g of ammonium chloride and mix with the help of a glass rod. Touch the bottom of the test tube with your palm. What do you feel? Is this an exothermic or endothermic reaction?

**Questions-**

**Q.1.** A solution of a substance 'X' is used for whitewashing. Name the substance 'X' and write its formula. Write the reaction of the substance 'X' with water.

## (3) Displacement Reaction

Such reactions in which a more reactive element displaces less reactive elements from their compounds are called displacement reactions.

For example, iron being more reactive than copper displaces copper from copper sulphate solution.

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

(Copper sulphate) (Iron sulphate)

Similarly, zinc and lead are also more reactive than copper. Hence, they displace copper from its compounds.

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

(Copper sulphate) (Zinc sulphate)

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

(Cupric chloride) (Lead chloride)

## Activity 1.9

- Take three iron nails and clean them by rubbing with sand paper.
- Take two test tubes marked as (A) and (B). In each test tube, take about 10 mL copper sulphate solution.
- Tie two iron nails with a thread and immerse them carefully in the copper sulphate solution in test tube B for about 20 minutes [Fig.(a)]. Keep one iron nail aside for comparison.
- After 20 minutes, take out the iron nails from the copper sulphate solution.
- Compare the intensity of the blue colour of copper sulphate solutions in test tubes and (B) [Fig.(b)].
- Also, compare the colour of the iron nails dipped in the copper sulphate solution with the one kept aside [Fig. 1.8 (b)].
- Why does the iron nail become brownish in colour and the blue colour of copper sulphate solution fades ?
- Write the chemical reaction taking place in this activity.

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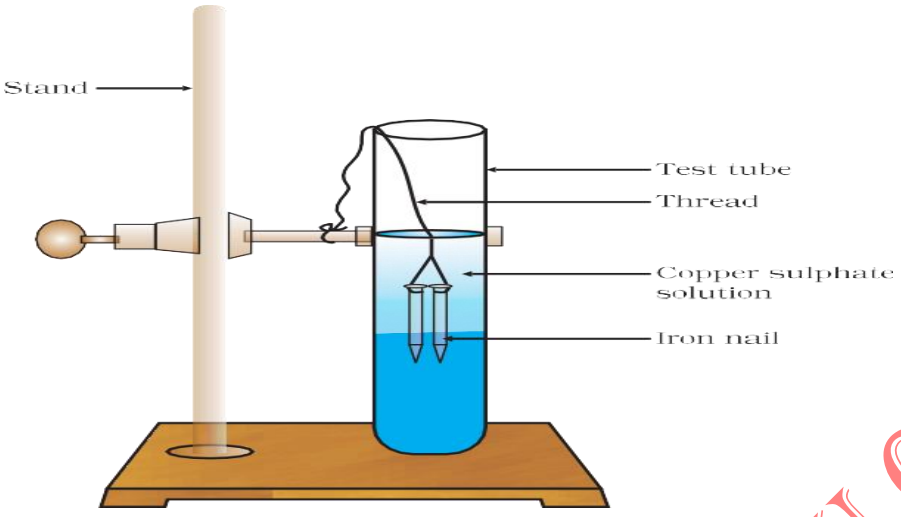



**Fig.-(a) Iron nails dipped in copper sulphate solution**

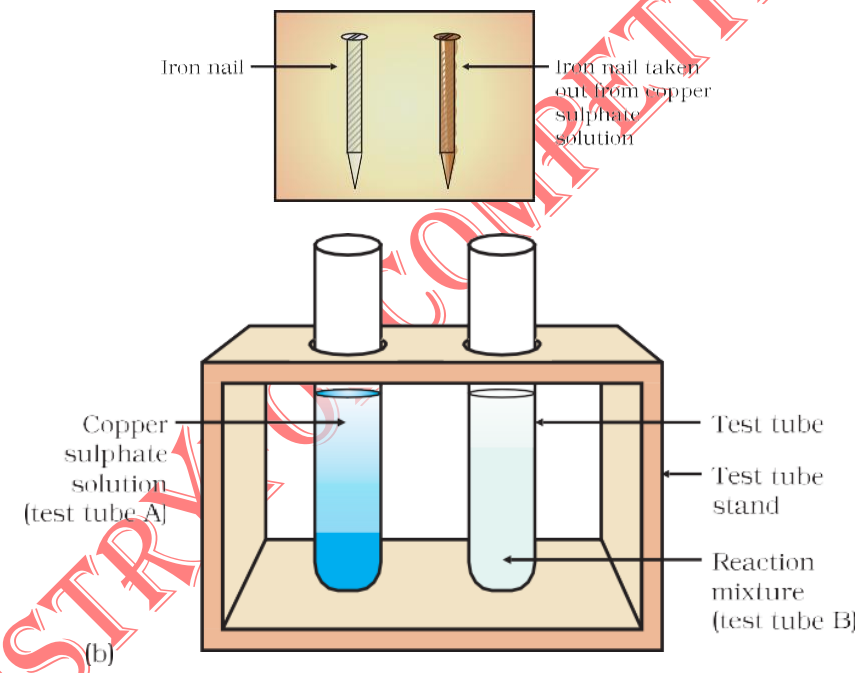



**Fig.(b)-Iron nails and copper sulphate solutions compared before and after the experiment**

## (4) Double Displacement Reaction

Such reactions in which there is an exchange of ions between the reactants are called double displacement reactions. For example,

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

Sodium sulphate Barium chloride Barium sulphate Sodium chloride

$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

Sodium chloride Silver nitrate Silver chloride Sodium nitrate

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## Activity 1.10

- Take about 3 ml of sodium sulphate solution in a test tube.
- Take about 3 mm of barium chloride solution in another test tube.
- Mix the two solutions
- What do you observe ?

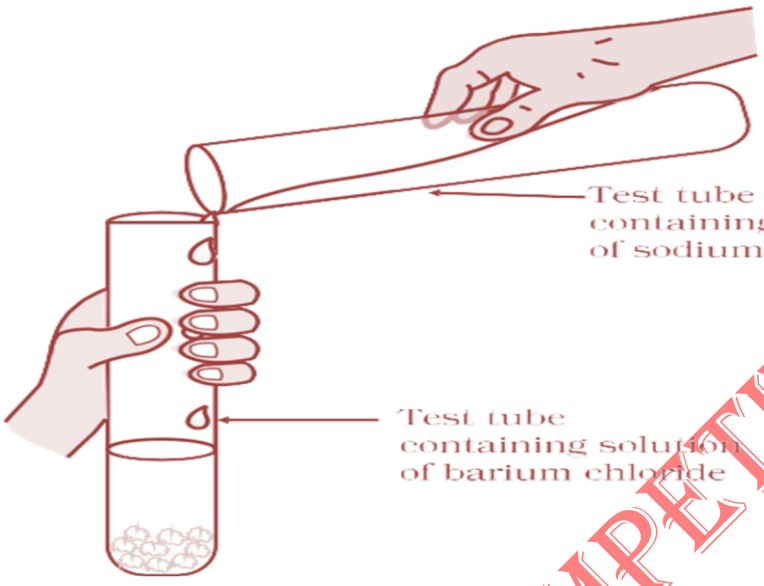



**Fig.- Precipitation Reaction**

Here, a white substance, which is insoluble in water is formed. This insoluble substance formed is called a precipitate. Such reactions which produce a precipitate are called a precipitation reactions.

**Q.** When lead (II) nitrate is mixed with potassium iodide-

(1) What is the colour of the precipitate formed ?

(2) Can you name the compound precipitated ?

(3) Write the balanced chemical equation for the reaction.

(4) Is this a double displacement reaction ?

## (5) Oxidation and Reduction

The process of addition of oxygen to a substance is called oxidation of the substance, while, the process of removal of oxygen from a substance is called reduction of the substance. If a substance gains oxygen during a reaction, it is said to be oxidized, but if it loses oxygen during a reaction, it is said to be reduced. For example,

$$2Cu(s) + O_2 \xrightarrow{Heat} 2CuO(s) \qquad \text{(Oxidation of Cu)}$$

$$CuO(s) + H_2 \xrightarrow{Heat} Cu(s) + H_2O(l) \qquad \text{(Reduction of CuO)}$$

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## Activity 1.11

- Heat a china dish containing about 1 g copper powder (Fig.).
- What do you observe ?

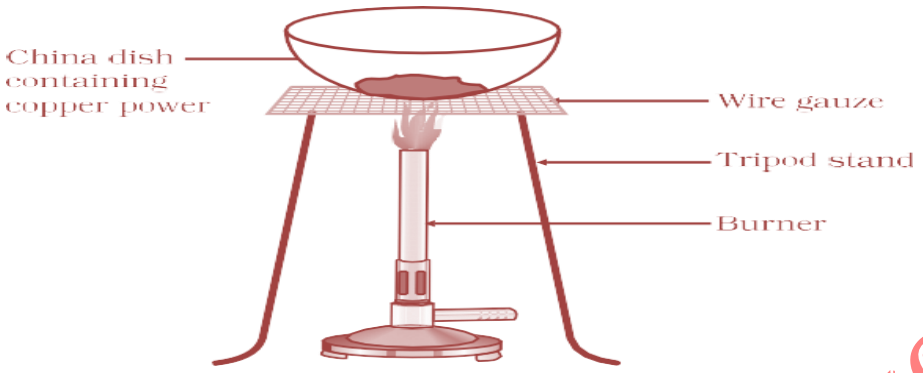



**Fig.-Oxidation of copper to copper oxide**

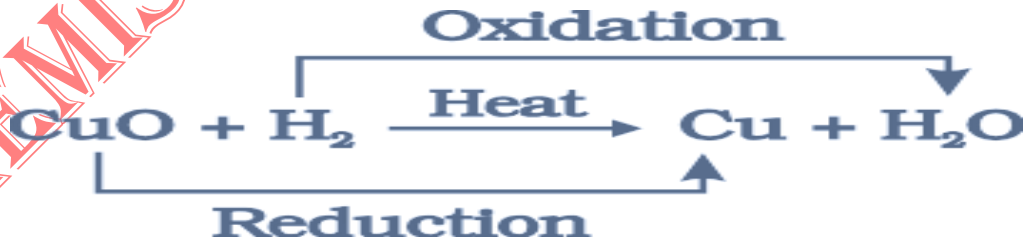
Here, the surface of copper powder becomes coated with black copper (II) oxide. It is because of the addition of oxygen to the copper forming copper oxide.

$$2Cu(s) + O_2 \xrightarrow{Heat} 2CuO(s)$$

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.

$$CuO(s) + H_2 \xrightarrow{Heat} Cu(s) + H_2O(l)$$

During this reaction, copper (II) oxide is losing oxygen and therefore, it is being reduced. On the other hand, hydrogen is gaining oxygen and therefore, it is being oxidised. Thus, in this reaction one reactant is being oxidized, while the other is being reduced. Such reactions are called oxidation-reduction reactions or redox reactions.




Some other examples of redox reactions are as under-

(1) $ZnO + C \rightarrow Zn + CO$

In this reaction carbon is oxidised to CO and ZnO is reduced to Zn.

(2) $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

Here, HCl is oxidised to $Cl_2$, while, $MnO_2$ is reduced to $MnCl_2$.

From these examples it can be concluded that, if a substance gains oxygen or

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loses hydrogen during a reaction, then it is oxidised. But, if a substance loses oxygen or gains hydrogen during a reaction, then it is reduced.

## Corrosion

When a metal is attacked by substances around it such as air, moisture, acids, etc., it is said to corrode and this process is called corrosion.

For example, Iron articles are shiny when new, but get coated with a reddish brown powder when left for some time. This process is commonly known as rusting of iron. The formation of black coating on silver and the green coating on copper are other examples of corrosion.

Corrosion causes damage to car bodies, bridges, iron railings, ships and to all objects made of metals, specially those of iron. Corrosion of iron is a serious problem. Every year an enormous amount of money is spent to replace damaged iron.

## Rancidity

When fats and oils are kept for a long time, they get oxidized and their taste and smell get changed. This phenomenon is called rancidity.

Usually substances which prevent oxidation (antioxidants) are added to foods containing fats and oil. Keeping food in air tight containers helps to slow down oxidation. Chips manufacturers usually flush bags of chips with gas such as nitrogen to prevent the chips from getting oxidised ?

## Question-

(1) Why does the colour of copper sulphate solution change when an iron nail is dipped in it ?

(2) Give an example of a double displacement reaction.

(3) Identify the substances that are oxidised and reduced in the following reactions-

(i) $4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

(ii) $CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$

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