

Chapter 10

Chemical Reactions and Equations



Look at the following examples from daily life and think about the changes taking place:

- Formation of curd/ yogurt from milk
- Burning of coal
- Food is cooked
- Rusting of iron nail

In the examples given above, we find that the nature and identity of the initial materials have changed in some way. We have already studied physical and chemical changes in previous classes. Whenever a chemical change occurs, we can say that a chemical reaction has taken place.

Let us perform some activities to understand chemical reactions.

Activity-1

- Take a magnesium ribbon about 2 cm long. Clean it by rubbing with sandpaper.
- Hold it with a pair of tongs. Burn it using a spirit lamp or burner and collect the ash so formed in a watch-glass as shown in fig.1. Dissolve the ash in water and test it using litmus paper.
- Do this activity with the help of your teacher and keep the burning ribbon as far from your eyes as possible.

1. Did a new substance form during the activity?
2. Where there any changes in the state of magnesium?

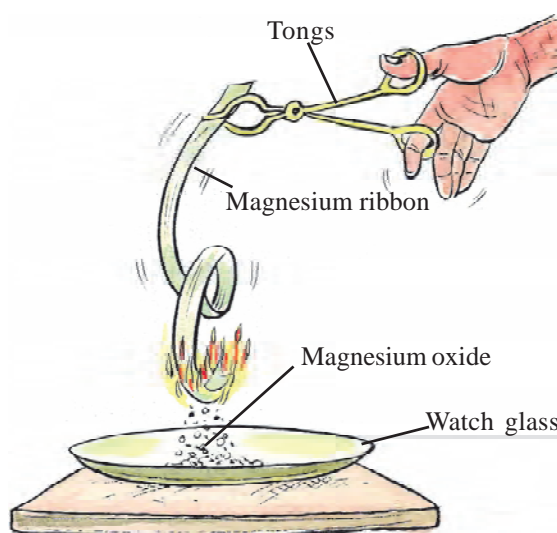


Fig.1 : Combustion of Magnesium ribbon

We saw that magnesium ribbon burns with a dazzling white flame and it changes into a white powder. This powder is magnesium oxide which is formed due to the reaction between magnesium and the oxygen present in the air. The solution of magnesium oxide in water is basic and turns red litmus blue.

Activity-2

- Take two test tubes. In the first, prepare a solution of sodium sulphate by dissolving it in water. Similarly, prepare a solution of barium chloride in the second test tube.
 - In another test tube, take 10 mL of the sodium sulphate solution and slowly add the barium chloride solution to it.
1. Did you get any precipitate?
 2. Note the colour of the precipitate?

Activity-3

- Take a few zinc granules in a boiling tube.
 - Add some dilute hydrochloric acid to it.
1. Do you observe anything happening around the zinc granules (Fig.2)?
 2. Touch the boiling tube. Is there any change in its temperature?
 3. What happens when you put a lighted matchstick close to the mouth of the boiling tube?

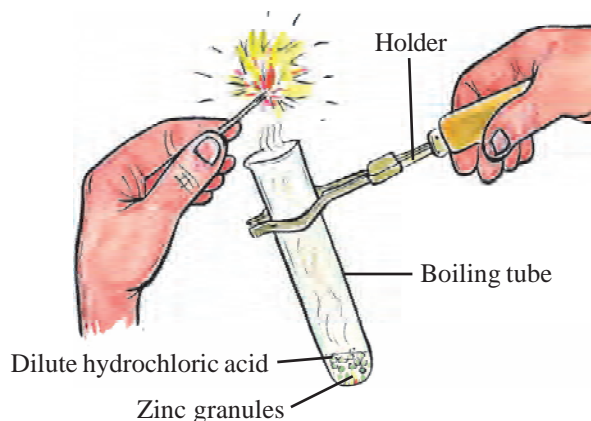


Fig. 2 : Formation of H_2 gas by the action of dilute hydrochloric acid on zinc

In the three activities given above, new substances are being formed. Further, one or more of the following changes is taking place on the basis of which we can determine that a chemical reaction is taking place:

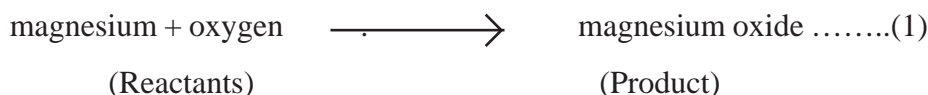
- Change in state
- Change in colour
- Evolution of gas during the reaction
- Change in temperature as a result of the reaction.

We see many chemical reactions around us in which we can observe these changes in state, colour etc. In this chapter, we will study some of these chemical reactions and their symbolic representation.

10.1 Chemical equations

In activity-1 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 is simpler to write it in the form of a word-equation.

The word-equation for the above reaction is-

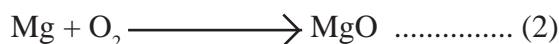


Magnesium and oxygen are the substances that undergo chemical change in the reaction and are known as reactants. The new substance, magnesium oxide, formed during the reaction, is the product.

A word-equation shows change of reactants to products through an arrow (\rightarrow) placed between them. The arrowhead points towards the products, and shows the direction of the reaction. The reactants are written on the left-hand side (LHS) and products are written on the right-hand side (RHS). If the number of reactants or products is more than one then they are separated by placing a plus sign (+) between them.

10.2 Writing a chemical equation

Chemical equations can be made more concise and useful if we use chemical formulae instead of words. Word-equation (1) can be written as:



Let us count and compare the number of atoms of each element on the LHS and RHS of the arrow. If the number of atoms of each element not same on both the sides then the equation is unbalanced.

From the law of conservation of mass, we know that matter (mass) is neither created nor destroyed during a chemical reaction, that is, atoms are neither created nor destroyed during 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 and therefore we need to balance chemical equations.

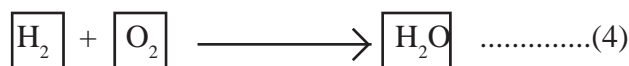
10.3 Balancing chemical equations

Let us learn how to step-wise balance a chemical equation.

Example- The chemical reaction showing the formation of water from oxygen and hydrogen can be written as follows:



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



Step-2. List the number of atoms of different elements present in the unbalanced equation (4)-

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

Step-3. In equation (4), the number of oxygen atoms on the LHS is 2 while it is only one on the RHS. Therefore, to balance the oxygen atoms-

Atoms of oxygen	In reactants	In products
Initially	2 (in O ₂)	1 (in H ₂ O)
To balance	2	1 × 2

You must remember that to equalise the number of atoms we cannot change the formulae of the compounds or elements involved in the reactions. For example, to balance oxygen atoms we can multiply by 2 and write 2H₂O but not H₂O₂.

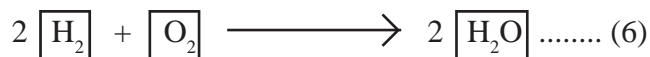
Now the partly balanced equation becomes –



Step-4. Since the hydrogen atoms are not balanced therefore we need to balance them in the partly balanced equation.

Atoms of hydrogen	In reactants	In products
In partly balanced equation	2 (in H ₂)	4 (in 2H ₂ O)
To balance	2×2	4

To balance the hydrogen atoms, multiply the LHS by 2. Now the equation becomes:



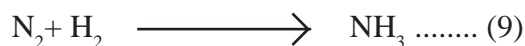
To check whether the equation is balanced, we compare the number of atoms of each element on both sides of the equation.



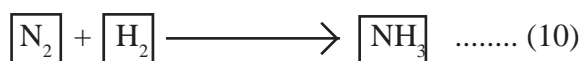
Try to balance the equation given below using the same method-



Let us take some examples of balancing equations-



Step-1. To balance a chemical equation, first draw boxes around each formula. Remember, do not change anything inside the boxes while balancing the equation.



Step-2. List the number of atoms of different elements present in the unbalanced equation (4)-

Element	Number of atoms in reactants (LHS)	Number of atoms in products (RHS)
N	2	1
H	2	3

Step-3. In equation (10), the number of nitrogen atoms on the LHS is 2 while it is only one on the RHS. Therefore, to balance the nitrogen atoms-

Atoms of nitrogen	In reactants	In products
Initially	2 (in N_2)	1 (in NH_3)
To balance	2	1×2

Now the partly balanced equation becomes –



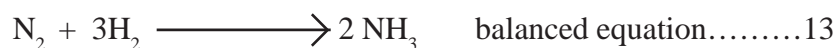
Step-4. The hydrogen atoms are still not balanced. We need to balance them in the partly balanced equation -

Atoms of hydrogen	In reactants	In products
In partly balanced equation	2 (in H_2)	6 (in 2NH_3)
To balance	2×3	6

To balance the hydrogen atoms, multiply the LHS by 3. Now the equation becomes:



To check whether the equation is balanced, we compare the number of atoms of each element on both sides of the equation.



The number of atoms of elements on both sides of the equation is equal. Therefore, the equation is balanced. This method of balancing equations is known as hit-and-trail method. In this method, we balance the equation by using the smallest whole number coefficient at first and multiplying it successively as required.

Questions

1. Write the balanced chemical equations for the following reactions:
 - (a) Hydrogen + Chlorine \longrightarrow Hydrogen chloride
 - (b) Sodium hydroxide + Sulphuric acid \longrightarrow sodium sulphate water
2. Balance the given chemical equations:
 - (i) $\text{CH}_4 + \text{O}_2 \longrightarrow \text{H}_2\text{O} + \text{CO}_2$
 - (ii) $\text{Fe} + \text{O}_2 \longrightarrow \text{Fe}_3\text{O}_4$
 - (iii) $\text{KClO}_3 \longrightarrow \text{KCl} + \text{O}_2$

10.4 Types of chemical reactions

Atoms are neither formed nor destroyed during a chemical reaction. Chemical changes take place during chemical reactions in which reactants form new products. The properties of products are different from their reactants. Actually, chemical reactions involve the breaking and making of bonds between atoms to produce new substances. Let us see different types of chemical reactions-

10.4.1 Combination reactions

Activity-4

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

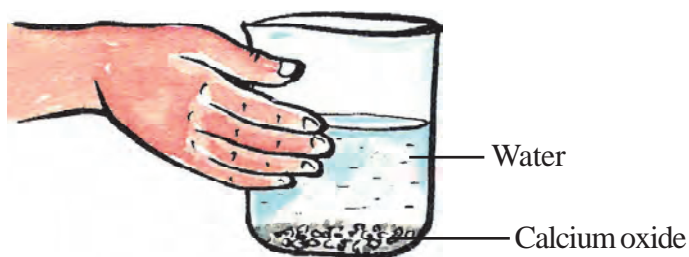


Fig. 3

Calcium oxide reacts rapidly with water to produce slaked lime (calcium hydroxide) releasing a large amount of heat (figure-3).

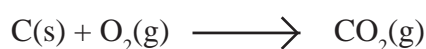
In this reaction, calcium oxide and water combine to form a single product, calcium hydroxide.



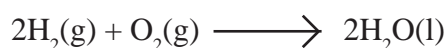
Such a reaction in which a single product is formed from two or more reactants is known as a combination reaction. Identify the type of reaction taking place in activity-1.

Let us discuss some more examples of combination reactions.

(i) Burning of coal



(ii) Formation of water from $\text{H}_2\text{(g)}$ and $\text{O}_2\text{(g)}$



10.4.2 Decomposition reactions

Activity-5

- Take a small amount of baking soda (sodium hydrogencarbonate) in a boiling tube.
- Heat the boiling tube over a spirit lamp.
- Take a lighted matchstick close to the mouth of the boiling tube as shown in figure-4.
- What do you observe?

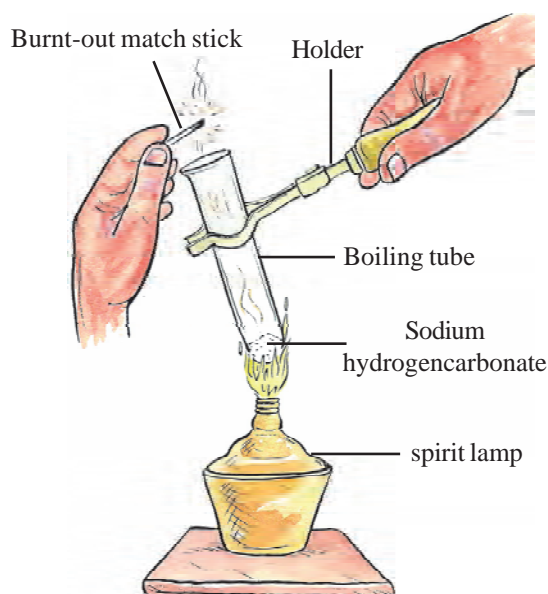


Fig. 4 : Decomposition of sodium hydrogencarbonate and evolution and testing of carbon dioxide gas

You will observe that the lighted matchstick goes out. When we heat sodium hydrogencarbonate, it breaks down into sodium carbonate, water and carbon dioxide.



In this reaction you can observe that a single reactant breaks down to give two or more products. This is a decomposition reaction. When a decomposition reaction is carried out by heating, it is called thermal decomposition.

Let us discuss some more examples of decomposition reactions-

- (i) Water decomposes into hydrogen and oxygen when electric current is passed through it.



This is an example of electrolytic decomposition.

- (ii) Decomposition of calcium carbonate to calcium oxide and carbon dioxide on heating is an important decomposition reaction used in various industries including cement industry.



10.4.3 Displacement reactions

Activity -6

- 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 30 minutes and for comparison, keep one iron nail separately (Fig.5a and b).

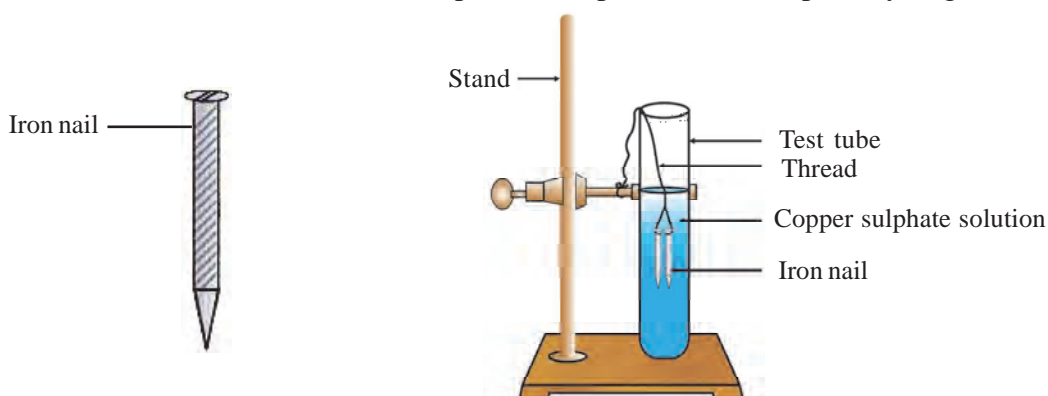


Fig. 5 (a) : Iron nail and iron nails dipped in copper sulphate solution

- After 30 minutes, take out both the iron nails from the copper sulphate solution.
- Compare the intensity of the blue colour of copper sulphate solutions in test tubes (A) and (B).
- Compare the colour of the iron nails dipped in the copper sulphate solution with the one kept separately.

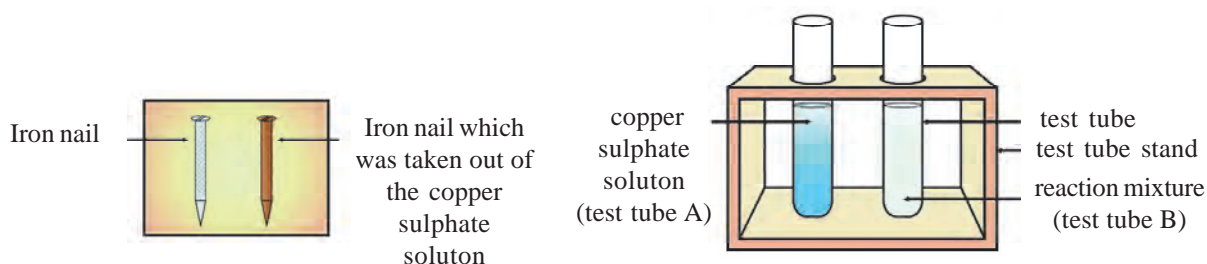


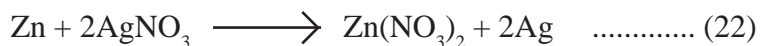
Fig. 5 (b) : Comparison between iron nail and copper sulphate solution before and after the experiment

Think, why did the iron nail become brownish in colour and the blue colour of copper sulphate solution fade? The following chemical reaction takes place in this activity–



In this reaction, iron has displaced or removed copper from copper sulphate solution and taken its place in the compound. This reaction is known as displacement reaction.

Let us see some other examples of displacement reactions:



From the examples given above, we realize that iron and lead are more reactive as compared to copper. They are able to displace copper from its compounds. Similarly, zinc is more reactive than silver and it can displace silver from its silver compounds. Recall activity-3 where you had reacted zinc granules with dilute hydrochloric acid.

1. Write the balanced chemical equation for this reaction.
2. Do you think it is a displacement reaction? Give reasons.

10.4.4 Double displacement reactions

In activity 2 we saw that a white substance is formed which is insoluble in water. This insoluble substance is called precipitate. In this reaction, we get white precipitate of barium sulphate when we add sodium sulphate solution to barium chloride solution.



What does this happen? The white precipitate of BaSO_4 is formed by the reaction of SO_4^{--} and Ba^{2+} . The other product formed is sodium chloride which is formed by combination of Na^+ and Cl^- ions and which remains in the solution. Such reactions in which there is an exchange of ions between the reactants are called double displacement reactions.

Some other examples of double displacement reactions are:

- (i) When we mix solutions of lead nitrate and potassium iodide, then a yellow precipitate of lead iodide is obtained along with potassium nitrate solution. Such reactions are known as precipitation reactions.



- (ii) In the reaction between sodium hydroxide (base) and hydrochloric acid, H^+ and OH^- ions combine to form water and Na^+ and Cl^- ions combine to give sodium chloride which remains dissolved in water. This reaction between acid and base is also known as neutralization reaction.



Questions

- (i) Write the balanced chemical equation for each of the following reactions and also identify the type of chemical reaction taking place:
- Zinc carbonate \longrightarrow zinc oxide + carbon dioxide
 - Sodium hydroxide + sulphuric acid \longrightarrow sodium sulphate + water
 - Potassium bromide + barium iodide \longrightarrow potassium iodide + barium bromide
 - Why does the colour of copper sulphate solution change when an iron nail is dipped in it?

10.4.5 Oxidation and reduction reactions

Activity-7

- Take about 1 g copper powder in a china dish and heat it as shown in figure 6.
- What do you observe?
- The surface of copper powder becomes coated with a black layer. Why has this black substance formed?

This black layer is copper oxide which is formed by the reaction between copper and oxygen.

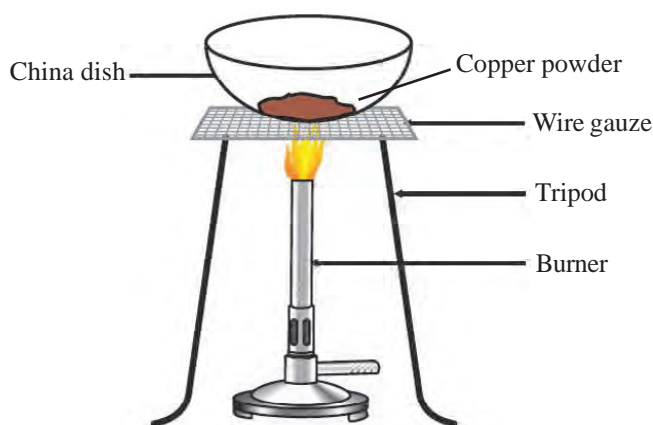


Fig. 6 : Oxidation of copper

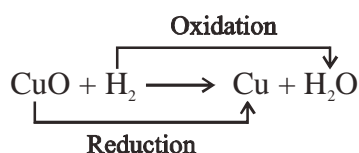


If hydrogen gas is passed over this heated material (CuO), the black coating on the surface turns brown as the copper oxide loses its oxygen and copper is obtained.



If a substance gains oxygen during a reaction, it is said to undergo oxidation. If a substance loses oxygen during a reaction, it is said to be reduced or undergoes reduction.

During this reaction (27), copper 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 this reaction. Such reactions are called oxidation-reduction reactions or redox reactions.



Some other examples of redox reactions are

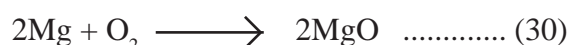


In reaction (28) carbon is oxidised to CO and ZnO is reduced to Zn. In reaction (29), oxygen is being lost by manganese oxide, that is, it is getting reduced and the hydrogen of HCl is gaining oxygen and getting oxidised to water.

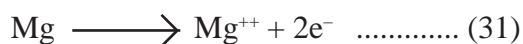
From the above examples we can say that if during a reaction, a substance gains oxygen or loses hydrogen it is oxidation and if a substance loses oxygen or gains hydrogen it is reduction.

Can we explain reduction-oxidation (redox) reactions on the basis of electron transfer?

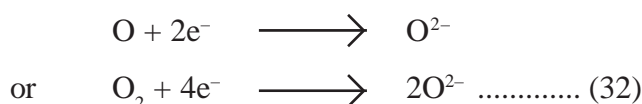
In activity-1, the magnesium ribbon burnt in oxygen to form a white powder of magnesium oxide.



We can say that magnesium oxide is formed by the oxidation of magnesium. If we try to understand this reaction by looking at the electronic configurations of magnesium and oxygen then we find that a magnesium atom has two electrons in its outermost shell which it loses to form a positive magnesium ion.



This electrons are accepted by oxygen to form the oxide ion which is negatively charged.



In this way, loss of electrons by magnesium is called oxidation and accepting electrons by oxygen is called reduction. Since both oxidation and reduction are happening simultaneously in the above example, the reaction is called a redox reaction.

So far we have looked at different types of reactions on the basis of the reactants or products formed in them. Let us reconsider some of the activities done so far in the chapter.

In activity-4, we saw that the formation of calcium hydroxide is accompanied by the release of a large amount of heat. Such reactions are known as exothermic reactions.

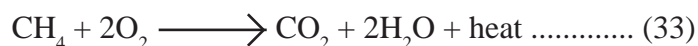
Recall activity-1 where a magnesium ribbon was burnt using a spirit lamp.

- (i) Was it a combination reaction?
- (ii) Is oxidation or reduction taking place?
- (iii) Is it exothermic?

Recall activity 3 where zin granules were reacted with dilute hydrochloric acid. Is this displacement reaction also an exothermic reaction?

Some more examples of exothermic reactions are given below-

1. Combustion of natural gas



2. The formation of manures and respiration are also exothermic reactions.

Activity-8

- Take a small amount of lead nitrate powder in a boiling tube.
- Use a test tube holder to hold the boiling tube and heat it over a flame (figure 7).
- What do you observe? Note down the change, if any.

You will observe the emission of brown fumes of nitrogen dioxide. The reaction that takes place is:



In this reaction, heat is required for the decomposition of the reactant. The reactions in which heat is absorbed are known as endothermic reactions.

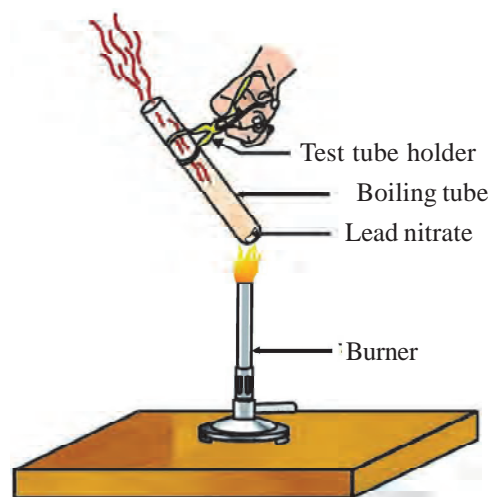


Fig. 7

Do the following activity

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

Activity-9

- Take about 2 g silver chloride in a china dish and note its colour.
- Place this china dish in sunlight for some time (Fig.8). Observe and note the colour of the silver chloride after some time.



Fig. 8 : In the presence of sunlight silver chloride becomes grey and forms 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.



This reaction takes place in the presence of sunlight. Such reactions are known as photochemical reactions.

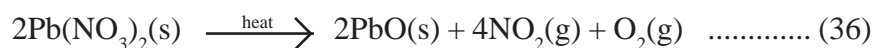
All such the decomposition reactions that require energy either in the form of heat, light or electricity for changing the reactants into products are known as endothermic reactions.

10.5 Making chemical equations more informative

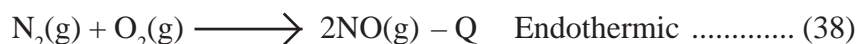
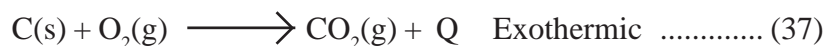
Chemical equations can be made more informative by including the following properties of the reactants and products: -

- | | | |
|-------------------|-------------------------|---------------------|
| 1. Physical state | 2. Change in heat | 3. Evolution of gas |
| 4. Precipitation | 5. Different conditions | |

- 1. Mentioning the physical states-** To make a chemical equation more informative, the physical states of the reactants and products can be 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. Now the unbalanced equation (34) can be rewritten as-



2. **Mentioning changes in heat-** Heat is released during exothermic reactions and absorbed during endothermic reactions. See the following examples:



In exothermic reactions, the heat released (Q) is added to the product side by using a plus sign (+). In endothermic reactions, a minus sign is used to show the heat absorbed.

3. **Showing the evolution of gas-** If the reaction involves evolution of a gas then it is shown using an upward arrow (\uparrow).



4. **Showing the formation of a precipitate-** If a precipitate is formed during a reaction it is shown using a downward arrow (\downarrow).



5. **Mentioning different reaction conditions-** Sometimes different reaction conditions such as temperature, heat, catalyst, pressure etc. can be mentioned above or below the arrow in the equation.



Similarly, try to make the different equations given in the chapter more informative.

Questions

- Identify which substance is getting oxidized and which is being reduced in the following reactions
- How are changes in heat (release, absorption) shown in chemical equations. Explain using examples.

Keywords

reactant, product, combination reaction, decomposition reaction, displacement reaction, double displacement reaction, oxidation, reduction, exothermic, endothermic, redox



What we have learnt

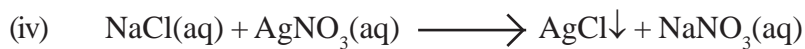
- A new substance is always formed during a chemical change.
- Chemical equations are a way of showing chemical reactions.

- A complete chemical equation represents the reactants, products and their physical states symbolically.
- According to the law of conservation of matter, a chemical equation must be balanced so that the numbers of atoms of each element involved in a chemical reaction are the same on the reactant and product sides of the equation.
- In a combination reaction two or more substances combine to form a new single substance.
- Decomposition reactions are opposite to combination reactions. In a decomposition reaction, a single substance decomposes to give two or more substances.
- A displacement reaction is one in which an element displaces another element from its compound.
- Ions are exchanged between reactants in double displacement reactions.
- Oxidation is the gain of oxygen or loss of hydrogen or loss of electrons.
- Reduction is the loss of oxygen or gain of hydrogen or gain of electrons.
- Reactions in which heat is given out along with the products are called exothermic reactions.
- Reactions in which energy is absorbed are known as endothermic reactions.

Exercises

1. Choose the correct option :

- (i) Which of the following reactions is taking place when hydrogen chloride is formed by reaction between hydrogen and chlorine
- (a) Decomposition (b) Displacement
(c) Combination (d) Double displacement
- (ii) $\text{Fe}_2\text{O}_3 + 2\text{Al} \longrightarrow \text{Al}_2\text{O}_3 + 2\text{Fe}$ This reaction is an example of
- (a) Combination (b) Decomposition
(c) Displacement (d) Double displacement
- (iii) $2\text{PbO}(\text{s}) + \text{C}(\text{s}) \longrightarrow 2\text{Pb}(\text{s}) + \text{CO}_2(\text{g})$ Which statement is true about this reaction
- (1) Lead is undergoing oxidation
(2) Carbon dioxide is undergoing oxidation
(3) Carbon is getting oxidized to carbon dioxide
(4) Lead oxide is being reduced to lead
- (a) 1 and 2 (b) 3 and 4
(c) 2 and 3 (d) all



The given chemical reaction is

- (a) Displacement (b) Combination
(c) Decomposition (d) Double displacement

2. Fill in the blanks

- (a) Substances on the LHS in a chemical equation are called and those on the RHS are known as.....
(b) is an example of reaction.
(c) The arrow between the reactants and products in a chemical equation shows the of a reaction.
(d) The type of reactions where heat is absorbed during the formation of products are reactions.

3. What is a chemical equation? Why should chemical equations be balanced?

4. Write balanced chemical equations for the following reactions:

- (a) Potassium metal reacting with water to give potassium hydroxide and hydrogen gas.
(b) Nitrogen gas combines with hydrogen to form ammonia.
(c) Hydrogen sulphide gas burns in air to give water and sulphur dioxide.
(d) Barium chloride reacts with aluminium sulphate to give a solution of aluminium chloride and a precipitate of barium sulphate.

5. Balance the following chemical equations.

- (i) $\text{C}_3\text{H}_8 + \text{O}_2 \longrightarrow \text{H}_2\text{O} + \text{CO}_2$
(ii) $\text{C}_6\text{H}_{12}\text{O}_6 \longrightarrow \text{C}_2\text{H}_5\text{OH} + \text{CO}_2$
(iii) $\text{Hg}(\text{NO}_3)_2 + \text{KI} \longrightarrow \text{HgI}_2 + \text{KNO}_3$
(iv) $\text{HNO}_3 + \text{Ca}(\text{OH})_2 \longrightarrow \text{Ca}(\text{NO}_3)_2 + \text{H}_2\text{O}$

6. Write the balanced chemical equation for the following and identify the type of reaction in each case.

- (a) Magnesium + iodine \longrightarrow magnesium iodide
(b) Magnesium + hydrochloric acid \longrightarrow magnesium chloride + hydrogen
(c) Zinc + copper nitrate \longrightarrow zinc nitrate + copper
(d) Sodium hydrogencarbonate \longrightarrow sodium carbonate + carbon dioxide + water

7. Why are decomposition reactions called the opposite of combination reactions? Write equations for these reactions.
8. Write one equation each for decomposition reactions where energy is supplied in the form of heat, light or electricity.
9. What is the difference between displacement and double displacement reactions? Write equations for these reactions.
10. Give two examples of redox reactions.
11. Explain the chemical reactions that take place in the presence of sunlight.
12. What do you understand by precipitation reactions? Explain using examples.
13. Explain exothermic and endothermic reactions through examples.
14. Hanif burnt a magnesium ribbon using a spirit lamp and on the basis of his observations he said that the type of chemical reaction taking place is combination as well as exothermic as well as oxidation. Do you agree with Hanif? Give reasons for your answer and explain.