3. Chemical Reactions and Equations

- Chemical reactions
- Rules of writing chemical reaction
- Balancing a chemical equation
- Types of chemical reactions

Can you recall?

1. What are the types of molecules of elements and compounds?
2. What is meant by valency of elements?
3. What is the requirement for writing molecular formulae of different compounds? How are the molecular formulae of the compounds written?

In earlier standards we have seen how compounds are formed by chemical combination of elements. We have also learnt that the driving force behind formation of a chemical bond is to attain an electronic configuration with a complete octet. The atoms attain a complete octet by giving, taking or sharing of electrons with each other.

Chemical Reaction

Some of the scientists of the 18th and 19th century carried out fundamental experiments on chemical reactions. They proved from their experiments that during chemical reactions composition of the matter changes and that change remains permanent. On the contrary during physical change only the state of matter changes and this change is often temporary in nature.

Identify physical and chemical changes from the phenomena given in the following table.

Phenomenon	Physical change	Chemical change
1. Transformation of ice into water.	✓	
2. Cooking of food.		✓
3. Ripening of fruit.		
4. Milk turned in to curd.		
5. Evaporation of water.		
6. Digestion of food in the stomach.		
7. Size reduction of naphtha balls exposed to air.		
8. Staining of Shahbad or Kadappa tile by lemon juice.		
9. Breaking of a glass object on falling from a height.		

3.1 Some common phenomenon

Note : Do the following activities in a group of friends. Take help of your teacher wherever necessary.

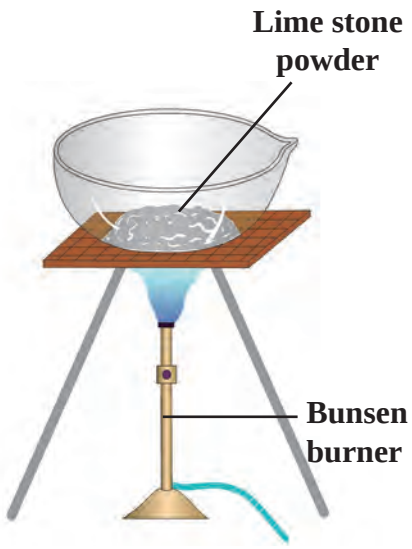
Try this.

Apparatus: Thermometer, evaporating dish, tripod stand, funnel, Bunsen burner, etc.

Chemicals : Lime stone powder, copper sulphate, calcium chloride, potassium chromate, zinc dust, sodium carbonate, phthalic anhydride, etc.

Procedure : Carry out the activities 1 to 5 as given below. Read and record the temperatures in the activities 2 to 4.

1. Take a spoonful of lime stone powder in an evaporating dish. Heat it strongly on a high blue flame.
2. Add zinc (Zn) dust into the copper sulphate ($CuSO_4$) solution.
3. Add potassium chromate (K_2CrO_4) solution to barium sulphate ($BaSO_4$) solution.
4. Add sodium carbonate (Na_2CO_3) solution to the calcium chloride ($CaCl_2$) solution.
5. Take phthalic anhydride in the evaporating dish. Close the end of the stem of a funnel with a cotton plug. Keep this funnel inverted on the evaporating dish. Heat the evaporating dish on a tripod stand slowly on a low flame. What did you observe in the funnel during heating?



3.2 To heat lime stone powder

Record the observation of all the activities. What did you find?

Complete the following observation table with reference to the activities 1 to 5.

Activity	Colour change (if present)	Gas released (yes/no)	Temperature change (if present)	Nature of change (chemical /physical)
1				
2				
3				
4				
5				

3.3 Observation table

Find out

Observe and keep a record of the physical and chemical changes that you experience in your daily life.

A physical change takes place due to change in the parameters such as temperature, pressure. Often a physical change in reversible. The composition of matter remains the same in a physical change. For example, ice is transformed into water on heating and water is transformed into ice on cooling. On the contrary, if the composition of matter changes during a process then it is called a chemical change. When we call a particular process or phenomenon as a chemical change, some chemical reactions are taking place in the concerned matter.

A chemical reaction is a process in which some substances undergo bond breaking and are transformed into new substances by formation of new bonds. The substances taking part in chemical reaction are called reactants, whereas the substances formed as a result of a chemical reaction by formation of new bonds are called products. For example, formation of carbon dioxide gas by combustion of coal in air is a chemical reaction. In this reaction coal (carbon) and oxygen (from air) are the reactants while carbon dioxide is the product. A chemical reaction is represented by writing a chemical equation.

Chemical equations

Let us first look at a chemical reaction. In the activity 2, a colourless solution of zinc sulphate ($ZnSO_4$) is formed on addition of zinc dust to the blue solution of copper sulphate ($CuSO_4$). This chemical reaction can be written in brief as follows.

Aqueous solution of copper sulphate + zinc dust ⟶ Aqueous solution of zinc sulphate + copper ..... (1)

This simple way of representing a chemical reaction in words is called a 'Word Equation'.

A word equation can be written in a further condensed form by using chemical formulae as follows.

$$CuSO_4 + Zn \longrightarrow ZnSO_4 + Cu \text{.....(2)}$$

The representation of a chemical reaction in a condensed form using chemical formulae is called as the chemical equation. In the above equation copper sulphate ($CuSO_4$) and zinc (Zn) are the reactants. They react with each other to form copper particles (Cu) and a solution of the colourless zinc sulphate ($ZnSO_4$) as the products having totally different properties. The ionic bond in the reactant $CuSO_4$ breaks and the ionic bond in the product $ZnSO_4$ is formed during the reaction.

Writing a Chemical Equation

Let us now see the conventions followed while writing a chemical equation.

1. In a chemical equation the reactants are written on the left hand side while the products on the right hand side. An arrow heading towards the products is drawn in between them. This arrow indicates the direction of the reaction.

2. If the reactants or products are two or more, they are linked with a plus sign (+) in between them. For example, in the equation (2) a plus sign (+) is drawn in between the reactants $CuSO_4$ and Zn. Similarly, a plus sign (+) is drawn in between the products $ZnSO_4$ and Cu.

3. To make the chemical equation more informative the physical states of the reactants are indicated in the equation. Their gaseous, liquid and solid states are indicated by writing the letters (g), (l) and (s), respectively in the brackets. Moreover, if the product is gaseous, instead of (g) it can be indicated by an arrow ↑ pointing upwards. If the product formed is insoluble solid, in the form of a precipitate, then instead of (s) it can be indicated by an arrow ↓ pointing downwards. When reactants and products are in the form of solution in water, they are said to be present in aqueous solution state. This state is indicated by putting the letters aq in brackets after their formula. Thus, the equation (2) is rewritten as equation (3) shown below.

$$CuSO_4\,(aq) + Zn\,(s) \longrightarrow ZnSO_4\,(aq) + Cu\,(s) \text{ ..... (3)}$$

4. When heat is to be given from outside to bring about a reaction, it is indicated by the sign △written above the arrow that indicates the direction of the reaction. For example, the reaction in which slaked lime is formed on heating lime stone is written as follows.

$$CaCO_3\,(s) \xrightarrow{\Delta} CaO\,(s) + CO_2\uparrow \text{ ..... (4)}$$

Similarly, the fact that heat is released during the reaction between the aqueous solution of copper sulphate and zinc dust is indicated as follows.

$$CuSO_4\,(aq) + Zn\,(s) \longrightarrow ZnSO_4\,(aq) + Cu\,(s) + Heat \text{ ..... (5)}$$

5. It is necessary to fulfill certain conditions like specific temperature, pressure, catalyst, etc. to bring about some reactions. These conditions are indicated below or above the arrow indicating the direction of the reaction. For example, the reaction of a vegetable oil takes place at the temperature of 60 ^{0}C with hydrogen gas in presence of the Ni catalyst and is written as follows.

$$\text{Vegetable oil (l)} + H_2(g) \xrightarrow[\text{Ni Catalyst}]{60^0\,C} \text{Vanaspathi ghee (s)} \ldots\ldots\ldots\ldots (6)$$

6 . Special information or names of reactants/ products are written below their formulae. For example, copper on reaction with concentrated nitric acid gives reddish coloured poisonous nitrogen di oxide gas.

$$Cu(s) + 4\,HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l) \ldots\ldots\ldots\ldots (7)$$

(Concentrated)

However, on reaction with dilute nitric acid, the product formed is nitric oxide gas.

$$3Cu(s) + 8HNO_3(aq) \longrightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l) \ldots\ldots\ldots\ldots (8)$$

(dilute)

Try this.

Apparatus: Test tube, conical flask, balance, etc.
Chemicals : Sodium chloride and silver nitrate.

Procedure :

1. Take sodium chloride solution in a conical flask and silver nitrate solution in a test tube.
2. Tie a thread to the test tube and insert it carefully into the conical flask. Make the conical flask air tight by fitting a rubber cork.
3. Weigh the conical flask with the help of a balance.
4. Now tilt the conical flask and mix the solution present in the test tube with the solution in the conical flask.
5. Weigh the conical flask again.

Which changes did you find? Did any insoluble substance form? Was there any change in the weight?

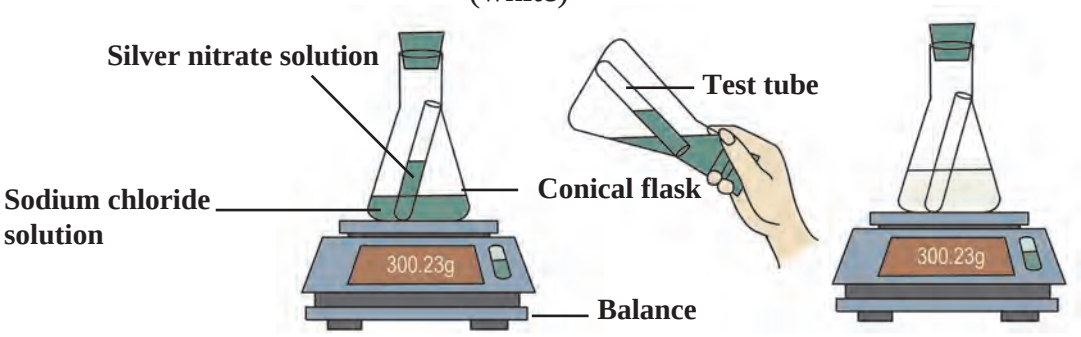
A word equation is written for the above activity as shown below.

Silver nitrate + Sodium chloride ⟶ Silver chloride + Sodium nitrate

The above word equation is represented by the following chemical equation.

$$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl\downarrow + NaNO_3(aq) \ldots\ldots\ldots (9)$$

(white)



3.4 The reaction of sodium chloride with silver nitrate

Do you know ? Silver nitrate is used in the voters-ink.

Find out What are the other uses of silver nitrate in everyday life?

Balancing a Chemical Equation

Complete the table aside on the basis of the equation (9).

It is seen that the number of atoms of the elements in the reactants in this equation is same as the number of atoms of those elements in the products. Such an equation is called a 'balanced equation'. If the number of atoms of each element is not the same on the two sides of an equation, it is called an 'unbalanced equation'.

	Reactants (Left side)	Products (Right side)
Element	Number of atoms	Number of atoms
Ag		
N		
O		
Na		
Cl		

3.5 Details of equation (9)

Always remember

In any reaction, the total mass of each of the elements in the reactants is same as the total mass of each of the respective elements in the products. This is in accordance with the law of conservation of mass that you studied in the previous standard.

Steps in balancing a chemical reaction

A chemical equation is balanced step by step. A trial and error method is used for this purpose. Consider the following equation as an example :

Sodium hydroxide + Sulphuric acid ⟶ Sodium sulphate + water.

STEP I. Write the chemical equation from the given word equation.

$NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$ .....(10)

STEP II. Check whether the equation (10) is balanced or not by comparing the number of atoms of the various elements present on the two sides of the equation.

It is seen that the number of atoms of all the elements on the two sides are not the same. It means that the equation (10) is not balanced.

	Reactants (Left side)	Products (Right side)
Element	Number of atoms	Number of atoms
Na	1	2
O	5	5
H	3	2
S	1	1

STEP III : It is convenient to start balancing an equation from the compound which contains the maximum number of atoms. Moreover it is convenient to first consider that element in this compound, which has unequal number of atoms on the two sides.

(i) In the equation (10), there are two components Na_2SO_4 and H_2SO_4, which contain the maximum number that is seven atoms each. Any one of them can be selected. Select the compound Na_2SO_4. Further select sodium for balancing as the number of atoms of sodium in this compound is unequal on the two sides. It should be remembered that, the formula of a compound cannot be changed while balancing the number of atoms. It means that, here to make the number of sodium atoms in the reactants as '2' the formula NaOH cannot be changed to Na_2OH. Instead a factor of '2' will have to be applied to NaOH. Write down the resulting equation (10)′ on doing this.

Number of sodium atoms	In the Reactants (in NaOH)	In the Products (in Na_2SO_4)
Initially	1	2
To balance	1 x 2	2

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$ .....(10)′

(ii) Check whether the equation (10)′ is balanced or not.

We find that the equation (10)′ is not balanced, as the number of oxygen and hydrogen atoms are unequal on the two sides. First balance the hydrogen number as it requires a smaller factor.

(iii) Apply a factor '2' to the product 'H_2O' for balancing the equation (10)′

Now write down the resulting equation (10)″.

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$ .... (10)″

(iv) Check whether the equation (10)″ is balanced or not. It is seen that the number of atoms of all the elements are equal on both the sides. It means that the equation (10)″ is a balanced equation.

	Reactants (Left side)	Products (Right side)
Element	Number of atoms	Number of atoms
Na	2	2
O	6	5
H	4	2
S	1	1

Step IV : Write down the final balanced equation again.

$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$ ....(11)

In this way, a balanced equation is obtained from an unbalanced equation by applying proper factors to appropriate reactant/product so as to balance the number of each element in steps.

Number of atoms of Hydrogen	In the reactants (In NaOH & H_2SO_4)	In the Products (In H_2O)
i) Initially	4	2
ii) To balance	4	2 x 2

Use your brain power!

1. (a) Identify the reactants and products of equation (6).

(b) Write down the steps in balancing the equation

$N_2(g) + H_2(g) \rightleftharpoons NH_3(g)$

2. Write down a balanced chemical equation for the following reaction

Calcium chloride + Sulfuric acid $\longrightarrow$ Calcium sulphate + hydrogen chloride

3.Write down the physical states of reactants and products in following reactions.

a. $SO_2 + 2H_2S \longrightarrow 3S + 2H_2O$

b. $2Ag + 2HCl \longrightarrow 2AgCl + H_2$

We saw that in a chemical reactions reactants get converted into the new substances called products. During this some chemical bonds in the reactants break and some new chemical bonds are formed so as to transform the reactants into the products. In this chapter we will be studying the types of reactions in detail.

Types of chemical reactions

Chemical reactions are classified into the following four types in accordance with the nature and the number of the reactants and the products.

1. Combination reaction

Try this.

Apparatus: Test tube, glass rod, beaker, etc.
Chemicals: hydrochloric acid, ammonia solution, slaked lime, etc.

Activity 1: Take a small amount of hydrochloric acid in a test tube. Heat the test tube. Dip a glass rod in the ammonia solution and hold on the top of the test tube. You will observe a white smoke emanating from the tip of the glass rod.

What must have happened?

Due to heating HCl vapours started coming out from the test tube, and NH_3 gas came out from the solution on the glass rod. The ammonia gas and hydrogen chloride gas reacted to form the salt ammonium chloride in gaseous state first, but immediately due to the condensation process at room temperature it got transformed into the solid state. As a result white smoke was formed. The chemical equation for this is as follows.

$$\underset{\text{Ammonia}}{NH_3\,(g)} + \underset{\text{Hydrogen chloride}}{HCl\,(g)} \longrightarrow \underset{\text{Ammonium chloride}}{NH_4Cl(s)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Activity 2: Hold a magnesium (Mg) strip in a pair of tongs and ignite. On burning in air a white powder of magnesium oxide is formed. The reaction can be written in the form of equation as shown below.

$$2Mg + O_2 \longrightarrow 2\,MgO \quad \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

In this reaction magnesium oxide is formed as the single product by combination of magnesium and oxygen.

Activity 3: Take water in a beaker up to half of its capacity. Add a few pieces of slaked lime (calcium oxide, CaO) to it. Calcium hydroxide ($Ca(OH)_2$) is formed by combination of calcium oxide and water with generation of large amount of heat.

$$\underset{\text{Calcium oxide}}{CaO} + \underset{\text{water}}{H_2O} \longrightarrow \underset{\text{calcium hydroxide}}{Ca(OH)_2} + \text{Heat} \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Use your brain power!

1. What is the number of reactants in each of the above reactions?
2. What is the number of molecules of reactants taking part in the above reactions?
3. How many products are formed in each of the above reactions?

When two or more reactants combine in a reaction to form a single product, it is a combination reaction.

2. Decomposition reaction

Try this.

Apparatus: Evaporating dish, Bunsen burner, etc.
Chemicals : Sugar, calcium carbonate, sulphuric acid, etc.

Procedure: Take some sugar in an evaporating dish and heat it with the help of a Bunsen burner. After some time you will see the formation of a burnt out black substance. Exactly what must have happened in this activity?

In the above activity a single reactant sugar is divided into two substances (C and H_2O)

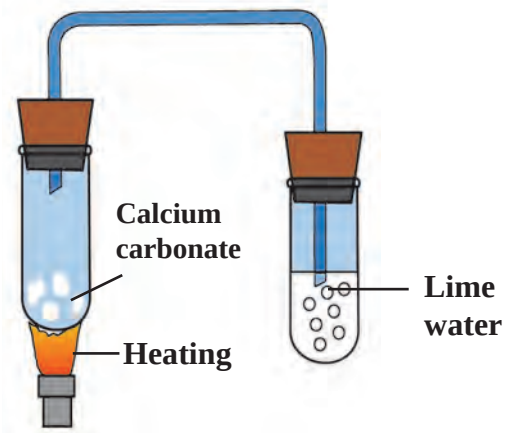
$$\underset{\text{Sugar}}{C_{12}H_{22}O_{11}} \xrightarrow{\text{Heat}} \underset{\text{carbon}}{12\,C} + 11H_2O \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

The reaction in which there is only one reactant giving rise to two or more products is called a decomposition reaction.

Try this. **Apparatus :** Two test tubes, bent tube, rubber cork, burner, etc.

Chemicals : Calcium carbonate, freshly prepared lime water.

Procedure : Take some calcium carbonate in a test tube. Fit a bent tube to this test tube with the help of a rubber cork. Insert the other end of the bent tube in the freshly prepared lime water taken in the other test tube. Heat the powdered calcium carbonate in the first test tube strongly. The lime water will turn milky.



3.6 Decomposition of calcium carbonate

We saw in the above activity that calcium carbonate undergoes decomposition reaction and the carbon dioxide gas formed turns the lime water milky (Eq. 16). The second product of the reaction, the calcium oxide powder, remains behind in the first test tube. Similarly, in another reaction (Eq. 17) hydrogen peroxide naturally undergoes slow decomposition into water and oxygen.

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2 \uparrow \text{ ..... (16)}$$

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2 \uparrow \text{ .... (17)}$$

(16) and (17) both are decomposition reactions.

Can you recall? Is it possible to produce hydrogen by decomposition of water by means of heat, electricity or light ?

We have studied in the previous standard that water decomposes into hydrogen and oxygen gases on passing electric current through acidulated water. This decomposition takes place by means of electrical energy. Therefore it is called electrolysis.

$$2H_2O(l) \xrightarrow{\text{Electrical Energy}} 2H_2 \uparrow + O_2 \uparrow \text{ .....(18)}$$

The chemical reaction in which two or more products are formed from a single reactant is a ‘‘Decomposition reaction”.

Many degradation processes take place in the nature surrounding us. Organic waste is decomposed by microorganisms and as a result manure and biogas are formed. Biogas is used as a fuel.

3. Displacement reaction

We saw in the beginning of this chapter that on adding zinc dust to blue coloured copper sulphate solution, a colourless solution of zinc sulphate is formed and heat is generated. See the equation (3) for this reaction.

From that we learnt that the Zn^{2+} ions formed from Zn atoms take the place of Cu^{2+} ions in copper sulphate, and Cu atoms, formed from Cu^{2+} ion come out. It means that Zn displaces Cu from $CuSO_4$.

The reaction in which the place of the ion of a less reactive element in a compound is taken by another more reactive element by formation of its own ions, is called displacement reaction.

(We will learn about reactivity of elements in the chapter on metallurgy.) The elements iron and lead, similar to zinc, displace copper from its compound.

Use your brain power !

Complete the following reactions and give names of the products.

1. $CuSO_4(aq) + Fe(s) \longrightarrow$ ..... + ...
2. $CuSO_4(aq) + Pb(s) \longrightarrow$ ..... + ...

4. Double displacement reaction

We have seen in the equation (9) that a white precipitate of silver chloride is formed by an exchange of silver and sodium ions present in the reactants.

The reaction in which the ions in the reactants are exchanged to form a precipitate is a double displacement reaction.

Recall the activity (3) in which you added potassium chromate (K_2CrO_4) into the solution of barium sulphate ($BaSO_4$).

1. What was the colour of the precipitate formed ?
2. Write the name of the precipitate.
3. Write down the balanced equation for this reaction.
4. Will you call this reaction a displacement reaction or a double displacement reaction.

Endothermic and Exothermic Processes and Reaction :

Heat is absorbed and given away in various processes and reactions. Accordingly processes and reactions are classified as 'Endothermic or Exothermic'.

Endothermic and Exothermic Processes

Heat from outside is absorbed during some physical changes. For example, (i) melting of ice (ii) dissolution of potassium nitrate in water. Therefore, these are **'Endothermic processes.'**

On the other hand, heat is given away during some physical changes. For example, (i) formation of ice from water, (ii) dissolution of sodium hydroxide in water. Therefore these are **'Exothermic processes.'** In the process of dilution of concentrated sulphuric acid with water, very large amount of heat is liberated. As a result, water gets evaporated instantaneously, if it is poured in to the concentrated sulphuric acid, which may cause an accident. To avoid this, required amount of water is taken in a glass container and small quantity of concentrated sulphuric acid at a time is added with stirring. Therefore, only a small amount of heat is liberated at a time.

To carry out endothermic and exothermic processes

Try this.

Apparatus : Two plastic bottles, measuring cylinder, thermometer etc.
Chemicals : Potassium nitrate, sodium hydroxide, water etc.
(Sodium hydroxide being corrosive, handle it carefully in presence of Teacher.)

Procedure : Take 100 ml water in each of the two plastic bottles. Plastic being insulator of heat, the dissipation of heat can be prevented. Note the temperature of water in the bottles. Put 5 g potassium nitrate (KNO_3) in the bottle and shake well. Note the temperature of the solution formed. Put 5 g sodium hydroxide (NaOH) in the other bottle. Shake the bottle well. Note the temperature.

In the first bottle the process of dissolution of potassium nitrate took place while in the second bottle the process of dissolution of sodium hydroxide took place. As per your observation which one is exothermic process and which is an endothermic process?

During the process of the dissolution of KNO_3 in water, heat from the surroundings is absorbed and therefore the temperature of the resulting solution is less. The process in which heat is absorbed from the outside, is called endothermic process. When the solid NaOH is dissolved in water heat is given out, and therefore the temperature increases. The processes in which heat is given out are called exothermic processes.

Endothermic and Exothermic Reactions

There is an exchange of heat in chemical reactions as well. Accordingly some chemical reactions are exothermic while some other are endothermic. During exothermic chemical reactions heat is given away when reactants are transformed into the products, while during endothermic chemical reactions heat is either absorbed from the surroundings or has to be supplied continuously from outside. For example,

$CaCO_3$ (s) + heat $\longrightarrow$ CaO (s) + CO_2(g) **(Endothermic Reaction)**

CaO (s) + H_2O (*l*) $\longrightarrow$ $Ca(OH)_2$ (aq) + heat **(Exothermic Reaction)**

Use your brain power !

1. What is the difference in the process of dissolution and a chemical reaction ?
2. Does a new substance form when a solute dissolves in a solvent ?

Rate of Chemical Reaction

Can you tell?

Take into account the time required for following processes. Classify them into two groups and give titles to the groups.

1. Cooking gas starts burning on ignition .
2. Iron article undergoes rusting.
3. Erosion of rocks takes place to form soil.
4. Alcohol is formed on mixing yeast in glucose solution under proper condition.
5. Effervescence is formed on adding baking soda into a test tube containing dilute acid.
6. A white precipitate is formed on adding dilute sulphuric acid to barium chloride solution.

It can be seen from the above examples that some reactions are completed in short time, that is, occur rapidly, while some other require long time for completion, that is, occur slowly. It means that the rate of different reactions is different.

The same reaction occurs at a different rate on changing the conditions. For example, during winter long time is required for setting milk into curd, while at the higher temperature during summer, the rate of setting of milk increases and the curd is formed early.

Now let us see the factors which decide the rate of a chemical reaction.

Factors affecting the rate of a chemical reaction

a. Nature of the Reactants

Let us see the reaction of the metals aluminium (Al) and zinc (Zn) with dilute hydrochloric acid.

On reaction of both Al and Zn with dilute hydrochloric acid H_2 gas is liberated and water soluble salts of these metals are formed. However, the reaction of aluminium metal takes place faster as compared to zinc metal. The nature of the metal is responsible for this difference. Al is more reactive than Zn. Therefore the rate of reaction of Al with hydrochloric acid is higher than that of Zn. Nature or reactivity of reactants influences the rate of a chemical reaction. (We are going to learn more about the reactivity of metals in the chapter on Metallurgy.)

b. Size of the Particles of Reactants

Try this.

Apparatus: Two test tubes, balance, measuring cylinder, etc.
Chemicals: Pieces of Shahabad tile, powder of Shahabad tile, dilute HCl etc.

Procedure : Take pieces and powder of Shahabad tile in equal weights in two test tubes. Add 10 ml dilute HCl in each of the test tubes. Observe whether effervescence of CO_2 is formed at a faster or slower speed.

You must have found in the above activity that the CO_2 effervescence is formed slowly with the pieces of Shahabad tile while at a faster speed with the powder.

The above observation indicates that the rate of a reaction depends upon the size of the particles of the reactants taking part in the reaction. Smaller the size of the reactant particles, higher is the rate of the reaction.

c. Concentration of the reactants

Let us consider the reaction of dilute and concentrated hydrochloric acid with $CaCO_3$ powder.

Dilute HCl reacts slowly with $CaCO_3$ and thereby $CaCO_3$ disappears slowly and CO_2 also liberates slowly. On the other hand the reaction with concentrated HCl takes place rapidly and $CaCO_3$ disappears fast.

Concentrated acid reacts faster than dilute acid, which means that rate of a reaction is proportional to the concentration of reactants.

d. Temperature of the Reaction

While studying decomposition reaction, you have carried out decomposition of lime stone. In this activity, the lime water does not turn milky before heating the lime stone; because of the zero rate of reaction. From this it is learnt that the rate of a reaction increases on increasing the temperature.

e. Catalyst

On heating potassium chlorate ($KClO_3$) decomposes slowly.

$$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2 \text{ ..... (19)}$$

The rate of the above reaction neither increases by reducing the particle size nor by increasing the reaction temperature. However, $KClO_3$ decomposes rapidly in presence of manganese dioxide (MnO_2) to liberate O_2 gas. No chemical change takes place in MnO_2 in this reaction.

"The substance in whose presence the rate of a chemical reaction increases, without causing any chemical change to it, is called a catalyst."

The decomposition of hydrogen peroxide into water and oxygen takes place slowly at room temperature (Eq. 17). However, the same reaction occurs at a faster rate on adding manganese dioxide (MnO_2) powder in it.

Do you know ?

1. One or more chemical reactions take place during every chemical change.
2. Some chemical reactions occur at fast speed whereas some occur at slow speed.
3. Strong acid and strong base react instantaneously.
4. In our body, enzymes increase the rate of physiological reactions.
5. Perishable foodstuff gets preserved longer in a refrigerator. The rate of decomposition of foodstuff gets lowered due to low temperature, and its freshness is maintained.
6. Vegetables cook quickly on oil rather than on water.
7. The chemical reactions are profitable in the chemical factories if their rate is fast.
8. The rate of chemical reaction is important from environmental point of view as well.
9. The ozone layer in the earth's atmosphere protects the life on earth from the ultraviolet radiation of the sun. The process of depletion or maintenance of this layer depends upon the rate of production or destruction of ozone molecules.

Oxidation and Reduction

Many types of substances give reactions called oxidation and reduction. Let us learn more about these reaction.

$$2Mg + O_2 \longrightarrow 2MgO \text{ .....(20)}$$

$$C + O_2 \longrightarrow CO_2 \text{ .....(21)}$$

$$MgH_2 \longrightarrow Mg + H_2\uparrow \text{ .....(22)}$$

$$CH_3\text{-}CH_3 \longrightarrow CH_2{=}CH_2 + H_2\uparrow \text{...(23)}$$

In the reactions (20) and (21) a reactant combines with oxygen, whereas in (22) and (23) hydrogen gas is removed from the reactant. All these are examples of the oxidation reaction.

The chemical reaction in which a reactant combines with oxygen or loses hydrogen to form the product is called oxidation reaction.

Some oxidation reactions are brought about by use of specific chemical substances. For example,

$$\underset{\text{Ethyl alcohol}}{CH_3 - CH_2 - OH} \xrightarrow[K_2Cr_2O_7/H_2SO_4]{[O]} \underset{\text{Acetic acid}}{CH_3 - COOH} \quad \ldots\ldots\ldots (24)$$

Here the acidic potassium dichromate makes oxygen available for the oxidation of the reactant ethyl alcohol. Such chemical substances which bring about an oxidation reaction by making oxygen available are called oxidants or oxidizing agents.

Do you know ?

A variety of oxidants are used to bring about a controlled oxidation. $K_2Cr_2O_7/H_2SO_4$, $KMnO_4/H_2SO_4$ are the commonly used chemical oxidants. Hydrogen peroxide (H_2O_2) is used as a mild oxidant. Ozone (O_3) is also a chemical oxidant. Nascent oxygen is generated by chemical oxidants and it is used for the oxidation reaction.

$O_3 \rightarrow O_2 + [O]$

$H_2O_2 \rightarrow H_2O + [O]$

$K_2Cr_2O_7 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 4H_2O + 3\,[O]$

$2KMnO_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 5\,[O]$

Nascent oxygen is a state prior to the formation of the O_2 molecule. It is the reactive form of oxygen and is represented by writing the symbol as [O].

Use your brain power !

1. Which is the oxidant used for purification of drinking water?
2. Why is potassium permanganate used during cleaning water tanks?

We have seen just now that potassium permanganate is a chemical oxidant. Now have a look at the following reaction.

$$2KMnO_4 + 10FeSO_4 + 8H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 5Fe_2(SO_4)_3 + 8H_2O \quad \ldots\ldots\ldots (25)$$

Which compound is oxidised by $KMnO_4$ in presence of acid in this reaction? Of course $FeSO_4$.

Here $FeSO_4$ is transformed into $Fe_2(SO_4)_3$. Let us now see, how this conversion is an oxidation reaction.

$$2FeSO_4 \rightarrow Fe_2(SO_4)_3$$

Ionic reaction $\quad Fe^{2+} + SO_4^{2-} \rightarrow 2Fe^{3+} + 3SO_4^{2-}$

The net change taking place in the above conversion is shown by the net ionic reaction as shown below.

Net ionic reaction $\quad Fe^{2+} \longrightarrow Fe^{3+}$

(Ferrous) (Ferric)

This net ionic reaction represents the oxidation brought about by $KMnO_4$. When ferric ion is formed from ferrous ion the positive charge is increased by one unit. While this happens the ferrous ion loses one electron. From this, we understand a new defination of oxidation, which is “oxidation means losing one or more electrons.”

Can you tell? Look at the chemical equation (6). What is the type of this reaction, in which Vanaspathi ghee is formed from vegetable oil?

The chemical reactions in which reactants gain hydrogen are called 'reduction' reactions. Similarly, the reaction in which a reactant loses oxygen to form the product is also called reduction reaction. The substance that brings about reduction is called a reductant, or a reducing agent.

When hydrogen gas is passed over black copper oxide a reddish coloured layer of copper is formed.

$$CuO + H_2 \longrightarrow Cu + H_2O \quad \text{..... (26)}$$

Which is the reductant in this reaction? And which reactant has undergone reduction?

In this reaction an oxygen atom goes away from CuO (copper oxide), which means that reduction of copper oxide takes place, whereas hydrogen molecule takes up oxygen atom and water (H_2O) is formed meaning, oxidation of hydrogen takes place. Thus oxidation and reduction reactions occur simultaneously. The reductant is oxidized by the oxidant and the oxidant is reduced by the reductant. Due to this characteristics of the reduction and oxidation reactions, a single term 'redox reaction' is used in place of the two terms.

Redox Reaction = Reduction + Oxidation

Use your brain power !

1. Some more examples of redox reaction are as follows. Identify the reductants and oxidants from them.

$$2H_2S + SO_2 \longrightarrow 3S\downarrow + 2H_2O \quad \text{..... (27)}$$

$$MnO_2 + 4\,HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2\uparrow \quad \text{..... (28)}$$

2. If oxidation means losing electrons, what is meant by reduction?

3. Write the reaction of formation of Fe^{2+} by reduction Fe^{3+} by making use of the symbol (e^-).

Think about it The luster of the surface of the aluminium utensils in the house is lost after a few days. Why does this happen?

When the positive charge on an atom or an ion increases or the negative charge on them decreases it is called oxidation, and when the positive charge decreases or the negative charge increases it is called reduction.

$$Fe \underset{\text{reduction}}{\overset{\text{oxidation}}{\rightleftharpoons}} FeO \underset{\text{reduction}}{\overset{\text{oxidation}}{\rightleftharpoons}} Fe_2O_3$$

Do you know ?

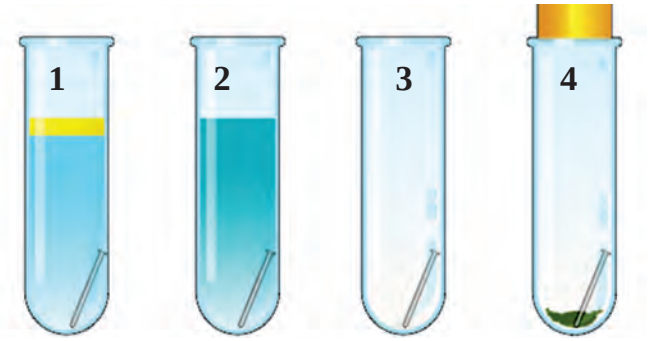
A redox reaction takes place during cellular respiration. Here the molecule of the enzyme called cytochrome C oxidase helps the transport of electron to bring about this reaction.

For more information refer to life processes in the living organisms.

Try This.

Apparatus : Four test tubes, four small iron nails, rubber cork, etc.
Chemicals : Anhydrous calcium chloride, oil, boiled water, etc.

Procedure : Place four test tubes on a test tube stand. Take some boiled water in one test tube and put an oil layer on it. Take some salt water in the second test tube. Let there be only air in the third test tube. Take some anhydrous calcium chloride in the fourth test tube. Place a small iron nail in every test tube. Close the fourth test tube with a rubber cork. Let all the four test tubes remain un attended for a few days.



3.7 To study rusting

Observe all the four test tubes after a few days. What did you find? Which test tubes had the nails as before? Both water and air are necessary for rusting. The rusting process takes place rapidly in presence of a salt. Have you seen the effect of redox reaction in your everyday life? The new vehicles look shiny, on the contrary old vehicles look dull. A certain type of reddish coloured solid layer collects on their metallic surface. This layer is called 'rust'. Its chemical formula is $Fe_2O_3 \cdot X\ H_2O$.

The rust on iron does not form by a simple reaction of oxygen with iron surface. The rust is formed by an electrochemical reaction. Different regions on the surface of iron become anode and cathode.

1. Fe is oxidised to Fe^{2+} in the anode region.

$$Fe\ (s) \longrightarrow Fe^{2+}\ (aq) + 2\ e^-$$

2. O_2 is reduced to form water in the cathode region.

$$O_2\ (g) + 4H^+\ (aq) + 4\ e^- \longrightarrow 2H_2O\ (l)$$

When Fe^{2+} ions migrate from the anode region they react with water and further get oxidised to form Fe^{3+} ions.

A reddish coloured hydrated oxide is formed from Fe^{3+} ions. It is called rust. It collects on the surface.

$$2Fe^{3+}(aq) + 4H_2O\ (l) \longrightarrow Fe_2O_3 \cdot H_2O\ (s) + 6H^+\ (aq) \quad \text{..... (29)}$$

Due to various components of atmosphere, oxidation of metals takes place, consequently resulting in their damage. This is called 'corrosion'. Iron rusts and a reddish coloured layer is collected on it. This is corrosion of iron. Corrosion is a very serious problem . We are going to study about it in the 'metallurgy' chapter.

Find out

How are the blackened silver utensils and patinated (greenish) brass utensils cleaned?

Rancidity

When we use old, left over cooking oil for making food stuff, it is found to have foul odour called rancidity. If food is cooked in such oil, its taste also changes. When oil or ghee is left aside for a long time or fried food is left aside for a long time it undergoes air oxidation and becomes rancid. Rancidity in the food stuff cooked in oil or ghee is prevented by using antioxidants. The process of oxidation reaction of food stuff can also be slowed down by storing it in air tight container.

Exercise

1. Choose the correct option from the bracket and explain the statement giving reason.

(Oxidation, displacement, electrolysis, reduction, zinc, copper, double displacement, decomposition)

a. To prevent rusting, a layer of ..... metal is applied on iron sheets.

b. The conversion of ferrous sulphate to ferric sulphate is ..... reaction.

c. When electric current is passed through acidulated water ..... of water takes place.

d. Addition of an aqueous solution of $ZnSO_4$ to an aqueous solution of $BaCl_2$ form a white precipitate is an example of ..... reaction.

2. Write answers to the following.

a. What is the reaction called when oxidation and reduction take place simultaneously? Explain with one example.

b. How can the rate of the chemical reaction, namely, decomposition of hydrogen peroxide be increased?

c. Explain the term reactant and product giving examples.

d. Explain the types of reaction with reference to oxygen and hydrogen. Illustrate with examples.

e. Explain the similarity and difference in two events, namely adding NaOH to water and adding CaO to water.

3. Explain the following terms with examples.

a. Endothermic reaction

b. Combination reaction

c. Balanced equation

d. Displacement reaction

4. Give scientific reasons.

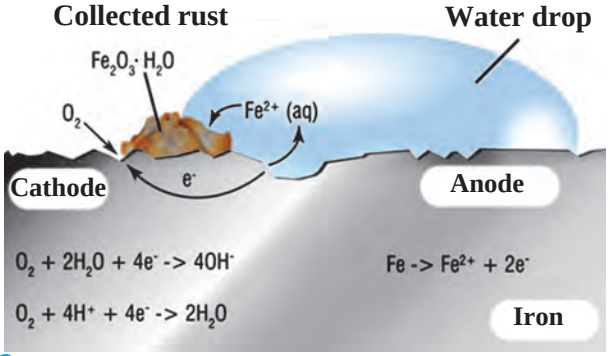
a. When the gas formed on heating limestone is passed through freshly prepared lime water, the lime water turns milky.

b. It takes time for pieces of Shahabad tile to disappear in HCl, but its powder disappears rapidly.

c. While preparing dilute sulphuric acid from concentrated sulphuric acid in the laboratory, the concentrated sulphuric acid is added slowly to water with constant stirring.

d. It is recommended to use air tight container for storing oil for long time.

5. Observe the following picture a write down the chemical reaction with explanation.



6. Identify from the following reactions the reactants that undergo oxidation and reduction.

a. $Fe + S \longrightarrow FeS$

b. $2Ag_2O \longrightarrow 4\,Ag + O_2\uparrow$

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

d. $NiO + H_2 \longrightarrow Ni + H_2O$

7. Balance the following equation stepwise.

a. $H_2S_2O_7(l) + H_2O(l) \longrightarrow H_2SO_4(l)$

b. $SO_2(g) + H_2S(aq) \longrightarrow S(s) + H_2O\,(l)$

c. $Ag(s) + HCl(aq) \longrightarrow AgCl\downarrow + H_2\uparrow$

d. $NaOH\,(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l)$

8. Identify the endothermic and exothermic reaction.

a. $HCl + NaOH \longrightarrow NaCl + H_2O + heat$

b. $2KClO_3(s) \xrightarrow{\Delta} 2KCl(s) + 3O_2\uparrow$

c. $CaO + H_2O \longrightarrow Ca(OH)_2 + heat$

d. $CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2\uparrow$

9. Match the column in the following table.

Reactants	Products	Type of chemical reaction
$BaCl_2\,(aq) + ZnSO_4\,(aq)$	$H_2CO_3(aq)$	Displacement
$2AgCl(s)$	$FeSO_4\,(aq) + Cu\,(s)$	Combination
$CuSO_4\,(aq) + Fe\,(s)$	$BaSO_4\downarrow + ZnCl_2\,(aq)$	Decomposition
$H_2O(l) + CO_2(g)$	$2Ag(s) + Cl_2(g)$	Double displacement

Project

Prepare aqueous solutions of various solid salts available in the laboratory. Observe what happens when aqueous solution of sodium hydroxide is added to these. Prepare a chart of double displacement reactions based on these observation.