CHEMISTRY

PART - II

Standard

X

Government of Kerala
Department of General Education

Prepared by
State Council of Educational Research and Training (SCERT) Kerala
2025

THE NATIONAL ANTHEM

Jana-gana-mana adhinayaka, jaya he
Bharatha-bhagya-vidhata
Punjab-Sindh-Gujarat-Maratha
Dravida-Utkala-Banga
Vindhya-Himachala-Yamuna-Ganga
Uchchala-Jaladhi-taranga
Tava subha name jage,
Tava subha asisa mage,
Gahe tava jaya gatha
Jana-gana-mangala-dayaka jaya he
Bharatha-bhagya-vidhata
Jaya he, jaya he, jaya he,
Jaya jaya jaya, jaya he!

PLEDGE

India is my country. All Indians are my brothers and sisters.

I love my country, and I am proud of its rich and varied heritage. I shall always strive to be worthy of it.

I shall give my parents, teachers and all elders, respect and treat everyone with courtesy.

To my country and my people, I pledge my devotion. In their well-being and prosperity alone, lies my happiness.

Chemistry

X

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Foreword

Dear students,

The researches and discoveries in various fields of science have helped in the progress and modernization of every sectors world wide. Science has become authoritative to be inevitable in everyday life. The method of science is a systematic approach of constructing knowledge, fostering the values based on humanity, understanding the nature around us and identifying and finding means to solve environmental problems.

This textbook has been organized by adopting the scientific method of problem solving which involves the stages such as designing experiments, observation, collection of data, analyzing data, drawing inferences, generalization, prediction and communication. Electrochemistry, Metals and Some compounds of industrial importance are the units included in this textbook.

The classroom activities, assessment and extended activities are organized in such a way that they are activity oriented, process based and encouraging investigative learning. We hope this textbook will help to develop the innate abilities, to think differently, to carry out innovative discoveries and make learning an enjoyable experience by effectively participating in learning activities with the help of the concepts in the textbook.

With love and best wishes.

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Certain icons are used in this textbook for convenience

For further reading (Not considered for evaluation)

Continuous assessment questions

Let us assess

Extended activities

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the [2][unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

---

1. Subs. by the Constitution (**Forty**-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (**Forty**-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation" (w.e.f. 3.1.1977)

5 ELECTROCHEMISTRY

We usually travel in vehicles. You can imagine how difficult it would be if vehicles breakdown midway due to electrical problems. Similar circumstances arise when mobile phones and laptops cannot be operated. We cannot even think of such situations these days. To operate all these, stored electrical energy is required. Cells or batteries are required as power sources to operate devices such as inverters, emergency lamps, watches, clocks, various remote controls, portable music devices, headphones, hearing aids, medical equipments for diagnosis and treatment, electrically operated toys etc.

Have you ever thought about how a cell stores electrical energy and makes it available as required? This is made possible by electrochemical reactions.

Electrochemistry is the branch of chemistry which deals with the studies on the processes that produce electricity through chemical reactions and use electricity to bring about chemical reactions. Electrochemical cells are the devices that make such changes possible.

Electrochemical cells can be divided into two types.

1. Galvanic cells
2. Electrolytic cells

Chemistry and Electricity

In 1794, Alessandro Volta discovered that electricity can be produced by placing two different metals (Zn,Cu) on either side of a piece of moist paper. In 1800, Voltas battery was used as a source of electricity to prove that water can be split into oxygen and hydrogen, and it was one of the most important experiments in the history of chemistry. This experiment indicated that hydrogen and oxygen atoms are associated with positive and negative electrical charges, and that this could be the reason for the bond between them. At the same time, the use of electricity as a means of effecting chemical reactions also played an important role in the development of chemistry. Humphry Davy was the first to produce elemental sodium by the electrolysis of molten sodium hydroxide. Michael Faraday was able to prove that there is a relationship between the amount of electric charge flowing through a solution and the amount of products of electrolysis. But we had to wait until the end of the nineteenth century to discover the electron.

Galvanic cells

Galvanic cells are devices that convert chemical energy into electrical energy. Daniel cell is an example of a galvanic cell. The method of constructing a Daniel cell is given below. Let us do this activity.

Materials required

- Beaker
- Zinc rod
- Copper rod
- Zinc sulphate solution
- Copper sulphate solution
- Salt bridge
- NH_4Cl / KCl / KNO_3
- Copper wires
- Galvanometer
- Voltmeter
- LED bulb

Experimental procedure

Dip a zinc rod in the zinc sulphate solution taken in a beaker as shown in Figure 5.1 (Half cell 1). Dip a copper rod in the copper sulphate solution in another beaker (Half cell 2). Connect the solutions using a salt bridge. (Take a piece of rolled filter paper and add a little potassium chloride or ammonium chloride or potassium nitrate into it and then sprinkle water to moisten it. This filter paper can be folded into 'U' shape and immersed in the two beakers connecting the two solutions in them and it can be used as a salt bridge.)

Connect the zinc rod and copper rod to the bulb using copper wires.

What did you observe?

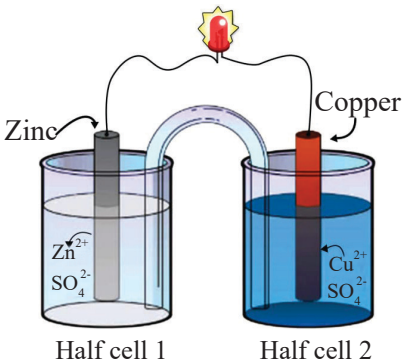


Fig. 5.1

What is the reason for the glowing of the bulb?

We can understand that there is a flow of electric current through the bulb.

Separate the copper wires from the bulb and connect them to a galvanometer as shown in Figure 5.2. When the copper rod is connected to the positive terminal of the galvanometer and the zinc rod to the negative terminal, it can be seen that the pointer of the galvanometer is deflecting towards the right (towards the positive terminal).

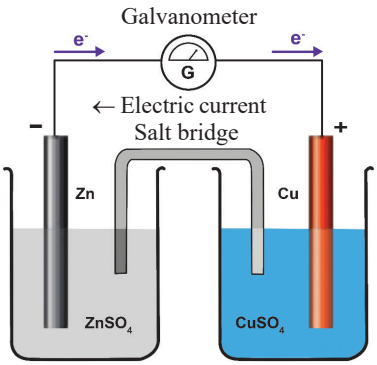


Fig. 5.2

From this, it is clear that the flow of electrons is from the zinc rod to the copper rod and that of electric current is in the opposite direction.

Now, connect a voltmeter instead of the galvanometer as shown in Figure 5.3 and find the voltage between the two electrodes.

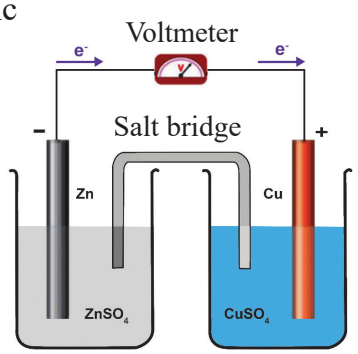


Fig. 5.3

The reaction that occurs at each electrode is given below.

Zinc electrode : $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

What type of chemical reaction takes place at the zinc electrode? (Oxidation / Reduction) ……

Copper electrode : $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

What type of chemical reaction takes place at the copper electrode?

It can be understood that oxidation occurred at the zinc electrode and reduction at the copper electrode.

The electrode where oxidation occurs is called the anode, and the electrode where reduction occurs is called the cathode.

The processes that takes place in the Daniel cell can be summarised as:

Anode : $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

Cathode : $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Cell reaction :

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

Salt bridge

A salt bridge is a U-shaped glass tube filled with inert electrolyte. The commonly used electrolytes are potassium chloride (KCl), ammonium chloride (NH_4Cl) and potassium nitrate (KNO_3) which are made into a gel using agar-agar. Salt bridge is used to connect the oxidation and reduction half cells of a galvanic cell. It helps to establish an electrical contact between the two solutions in such a way that they do not mix with each other. It is the salt bridge that enables smooth cell operation by ensuring electrical neutrality within the internal circuit.

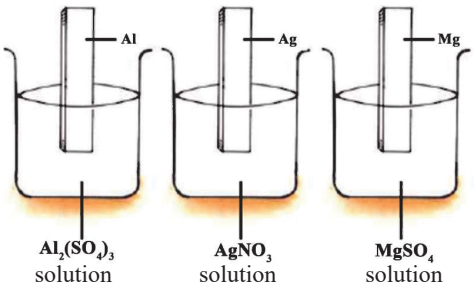


Fig. 5.4

The electric current is produced as a result of a redox reaction taking place in the galvanic cell.

Examine the metal rods and the solutions in which they are immersed in Figure 5.4.

In the Daniel cell, replace the zinc rod in zinc sulphate by aluminium, silver and magnesium rods (plates) and immerse these metals in their own salt solution. Repeat the experiment by connecting each to the copper rod immersed in copper sulphate.

List out the direction of flow of electrons, equation of reaction at each electrode, cell voltage and analyse them.

Electrode pair	Direction of flow of electrons	Anode	Cathode	Anode reaction	Cathode reaction	Cell reaction	Cell voltage
Al - Cu							
Ag -Cu							
Mg - Cu							

Table 5.1

- Which has the higher value of voltage, Zn - Cu galvanic cell or Al - Cu galvanic cell? .....

  It is clear that the tendency of aluminium to get oxidised in redox reactions is greater than that of zinc. That is, aluminium is more reactive than zinc.
- Which has the higher value of voltage, Mg - Cu galvanic cell or Al - Cu galvanic cell?

  It can be found that the value of voltage for the Mg - Cu galvanic cell is higher.
- Here, what is the direction of flow of electrons in a galvanic cell made up of a pair of copper and silver electrodes?

  .....

  It is found that the direction of flow of electrons is from the copper electrode to the silver electrode.

? Draw a diagram of the galvanic cell having silver and copper as electrodes and mark the direction of flow of electrons.

Prepare a list of the metals, familiarised through the experiment, in the order of their tendency to get oxidised in redox reactions.

Metal	Oxidation tendency (reactivity) decreases ↓
Mg	
.....	
.....	
.....	
Ag	

Table 5.2

In this way, we can construct galvanic cells using different elements as electrodes and compare their reactivities. The series in which elements are arranged in the decreasing order of their reactivity is known as reactivity series. Examine the reactivity series given below.

Potassium	K
Sodium	Na
Calcium	Ca
Magnesium	Mg
Aluminium	Al
Zinc	Zn
Iron	Fe
Nickel	Ni
Tin	Sn
Lead	Pb
Hydrogen	H
Copper	Cu
Mercury	Hg
Silver	Ag
Gold	Au

Reactivity decreases ⟶

Table 5.3

Electrical neutrality

The formation of excess positive or negative charge in a substance leads to instability. For example, immerse a zinc rod in zinc sulphate solution. Some Zn atoms enter the solution as Zn^{2+} ions, and the electrons they release remain in the metal.

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

As this process continues, the electrons remaining in the zinc create a negative charge on the metal, making subsequent oxidation difficult. The increase in positive charge that occurs in the aqueous solution also increases this obstruction. So the process stops very quickly. If the electrons can be removed from the metal as the positive ions go into the solution, stoppage of the process can be avoided. One method to regulate this is to bring the extra electrons outside through an external circuit. That is, to connect it with another metal that can accept electrons. For example, it can be connected to a copper rod that is immersed in copper sulphate. This system can be converted into an electrochemical cell by using a salt bridge which ensures continuity of electrical flow.

Applications of the reactivity series

1. To identify which metal is being displaced.

You have studied about displacement reactions in ninth standard. Let us do the experiment given below.

Place a zinc rod in a beaker of copper sulphate solution. Observe for some time.

Did the colour of $CuSO_4$ solution change?

What change was observed in the zinc rod?

What may be the reason for the fading of colour of the solution?

With the help of the reactivity series, find out which metal is more reactive, Zn or Cu?

What are the ions formed when $CuSO_4$ dissolves in water?

A decrease in the concentration of Cu^{2+} ions is the reason for the fading of blue colour.

What changes have occurred to the Cu^{2+} ions?

Write the chemical equation of the reaction.

What changes have occurred to Zn?

Write the chemical equation of the reaction.

Examine the equation of the reaction which specifies the ions involved.

$$Zn + Cu^{2+}SO_4^{2-} \rightarrow Zn^{2+}SO_4^{2-} + Cu$$

Zn underwent oxidation and Cu^{2+} underwent reduction. That is, it can be seen that a redox reaction has taken place here.

Which metal is displaced here?

Take a little silver nitrate solution in a beaker and dip a copper rod in it. Observe for some time.

Is there any change in the colour of the solution?

What change was observed in the copper rod?

Examine the equation of the chemical reaction taking place here.

$$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$$

Explain the reaction by comparing the positions of Ag and Cu in the reactivity series.

Complete this chemical equation by assigning oxidation number.

$$\overset{(...)}{Cu} + \overset{+1}{2AgNO_3} \rightarrow \overset{(...)}{Cu(NO_3)_2} + \overset{0}{2Ag}$$

Which ion is responsible for the change in the colour of the solution?

Which metal is oxidised here?

Complete the equation for oxidation.

$$Cu \rightarrow \ldots\ldots\ldots\ldots\ldots + 2e^-$$

Which one is reduced here?

Write the equation for reduction.……

The more reactive metal displace the less reactive metal from its salt solution.

Silver nitrate solution cannot be stored in a copper vessel. Why?

2. To identify oxidising agent and reducing agent

Consider the displacement reaction given below.

$$Mg + Cu^{2+}SO_4^{2-} \rightarrow Mg^{2+}SO_4^{2-} + Cu$$

Which metal is oxidised here?

Write the equation for oxidation. ……

Which metal is reduced here?

Write the equation for reduction. ……

Which reaction occurs to the more reactive metal?

Oxidation / Reduction

Which reaction occurs to the ion of the less reactive metal?

Oxidation / Reduction

The more reactive metal gets oxidised while the ion of the less reactive metal gets reduced.

What is the oxidising agent and the reducing agent in this reaction? ……

The substance that causes oxidation is called an oxidising agent and the substance that causes reduction is called a reducing agent.

In this reaction, Cu^{2+} is the oxidising agent. Similarly, Mg is the reducing agent.

What happens to the oxidising agent in this redox reaction? ……

What happens to the reducing agent? ……

In a redox reaction, the oxidising agent gets reduced and the reducing agent gets oxidised.

Identify the oxidising agent and reducing agent in the reaction given below.

$$2AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2Ag$$

Oxidising agent :

Reducing agent :

In redox reactions, the more reactive metal acts as a reducing agent and the less reactive metal acts as an oxidising agent.

3. To identify the displacement of hydrogen from acid

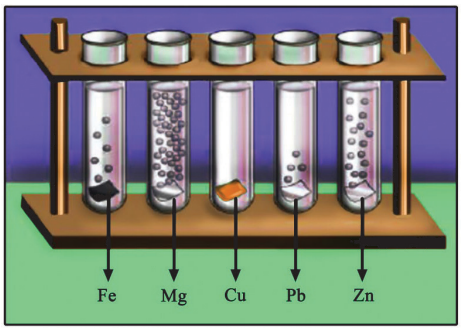


Fig. 5.5

Take equal amounts of dilute HCl in different test tubes as shown in Figure 5.5. Treat equal masses of polished Fe, Mg, Cu, Pb, Zn with dilute hydrochloric acid.

In which of the test tubes is hydrogen gas produced?

Is the rate of formation of hydrogen gas the same in all the test tubes?

Examine the position of hydrogen and the metals used here in the reactivity series and record your observations.

The metals placed above hydrogen in the reactivity series can displace hydrogen from dilute acids.

? Which of the following metals can displace hydrogen from hydrochloric acid?

Sodium, gold, silver, aluminium

Electrolytic cells

You are familiar with electrochemical cells which produce electricity through chemical changes. Likewise, there are cells which utilise electrical energy to bring about chemical changes. These cells are called electrolytic cells.

Let us do the experiment of electrolysis of acidified water.

Procedure of the experiment

Take a plastic cup. Make two holes at the bottom and attach rubber stoppers as shown in Figure 5.6. Insert carbon electrodes (graphite rods from old torch cells can be used for this purpose) into these rubber stoppers. Connect the electrodes to a 6V battery. Fill the cup with water so that the electrodes are immersed. Add 2-3 mL of dilute sulphuric acid. Dilute sulphuric acid is added to increase the ionisation of water and thereby increase its electrical conductivity. Take two test tubes filled with water and invert them over the carbon electrodes. Turn on the switch and leave the experimental setup undisturbed for some time.

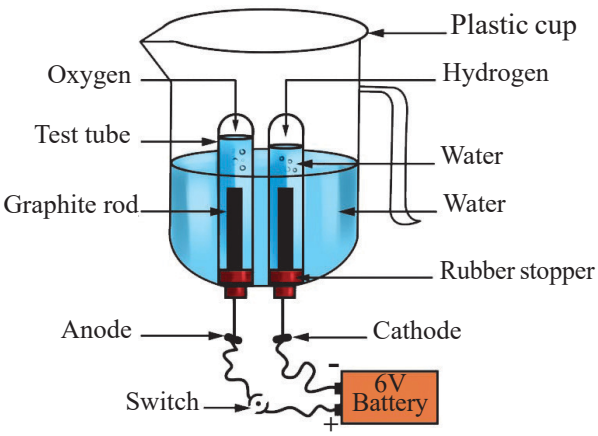


Fig. 5.6

You will observe bubbles forming at both the electrodes.

After some time, remove the test tubes carefully.

Bring a burning candle close to the mouth of the test tubes and record the observations.

.....

Which gas is produced in each test tube?

Write the chemical equation of the reaction. .....

Here, acidified water decomposes into hydrogen and oxygen. This is because of the flow of electricity from the external electrical source into the solution through the electrodes.

Electrolytes are substances that undergo chemical changes when electricity passes through them.

> Electrolytes are substances that conduct electricity in molten state or in an aqueous solution and undergo chemical changes. Electrolysis is the process by which an electrolyte undergoes chemical changes when electricity is passed through it.

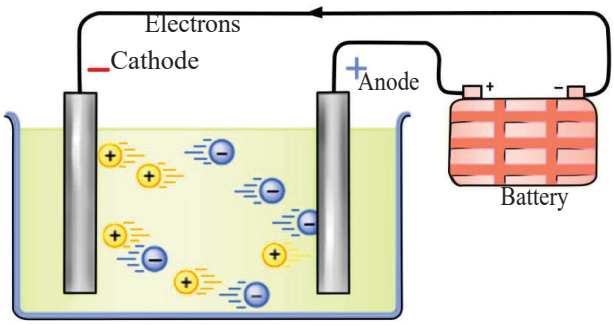


Fig. 5.7

Examine Figure 5.7 which represents the electrolytic process.

Ions are free to move in the liquid state or in an aqueous solution of an electrolyte. These ions are responsible for the electrical conductivity in the electrolyte.

Acids (HCl, H_2SO_4, HNO_3, CH_3COOH, ...) and alkalies (KOH, NaOH,...) contain free ions in their aqueous solutions. Salts (NaCl, KCl,.....) contain free ions in their aqueous solutions and molten state. For example, sodium chloride dissociates into Na^+ and Cl^- ions in the molten state or in the aqueous solution. Electrodes are conductors through which electricity enters or leaves the electrolyte. During electrolysis, the electrode connected to the positive terminal of the battery is called the anode and the electrode connected to the negative terminal is called the cathode. Reduction takes place at the cathode and oxidation at the anode.

In an electrolytic cell, oxidation takes place at the anode which is the positive electrode and reduction takes place at the cathode which is the negative electrode.

In a galvanic cell, the anode where oxidation takes place is represented as the negative electrode and the cathode, where reduction takes place is represented as the positive electrode.

Electrolysis of molten sodium chloride

In the solid state, sodium chloride does not conduct electricity. The reason is that, though the ions can vibrate about their fixed positions, they are not free to move. However, molten NaCl is a good conductor because its ions move freely. Examine Figure 5.8.

Two graphite electrodes are connected to a direct current (DC) source through wires. They are dipped in a vessel containing molten sodium chloride. When electricity is passed through them, the following observations can be made.

1. Chlorine gas (Cl_2), having a pale green colour, is liberated at the anode.
2. Silvery molten sodium metal (Na) is formed at the cathode.

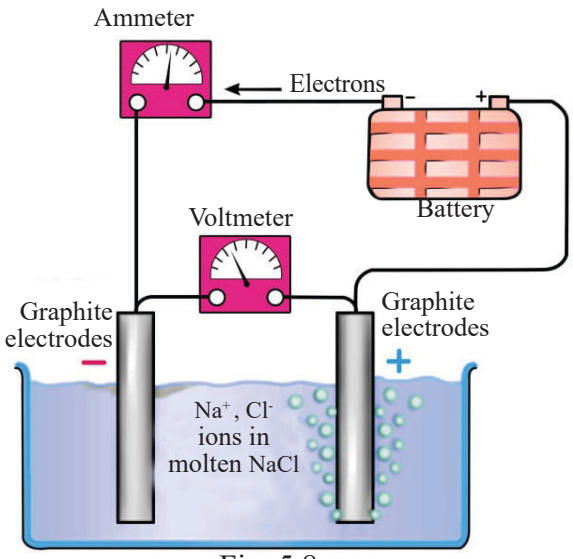


Fig. 5.8

What are the ions in molten sodium chloride?

.....

What is the chemical reaction taking place at the anode?

Oxidation / Reduction

Write the equation of the reaction. .....

What is the chemical reaction taking place at the cathode?

Oxidation / Reduction

Write the equation of the reaction.

.....

What are the products obtained as a result of the electrolysis of molten sodium chloride?

Electrolysis of aqueous sodium chloride solution

Examine Figure 5.9 representing the electrolysis of aqueous sodium chloride solution.

When a suitable voltage is applied across the electrodes of the cell, the following observations can be made.

1. H_2 gas is liberated at the cathode. If phenolphthalein indicator is present in the solution, the solution around the cathode (Figure 5.9) turns pink. That is, the solution becomes basic in nature.
2. Cl_2 gas is liberated at the anode.

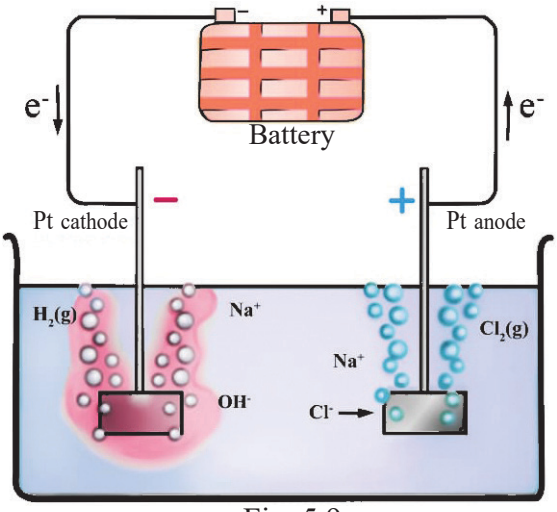


Fig. 5.9

Let us see how these observations can be explained.

At the anode, chloride ions are getting oxidised to Cl_2 gas.

Write the equation of the reaction.

.....

Based on the reactivity series, which has greater oxidising tendency- sodium or hydrogen?

If so which of the following is getting reduced at the cathode, Na^+ or H_2O?

At the cathode, H_2O molecules are reduced to produce H_2 gas and OH^- ions. Observe the equation for the reduction reaction.

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$$

As a result of the processes taking place in the cell, gases such as H_2, Cl_2 and an aqueous solution of NaOH are formed. This aqueous solution can be evaporated to produce solid NaOH.

Electrodes	Chemical change	Product
Anode	$2Cl^- \rightarrow Cl_2 + 2e^-$	Chlorine gas
Cathode	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	Hydrogen gas

Table 5.4

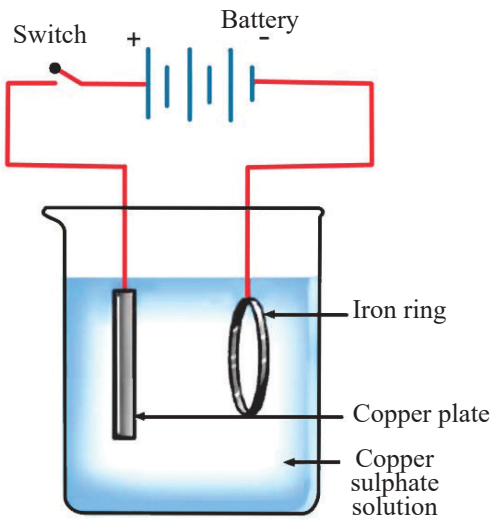


Fig. 5.10

Electroplating

Observe Figure 5.10.

Carry out this electrolysis with the help of teacher.

Record your observations.

Which metal is connected to the positive terminal of the battery? .....

Which metal is connected to the negative terminal of the battery? .....

Which solution is used as the electrolyte?

What are the ions present in the electrolyte?

Which electrode is connected to the positive terminal of the battery? Anode / Cathode

What is the reaction taking place at the anode?

Complete the equation of the oxidation reaction taking place at the copper plate.

$$Cu \rightarrow \ldots\ldots\ldots\ldots\ldots + 2e^-$$

Which electrode is connected to the negative terminal of the battery? Anode / Cathode

What is the reaction taking place at the cathode?

Which ions will be attracted to the cathode, the iron ring, from the solution?

Complete the equation of the reduction reaction taking place here.

$$Cu^{2+} + 2e^- \rightarrow \ldots\ldots\ldots\ldots$$

The reactions taking place at the anode and cathode:

Anode : $Cu \rightarrow Cu^{2+} + 2e^-$

Cathode : $Cu^{2+} + 2e^- \rightarrow Cu$

That is, at the anode, copper undergoes oxidation and enters into the solution as Cu^{2+} ions. At the same time, Cu^{2+} ions from the solution are reduced on the surface of the iron ring, which is the cathode, forming a thin coating of copper on it.

Electroplating is the process of coating a layer of one metal onto another metal through electrolysis.

The coating thus formed not only enhances the beauty of the metal but also prevents its corrosion. The object to be coated is connected to the negative terminal of the battery, after cleaning it. The metal which is used for plating is connected to the positive terminal of the battery. A salt solution of the metal to be plated is used as the electrolyte.

The metal to be coated	Electrolyte
Silver	Silver nitrate solution / sodium cyanide + silver cyanide solution
Gold	Sodium cyanide + gold cyanide solution

Table 5.5

Applications of electrolysis

1.	Production of metals	: Metals like sodium, potassium, calcium and aluminium are produced by the electrolysis of some of their compounds.
2.	Production of nonmetals	: Electrolysis is used in the industrial production of nonmetals like hydrogen, oxygen and chlorine.
3.	Manufacture of compounds	: Electrolysis is used in the production of sodium hydroxide and potassium hydroxide.
4.	Electroplating	: Gold plated jewellery, silver plated utensils, chromium plated iron objects etc are produced through electroplating.
5.	Purification of metals	: Electrolysis is useful in the purification of metals such as copper, gold etc.

Electrochemical cells as energy sources

A cell is a device that helps to convert the energy released in a chemical reaction directly into electricity. Cells perform two main functions.

1. As portable sources of electrical energy:

   Examples range from the button cells, used in electronic watches, to the lead acid cells used in vehicles.

2. As storage devices of electrical energy provided by an external source:

   Such cells can be used for powering electric vehicles, emergency power distribution and storing solar energy.

Different types of cells

There are two main types of cells.

Primary cells

In primary cells, the cell become dead, when the electrical energy produced by chemical reaction is used up. Such cells cannot be recharged and reused. Examples of primary cells are dry cells and button cells. Dry cells are commonly used in clocks. You may be aware that button cells are used in watches.

Secondary cells

A secondary cell can be recharged and used again. The most important type of secondary cell is the lead acid cell used in vehicles. The nickel-cadmium cell used in flashlights is also a secondary cell.

Lithium ion batteries are secondary cells that have become an integral part of our daily life. They are used as power sources for devices ranging from smartphones and laptops to electric vehicles. Lithium ion batteries are used in portable electronic devices due to their high energy density, long lifespan and low self discharge rate. Lithium ion batterries are also used as satellite batteries, a crucial component in the energy systems of spacecrafts.

Fuel cells

Fuel cells are galvanic cells designed to convert the chemical energy produced by the combustion of fuels such as hydrogen, methane and methanol into electrical energy. Such cells operate continuously as long as fuel is supplied. One of the advantages of fuel cells is that they produce electricity with high efficiency.

Dry cell

Button cell

Fig. 5.11

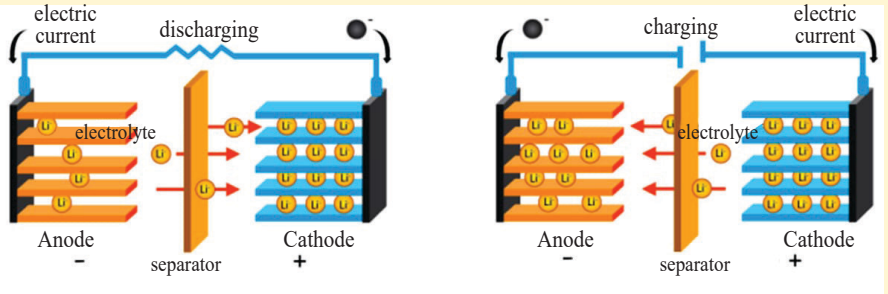
Lead acid cell

Nickel-cadmium cell

Fig. 5.12

Lithium ion batteries

The working principle of lithium ion batteries is the movement of lithium ions. The lithium ions move between the positive electrode (cathode) and the negative electrode (anode) in a liquid / gel polymer electrolyte.

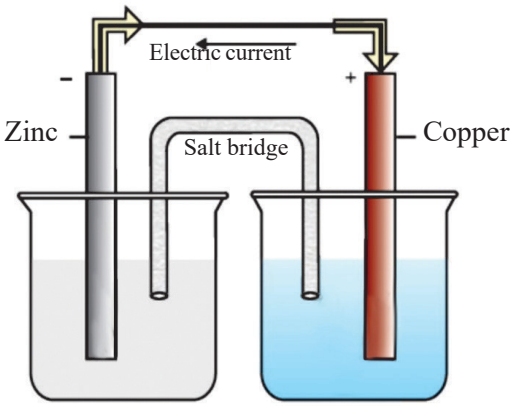


When a lithium ion battery is charged, lithium ions move from the cathode to the anode. This process allows the battery to store electrical energy. When the battery is discharging, lithium ions move from the anode to the cathode, which releases electrical energy to devices.

In 2019, Stanley Whittingham, John B. Goodenough, and Akira Yoshino won the Nobel Prize for Chemistry for their contributions to the development of lithium ion batteries.

Let us assess

1. Examine the diagram of a galvanic cell and find out whether the given statements are true or false.



   a) As the cell operates, the mass of the zinc rod, Zn(s) decreases.
   b) The copper electrode is the anode.
   c) Electrons flow from the zinc electrode to the copper electrode through the external circuit.
   d) During cell reaction, reduction takes place at the copper electrode.
   e) During cell reaction, the concentration of Cu^{2+} decreases.

2. The chemical equation of the reaction taking place in a galvanic cell is given.

$$Zn(s) + 2Ag^{+}(aq) \rightarrow Zn^{2+}(aq) + 2Ag(s)$$

   a) Represent diagrammatically the above galvanic cell.
   b) Which electrode has a negative charge?
   c) What is the reaction taking place at each electrode?

3. A galvanic cell is made up of the following half cells:
   - A magnesium electrode immersed in magnesium sulphate solution.
   - A nickel electrode immersed in nickel sulphate solution.

   The reactions taking place in the half cells are given.

$$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^{-} \qquad Ni^{2+}(aq) + 2e^{-} \rightarrow Ni(s)$$

   Draw the cell diagram and label the anode, cathode and direction of flow of electrons.

4. When an aqueous sodium chloride solution is electrolysed, the reaction that takes place at the anode is:

   (i) $Na^{+}(aq) + e^{-} \rightarrow Na(s)$ (ii) $2H_2O(l) \rightarrow 4H^{+}(aq) + O_2(g) + 4e^{-}$

   (iii) $H^{+}(aq) + e^{-} \rightarrow \frac{1}{2} H_2(g)$ (iv) $Cl^{-}(aq) \rightarrow \frac{1}{2} Cl_2(g) + e^{-}$

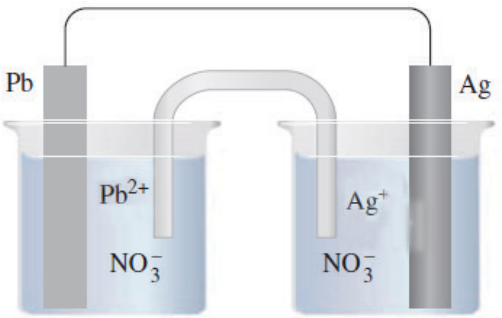
5. Write the products obtained when the following solutions undergo electrolysis.
   (i) Aqueous solution of NaCl (ii) Aqueous solution of $CuSO_4$ (using copper electrodes)

6. Brass is an alloy of zinc and copper. When brass comes into contact with saline water, corrosion of metal takes place and zinc gradually dissolves in the solution, leaving copper behind. Explain why zinc dissolves in comparison to copper.
7. List the cells we use in our daily life and classify them into primary and secondary cells.
8. Define fuel cells and write its advantage.

Extended activities

1. The following are certain observations about metals A, B, C and D.
   (a) When a plate of metal A is placed in a solution containing B^{2+} ions, no reaction is observed.
   (b) When the plate of A is placed in a solution containing C^{+} ions, no change occurs.
   (c) When a plate of metal D is placed in a solution containing C^{+} ions, a black precipitate of C is formed on the surface of D and the presence of D^{2+} ions can be detected in the solution.
   (d) When a plate of B is placed in a solution of D^{2+} ions, D appears on the surface of B and B^{2+} ions appear in the solution.

   List A^{+}, B^{2+}, C^{+} and D^{2+} in the ascending order of their ability to attract electrons.
2. As shown in the galvanic cell of the given figure, place a silver electrode in a solution of silver nitrate and a lead electrode in a solution of lead nitrate. Connect the two electrodes using a copper wire. Also connect the two beakers using a salt bridge.
   Next, find the answers to the questions given below.



   (a) What is the anode? (b) What is the cathode? (c) Where does oxidation occur?
   (d) Where does reduction occur?
   (e) In which direction do electrons flow through the copper wire?
   (f) What will be the cell voltage?
   (g) Will the cell voltage vary if the two solutions are diluted alternately?

6 METALS

Look at these pictures... They provide a glimpse of the modern world. Trains running on electricity, the prominent changes in the field of construction, the diversity of electronic technology etc. have all changed our lives drastically. You might have seen in news clips how the army quickly build the Bailey bridge on the site of a disaster. Can we think of a world without cars, smartphones, computers, internet, electricity, buildings or bridges? For this, we are indebted to a special class of elements. Do you know which class it is?

The discovery of metals and their role in human progress is amazing. The term 'metal age' refers to the transition period from the stone age to the use of metals. Our ancient period is marked by the names copper age, bronze age, iron age etc. Metals are used in many forms in different fields of our life.

Try to find some of them and complete the table.

Transport sector	Cars, cycles, ..., ...
Agricultural sector	Agricultural tools, tillers, ..., ...
Construction sector	Buildings, bridges, pipes ....., ...
Technology sector	Phones, laptops, electrical wires ....., ...
Consumer goods	Jewellery, household articles ....., ...

Table 6.1

Which metals are mostly used in these situations? List them.

Iron, gold, ..., ..., ...,

You have learnt that metals are used in various fields because of some of their common properties.

What properties of metals are utilised in various fields?

- Sonority
- Malleability
- Ductility
-
-

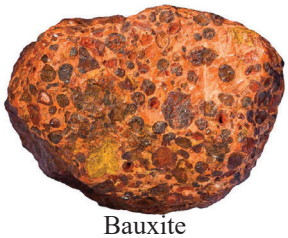
Bailey bridge

Bailey bridge is an emergency bridge constructed in disaster stricken areas temporarily. Such bridges are also used for military purposes. It is a kind of portable bridge that can be easily constructed by assembling prefabricated parts. Steel and wood are the main components of the bridge. The role played by such metal bridges in rescue operations in disaster stricken regions is very important. Such a bridge was first built by a civil engineer Donald Coleman Bailey, an officer in the British War Office, during World War II and the bridge was named after him.

Occurrence of metals in nature

The earth's crust is the major source of metals. Metals are generally found in combined state as they are highly reactive. Metal compounds like sodium chloride and magnesium chloride are dissolved in sea water also. A very few metals are seen in free state too. Can you identify these? .....

Naturally occurring metals or compounds are generally called minerals. These include metallic compounds and non metallic compounds.


Bauxite

The same metal can be found in the form of various minerals in nature. Metals are separated from the most suitable ones among these. For example, clay ($Al_2O_3.2SiO_2.2H_2O$) is an abundant mineral of aluminium. Bauxite ($Al_2O_3.2H_2O$) and cryolite (Na_3AlF_6) are also minerals of aluminium. But among these, bauxite is the mineral that is commonly used to produce aluminium. What will be the reason?


Copper pyrites

What are the qualities of a mineral which is used to extract a metal?

- Abundance
- Ease of extraction
- High metal content
- Low production cost.


Haematite

Based on these characteristics, bauxite is the most suitable mineral for the production of aluminium.

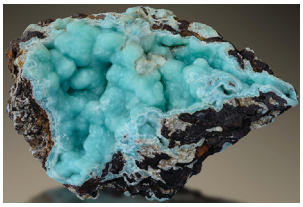

Calamine

Fig. 6.1

Any mineral from which a metal can be extracted easily and economically is called an ore of that metal.

The ores of some metals are listed in Table 6.2.

Metal	Ore	Chemical formula
Aluminium(Al)	Bauxite	$Al_2O_3.2H_2O$
Iron (Fe)	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
Copper (Cu)	Copper pyrites	$CuFeS_2$
	Copper glance	Cu_2S
	Cuprite	Cu_2O
Zinc (Zn)	Zinc blende	ZnS
	Calamine	$ZnCO_3$
Tin (Sn)	Cassiterite / Tinstone	SnO_2

Table 6.2

Highly reactive metals are found in nature in their combined form. Let us examine how pure metals are extracted from these.

The process of extraction of metal from ores involves three major stages. Such processes are generally referred to as metallurgy.

Concentration of ores	Extraction of metal from concentrated ore	Refining of metal

Concentration of ores

Ores are mined from the earth's crust. A lot of earthy impurities like soil and sand may be mixed with this. Concentration of ores is the process of increasing the metal content of the ore by removing such impurities, known as gangue. Depending on the nature of the ore and gangue, various methods are adopted for this purpose.

1. Levigation or Hydraulic washing

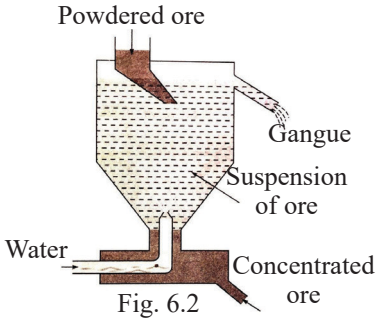


Fig. 6.2

This method is employed when the density of the ore is more than that of the gangue. The powdered ore is washed in a stream of water. The less dense gangue, which floats, is filtered out. The more dense ore remains at the bottom. Generally, oxide ores can be concentrated by this method.

2. Froth floatation

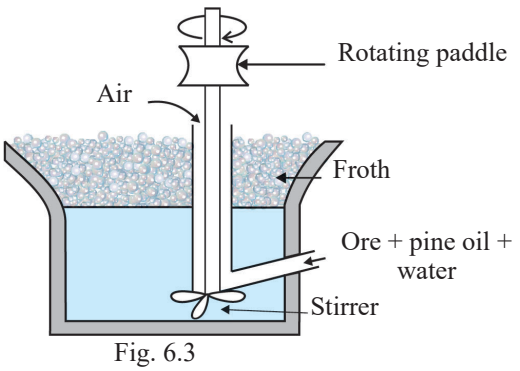


Fig. 6.3

The froth floatation process is used when the ore is less dense than the gangue. The powdered ore is added to a mixture of water and pine oil and is stirred in a strong current of air. The ore particles stick to the froth formed, and float. It is removed and then the ore is separated and dried.

Generally, sulphide ores are concentrated by this method.

3. Magnetic separation

When the powdered ore is passed through a magnetic roller, either the ore or the impurities having magnetic property is separated. In this way, pure ore is obtained by magnetic separation.

For example, magnetite (Fe_3O_4) ore has magnetic properties, but the gangue is non magnetic. Tinstone (SnO_2) ore is non magnetic, but iron tungstate, the gangue present in it is magnetic.

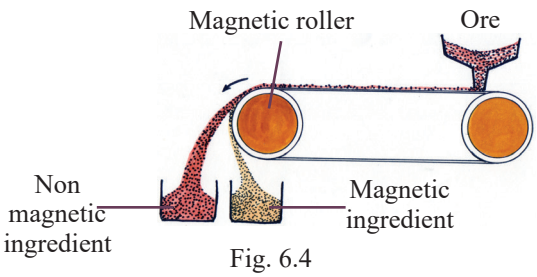


Fig. 6.4

4. Leaching

The powdered ore is mixed with a suitable solvent. The ore dissolves in it or undergoes a chemical reaction to become a solution. The gangue remains insoluble in it. It is then filtered out. This process is called leaching.

Bauxite, the ore of aluminium, is concentrated in this way.

Metals such as gold and silver occur almost freely in nature. The ores of these metals are leached with a dilute solution of sodium cyanide (NaCN) or potassium cyanide (KCN) in the presence of air to extract the metals.

The nature of ores is given. Complete the table using appropriate concentration methods.

Nature of ore	Concentration method
1. Ores are less dense than the impurities.	.....
2. Ores have magnetic properties but impurities are non magnetic.	.....
3. A solvent which dissolves the ore is used.	.....
4. Ores are denser than the impurities.	.....

Extraction of metal from concentrated ore

You have learnt that the reactivity of metals differ. You also know about the reactivity series that is prepared based on this.

How are metals arranged in the reactivity series?

Decreasing order of reactivity / increasing order of reactivity

Is there any relation between the production of metal and the reactivity series?

Here are some metals in the reactivity series.

Reactivity decreases ↓

Potassium (K) Sodium (Na) Calcium (Ca) Magnesium (Mg) Aluminium (Al)	Metals that are highly reactive and form stable compounds.
Zinc (Zn) Iron (Fe) Tin (Sn) Lead (Pb)	Metals with comparatively moderate reactivity and form stable compounds.
Copper (Cu) Mercury (Hg) Silver (Ag) Gold (Au)	Less reactive metals and form less stable compounds. They occur more or less in the free state in nature.

Mercury can be easily separated from its ores by controlled heating.

Metals with comparatively moderate reactivity like Zn, Fe, Sn, Pb, are generally found as oxides, sulphides or carbonates.

Eg. $ZnCO_3$, ZnS, Fe_2O_3, SnO_2, PbS.

There are two stages for the production of metal from them.

1. Conversion of concentrated ore to oxide

Two methods are commonly used for this.

(a) Calcination

Metal carbonates or hydroxides are converted to their oxides by a process called calcination.

Calcination refers to heating the concentrated ore in limited quantities or absence of air at a temperature below the melting point.

Eg. $CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$

$ZnCO_3(s) \xrightarrow{heat}$ ..... + ...

(b) Roasting

Roasting refers to heating the concentrated ore at a temperature below the melting point in the presence of air.

Zinc sulphide and lead sulphide can be easily converted into their oxides by this method.

$2ZnS(s) + 3O_2(g) \xrightarrow{heat} 2ZnO(s) + 2SO_2(g)$

$2PbS(s)$ + ... $\xrightarrow{heat}$ ..... + ...

When the concentrated ore is subjected to roasting, the water content in them gets released as vapours. They become pure and moisture free oxide ores.

2. Reduction of oxide ore

The metal part of the ores is in the form of positive ions, and hence it can be extracted by a reduction process.

Note the process that separates zinc from zinc oxide.

$$ZnO + C \rightarrow Zn + CO$$

Which is the reducing agent in this case?

.....

Reducing agents such as coke (an allotrope of carbon) and carbon monoxide are used to extract moderately reactive metals such as iron, zinc and tin from their oxide ores. Carbon has a greater tendency to react with oxygen at high temperatures, so oxygen is easily removed from the ore.

Strong reducing agents are required to extract highly reactive metals such as sodium, potassium, calcium, magnesium and aluminium from their ores. Such metals are produced by electrolysis.

Complete Table 6.3 regarding the manufacture of metals.

Method of separating metals from ores	Metals
Electrolysis	.....
Reduction using coke	.....
Heating in controlled ways	.....

Table 6.3

The order of reactivity of some metals is given.

Al > Zn > Fe > Au

- Which metal forms the most stable compound?
- Which metal is produced by electrolysis?
- Which metal can displace zinc from compounds of zinc? Why?
- Which metal is found in the free state in nature?
- Which metal is produced by reduction using carbon?

Refining of metals

The metal extracted from concentrated ore may contain other elements or their compounds as impurities. Refining of metals is the process of removal of these impurities to produce pure metal.

Various methods are adopted for this purpose depending upon the nature of the metal to be purified and the impurities contained in it. Some are given below.

(a) Liquation

When metals with low melting point contain impurities with high melting point, the metal is heated on the inclined surface of the furnace. The pure metal separates from the impurities, melts, flows down and it is collected. This is known as liquation. Metals such as tin (Sn) and lead (Pb) having low melting point can be purified by this method.

(b) Distillation

This method is used to purify metals with relatively low boiling points. When the metal containing impurities is heated under suitable conditions, only the pure metal vapourises. When this vapour condenses, pure metal is obtained.

Metals like zinc (Zn), cadmium (Cd) and mercury (Hg) can be purified using this method.

(c) Electrolytic refining

In an electrolytic cell, an impure metal is used as the anode and a thin piece of pure metal is used as the cathode. A suitable salt solution of the same metal is used as the electrolyte. When electric current is passed, the pure metal alone is separated from the anode and deposited at the cathode.

Anode : $M \rightarrow M^{n+} + ne^-$

Cathode : $M^{n+} + ne^- \rightarrow$ .....

(Hint : M - metal, n - number of electrons involved in the reaction)

Copper (Cu) and zinc (Zn) can be purified in this way.

Now, let us get familiar with the manufacturing methods of some industrially important metals.

Extraction of iron

Iron comprises about 5% of the earth's crust and it is the second most abundant metal.

Complete Table 6.4 regarding the manufacture of iron.

Ores of iron and its chemical formula	.....
Methods used for concentration	Washing in stream of water, roasting, ...
Substance used to reduce the ore	.....

Table 6.4

Iron is produced in steel towers, known as blast furnaces, which are 25 to 30 meters high. Its interior is lined with bricks (Refractory bricks) capable of withstanding high temperatures (Figure 6.5). The concentrated ore mixed with limestone ($CaCO_3$) and coke (C) is fed from the top of the furnace via cup & cone arrangement. This mixture is called charge.

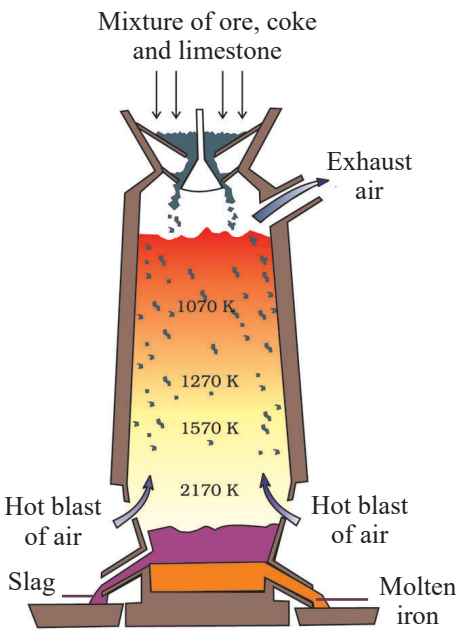


Fig. 6.5

A blast of hot air is blown into the furnace from its bottom. As the charge descends from the top of the furnace, various chemical changes take place inside it. The coke combines with the oxygen in the air, when the blast of hot air flows from the bottom to the top of the blast furnace.

$$C + O_2 \rightarrow CO_2 + \text{heat}$$

This is an exothermic reaction.

Coke reacts with carbon dioxide to produce carbon monoxide.

This is an endothermic reaction.

$$CO_2 + C + \text{heat} \rightarrow 2CO$$

The main chemical reaction taking place in the blast furnace is the reduction of iron ore using carbon monoxide.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

In the production of iron, limestone is added to the ore. What could be the reason?

Even though the iron ore fed into the furnace is in the most refined form, it may contain acidic impurities such as sand (silica SiO_2) that cannot be removed in the first stages of concentration methods. For this, a substance known as flux is added during the metallurgical stage. As the impurities are acidic in nature, a basic substance is used as the flux. The flux combines with gangue to form molten slag.

$$\text{Gangue} + \text{Flux} \rightarrow \text{Slag}$$

When heated at high temperature, the limestone decomposes to calcium oxide (Quick lime). Calcium oxide produced in this reaction acts as flux.

Let us examine the chemical changes of limestone inside the blast furnace.

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

Calcium oxide reacts with sand (SiO_2) to form calcium silicate (slag) which melts easily.

$$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$$

Flux Gangue Slag

If the gangue in the ore is basic in nature, what type of flux should be used? .....

Since the molten slag is less dense, it floats on the molten iron. These are removed at regular intervals through a separate tube / tap. This slag is used in the production of cement and in the construction of roads.

The molten iron obtained from the blast furnace contains 4% carbon and small amounts of other impurities such as manganese, silicon, phosphorus and sulphur. This is called pig iron.

If the percentage of impurity in it is reduced, the iron obtained can be cast as desired. It is called cast iron. It contains more than 2% carbon.

Wrought iron is a relatively pure form of iron, containing 0.02% - 0.05% carbon and small amounts of phosphorus, silicon, manganese, sulphur etc.

Steel

The pig iron obtained from the blast furnace is not suitable either for hammering into various shapes or for drawing into wires. The steel obtained from this is used for various industrial purposes. Steel is iron containing 0.05% to 1.5% carbon. There are different types of carbon steels depending on the amount of carbon. They differ in properties also (Table 6.5).

Carbon steel	Amount of carbon (%)	Features
Mild steel	0.05 - 0.2	Easy to draw into wires and hammer into plates. Strong and hard. Used for making agricultural tools.
Medium steel	0.2 - 0.6	High hardness. Used for the construction of railway tracks, handrails, rafters etc.
High carbon steel	0.6 - 1.5	Very high elasticity and hardness. Used for the manufacture of surgical instruments, springs, knives, drills etc.

Table 6.5

Prepare a list of different types of steels, their methods of manufacture and use. ICT can be utilised.

Alloy steel

The use of metals in their pure form is relatively less. Most of the metals are converted into alloys to be used for various purposes in daily life. List the alloys familiar to you.

Brass, ……., ……., ……..

Alloys are mixtures of two or more metals. Nonmetals like carbon, nitrogen and phosphorus are also used for the production of alloys.

What are the constituents of steel? Iron, ……..

Alloy steels are made by adding other metals to steel. Their properties are different from those of steel.

Let us get familiar with some important alloy steels.

Alloy steels	Constituent elements	Properties and uses
Stainless steel	Fe, Cr, Ni, C	Resists corrosion. Manufacture of household appliances and blades.
Manganese steel	Fe, Mn, C	High hardness. Used for the manufacture of drills, safes, plates and railway tracks.
Silicon steel	Fe, Si, C	Also known as electrical steel. As it reduces electric loss, it is used in the core of electromagnetic instruments like motors, generators, transformers etc.

Table 6.6

Expand the list by finding more alloys, their constituents and uses.

Extraction of zinc

Zinc is another industrially important metal. Complete Table 6.7 regarding the production of zinc.

Sulphide ore of zinc (Common name, chemical formula)	.....
Concentration method	.....
Carbonate ore of zinc (Common name, chemical formula)	.....

Table 6.7

What are the processes used in the conversion of zinc ore to zinc oxide after the concentration of ore?

.....

Coke is mixed with the zinc oxide obtained after these processes.

This mixture is put into a furnace similar to a blast furnace. At high temperature in the furnace, the coke reduces zinc oxide to zinc.

$$ZnO(s) + C(s) \xrightarrow{heat} Zn(s) + CO(g)$$

Zinc has comparatively low boiling point (907°C) and hence it vapourises at high temperature and comes out. It is immediately cooled to liquid form.

You are familiar with the purification process of zinc. What is it known as?

.....

Brass is an important alloy containing zinc.

Prepare a note on the production of zinc and its use. Record it in the science diary.

Extraction of copper

Principal ores of copper

Copper pyrites - $CuFeS_2$ Copper glance - Cu_2S

What method of concentration is suitable for these sulphide ores?

.....

The ore contains basic impurities such as iron oxide even after concentration. What type of flux is suitable to remove it?

Acidic / Basic

Sand (SiO_2) having acidic nature is added to the ore and heated to form cuprous sulphide (Cu_2S) of maximum purity. It is partially converted to cuprous oxide (Cu_2O) when heated under controlled flow of air. The cuprous oxide converts the remaining cuprous sulphide into copper.

$$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2\uparrow$$

Note that no reducing agent is added here.

Molten copper is cooled in moulds. The copper lumps thus obtained are called blister copper. Why is it called so? The sulphur dioxide gas produced during the production of copper is released when the metal condenses. As a result blisters are formed and they appear as such on the surface of copper lumps.

Brass and bronze are important alloys that contain copper. List the constituent metals in them.

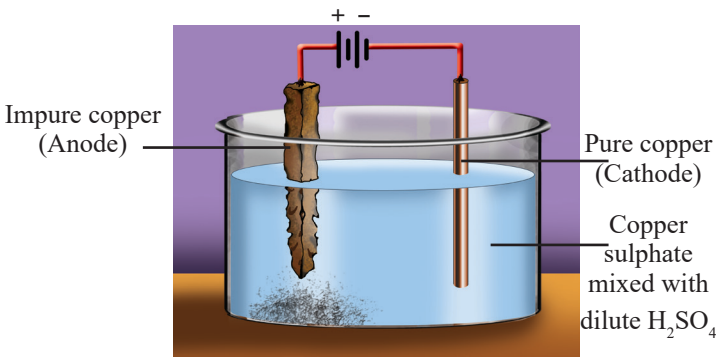


Fig. 6.6

Purification of Copper

You are familiar with the method of refining copper. Copper used for electrical purposes should be 99.99% pure. A high quality product is obtained through electrolytic refining. The diagram of refining of copper is given (Figure 6.6).

Observe the diagram and complete Table 6.8.

Anode	
Cathode	
Electrolyte	
Chemical equation of the reaction taking place at anode.	
Chemical equation of the reaction taking place at cathode.	

Table 6.8

Prepare a note on the process involved in the purification of copper and record it in the science diary.

Extraction of aluminium

Aluminium is produced by Hall-Heroult process. It has two stages.

1. Concentration of bauxite

You have learnt that bauxite is concentrated by leaching. The powdered ore is treated with hot concentrated sodium hydroxide (NaOH) solution. The ore alone dissolves in it to form sodium aluminate ($NaAlO_2$) solution. Impurities are then filtered off.

Aluminium (Al)

Aluminium is the most abundant metal in the earth's crust. It is almost 8.3%. In 1827, the German scientist Friedrich Wohler extracted the metal from aluminium chloride using potassium. In those days, aluminium was more expensive than gold due to high production cost and difficulty in manufacturing. Aluminium was rarely used at that time. Later, when it was discovered that aluminium can be separated by electrolysis, it became an easily available metal. In 1886, the American scientist Charles Martin Hall and the French scientist Paul Heroult, through independent efforts, discovered a method to extract aluminium from bauxite. As the credit of discovering this method goes to both of them, the process is called Hall-Heroult process.

Charles Martin Hall
1863 - 1914

Paul Heroult
1863 - 1914

$$Al_2O_3.2H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2O$$

A little aluminium hydroxide ($Al(OH)_3$) is added to the solution of sodium aluminate and stirred vigorously. It is diluted by adding water. As a result, pure aluminium hydroxide separates out from the solution.

$$NaAlO_2 + 2H_2O \rightarrow Al(OH)_3 + NaOH$$

If the aluminium hydroxide thus obtained is heated strongly, anhydrous alumina (Al_2O_3) is obtained.

$$2Al(OH)_3 \xrightarrow{\text{heat}} Al_2O_3 + 3H_2O$$

2. Electrolysis of aluminium oxide

Molten cryolite (Na_3AlF_6) is added to the alumina, obtained after concentration, to get a solution. This is the electrolyte used in the production of aluminium. The melting point of alumina is 2017°C. Cryolite is added to reduce the melting point and to increase the electrical conductivity.

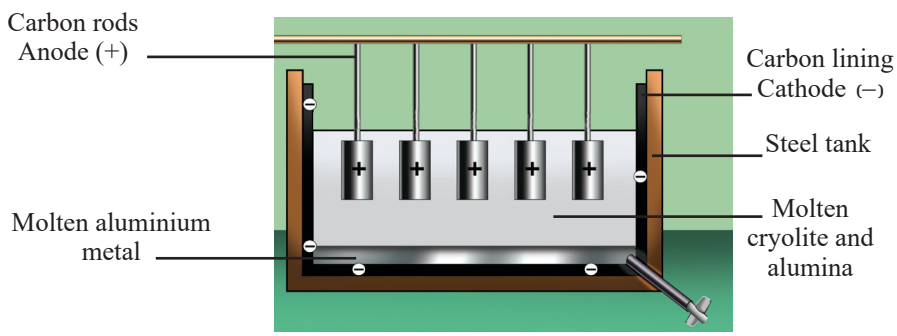


Fig. 6.7

Aluminium is separated at the cathode when a high voltage electric current is passed through the molten mixture. Examine the chemical equations of the reactions.

$$Al_2O_3 \rightarrow 2Al^{3+} + 3O^{2-}$$

What reaction takes place at the cathode?

$$Al^{3+} + 3e^- \rightarrow .....$$

What reaction takes place at the anode?

$$2O^{2-} \rightarrow O_2(g) + 4e^-$$

Which gas is liberated at the anode? .....

In the electrolytic cell, the positively charged carbon rods are replaced periodically. What is the reason?

Winged Metal (Duralumin)

At the beginning of the 20th century, a German scientist Alfred Wilm made an alloy of aluminium by adding copper, manganese and magnesium. Constant experimentation was undertaken to improve its strength and quality, and a new alloy was produced in Duren in 1911 by adding accurate amount of constituent metals and heating them at suitable temperature. It was named duraluminium by adding the name of the place. Later, the name was changed to duralumin. In 1919, duralumin began to be used in the construction of airplanes. Duralumin is used as an alloy in the manufacture of aircraft and aerospace vehicles and therefore be described as winged metal. The components of duralumin are Al-95.5%, Cu-3%, Mg-1% and Mn-0.5%. The duralumin produced in this way has the same strength as that of steel.

Oxygen released at the anode oxidises the carbon rod to oxides of carbon. As a result, the size of the anode rod decreases.

Complete Table 6.9 related to electrolysis of aluminium.

Anode	
Cathode	
Electrolyte	
The product formed at anode	
The product formed at cathode	
Reducing agent	

Table 6.9

Duralumin and alnico are important alloys which contain aluminium. The constituents of alnico are Fe, Al, Ni, Co etc. Alnico is used for making permanent magnets.

Corrosion of metals

Corrosion of metal is a process in which the metal reacts with a surrounding medium and undergoes chemical change. Corrosion of iron has been discussed in previous classes.

What are the factors influencing the corrosion of iron?

.....

The metals occupying higher positions in the reactivity series readily corrode upon contact with atmospheric air. The rate of corrosion decreases as we move down. What could be the reason? Examine in terms of reactivity.

Fig. 6.8

Even though aluminium is a metal at the top of the reactivity series, it resists corrosion to some extent. Why?

The oxide coatings on metals such as aluminium, zinc and tin are thin and nonporous and therefore protect the metal from further corrosion.

How does the corrosion of iron differ from this? The hydrated iron oxide (rust) that forms on the surface of iron is porous and powdery. So this process of corrosion continues until the metal is completely destroyed.

The factors given below influence the corrosion of metals.

- Nature of the metal
- Moisture in which gases or salts are dissolved
- Contact with other metals

How does the contact with other metals alter the rate of corrosion? Let us do an experiment (Figure 6.9).

Prepare a very dilute solution of sodium chloride in two large test tubes. Place iron nails, one tightly wrapped with copper wire and the other with magnesium wire. Observe the test tube for five to six days. Record the results of the observation in the science diary.

In which test tube, the iron nail undergoes rusting?

It is found that the iron nail in contact with copper corrodes easily while that in contact with magnesium is protected. Why does this happen?

When a metal comes in contact with another metal in the presence of an electrolyte, it acts as a simple voltaic cell.

When iron comes into contact with copper, which metal will release electrons? Why?

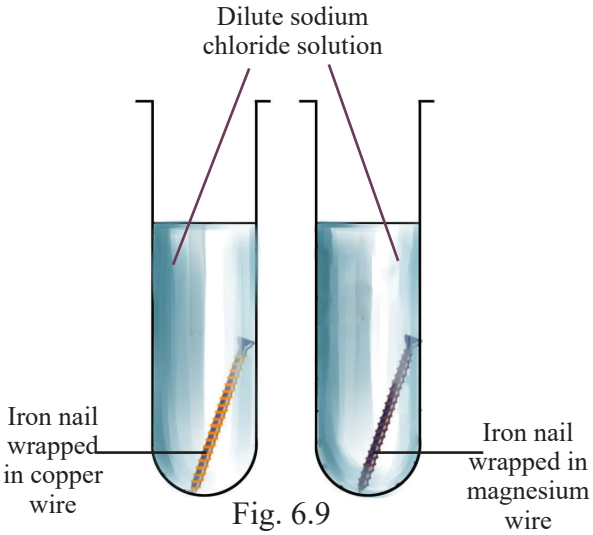


Fig. 6.9

The iron atoms, that lose electrons, change into ions. The rate of corrosion of iron increases. Here iron acts as anode and copper acts as cathode.

Why is iron protected when it is in contact with magnesium?

Isn't it because the more reactive magnesium donates electrons?

In the cell formed here, magnesium acts as anode and iron as cathode.

Which metal will corrode when two metals are in contact in the presence of moisture in the air?

The more reactive / The less reactive

It is seen that the metal acting as anode is destroyed and the metal acting as cathode is protected. This is an important method to prevent corrosion of iron. This is known as cathodic protection.

- Why is it not advisable to join aluminium wires and copper wires, and to join iron materials to copper piping for electrical purposes?
- Why are zinc or magnesium blocks always attached to sea bridges and ship hulls?

Discuss various methods to prevent corrosion of metals and list them in the science diary.

Metals play a crucial role in the human body also. We can learn more about it in the higher classes.

Bioinorganic chemistry

The presence of certain metals in humans, albeit in minute amounts, is essential for normal biological functions. Bioinorganic chemistry is a branch of chemistry that deals with the role of metals in biological processes. It can also be said that it is a branch of science that connects inorganic chemistry and biochemistry. This branch of chemistry deals with the movement and storage of metal ions in the human body, toxic properties of metal ions, metals with medicinal uses and much more.

Haemoglobin

Iron is one of the elements required for the day to day functioning of the human body. Haemoglobin is an iron containing protein molecule which carries oxygen. These pigments, found in the red blood cells in human body, carries oxygen from the lungs to cells and carbon dioxide from cells to the lungs.

Chlorophyll

Chlorophyll is a green pigment containing magnesium. This substance, found in the leaves of plants, is the basic factor in photosynthesis.

Let us assess

1. Define the following and answer the given questions.

   (1) Ore - What is the ore of aluminium?

   (2) Roasting - Which type of ores are subjected to roasting?

   (3) Reducing agent - What is the reducing agent used in the manufacture of aluminium?

   (4) Flux - Which flux is used in the manufacture of copper? Why?

   (5) Leaching - Which metal ore is leached with sodium cyanide?

2. Find the relation and write the answer.

   Zinc sulphide : Roasting Calcium carbonate : .....

   Magnetite : Magnetic separation Bauxite : .....

3. The chemical reaction that occurs when calcium carbonate is heated is given.

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

   How is this chemical change of calcium carbonate utilised in the industrial preparation of iron?

4. Following are two facts related to the manufacture of an industrially important metal.
   - The ore is treated with hot NaOH solution.
   - Electricity is used as the reducing agent to extract the metal.

   (i) These facts are related to the production of which metal?

   (ii) What is the reason for using electricity as the reducing agent?

   (iii) Which substance is used as the electrolyte here?

   (iv) Which gas is liberated at the anode?

5. A portion of the periodic table is given.

	^{5}B	
	^{13}Al	^{14}Si
	^{31}Ga	

   (i) Which method given below is more possible for the production of gallium?

   (Reduction using carbon, electrolysis)

   (ii) If gallium chloride ($GaCl_3$) is electrolysed, what is the product formed at the cathode. Write the chemical equation.

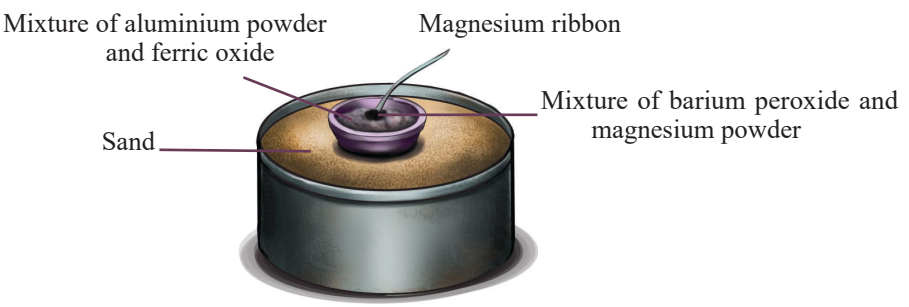
   (iii) Write the subshell electron configuration of the outermost shell of gallium.

6. Corrosion is a process by which iron is converted into its oxide. This is an oxidation reaction.
   (i) What is oxidation?
   (ii) Complete the following chemical equation.
   ..... Fe + ... O_2 → ..... Fe_2O_3
   (iii) Suggest two methods for preventing the corrosion of iron.
7. Alloys containing iron are given. Find a, b, c, d.

Alloys	Constituent elements	Uses
Alnico	(a)	(b)
(c)	Fe, Cr, Ni, C	Resist the corrosion of iron. Making of utensils
Silicon steel	Fe, Si, C	(d)

Extended activities

1. Thermite process



Mix equal amounts of anhydrous aluminium powder and iron oxide in a crucible. Immerse it in a tin pot filled with sand. Place a little of barium peroxide and magnesium powder mixture on top of the first mixture. Fix a 6 cm long polished magnesium ribbon in slanting position on its top. After lighting the ribbon, watch it from a distance.

After the reaction stops, examine the crucible and you will find a small globule of iron.

$$Fe_2O_3 + 2Al \xrightarrow{heat} Al_2O_3 + 2Fe$$

- Analyse the chemical changes that took place here based on the metallurgical process.
- Find instances where thermite process is used in daily life.
- Write the chemical equation for the production of chromium from chromic oxide (Cr_2O_3) in this way.

2. Prepare a note on how the rusted iron materials collected from the scrap iron shop are used in making steel. Present it in the class.
3. Prepare a flow chart showing the various steps in the purification of bauxite.

7 SOME COMPOUNDS OF INDUSTRIAL IMPORTANCE

Industrial Revolution and Green Revolution have brought about major changes in human history. These changes can be seen as a step from a traditional way of life to a modern lifestyle.

Look at the picture.

Sprawling paddy fields were once a common sight. Has that changed today?

Agriculture is something that man has learnt from nature. Ours is a land of agricultural abundance. The country has been able to achieve self-sufficiency in food through improved farming methods. Chemistry plays a major role in this.

You know that fertilizers are necessary for the proper growth and better yield of agricultural crops.

What are the elements essential for the growth of plants?

.....

On the basis of examining the presence of acids, bases and salts in the soil, necessary remedial measures are taken before cultivation. This helps agricultural crops to grow well and give maximum yield.

Let us get familiar with the industrial production of some chemicals that are important in agricultural and industrial fields and the characteristics of fertilizers, acids and bases.

Ammonia (NH_3)

Ammonia is a chemical used for the production of nitrogenous fertilizers which are required for the growth of plants.

Let us do an experiment to prepare ammonia.

Take a little ammonium chloride (NH_4Cl) in a watch glass. Add a little calcium hydroxide ($Ca(OH)_2$) to it and stir well using a glass rod.

Observe the colour and odour of the ammonia gas produced and tick (✓) the correct one in the table given below.

Colour	Yes / No
Odour	Pungent smell / No smell

Table 7.1

Moist blue and red litmus papers are shown above the watch glass. Which litmus paper shows a change in colour?

Blue litmus paper / Red litmus paper

.....

What property of the gas is indicated by the change in colour of the litmus paper?

Acidic nature / Basic nature

.....

Complete the chemical equation of the reaction that occurred in the watch glass.

$2NH_4Cl + Ca(OH)_2 \rightarrow$ ..... + ... + ...

Look at the figure illustrating the preparation of ammonia in the laboratory.

You have noticed that a drying tower is used in the picture.

When ammonia is passed through quick lime (CaO) in the drying tower, the moisture contained in it is removed.

In Figure 7.1, the jar used for collecting ammonia is kept inverted. Write the reason for this, relating it to the density of ammonia.

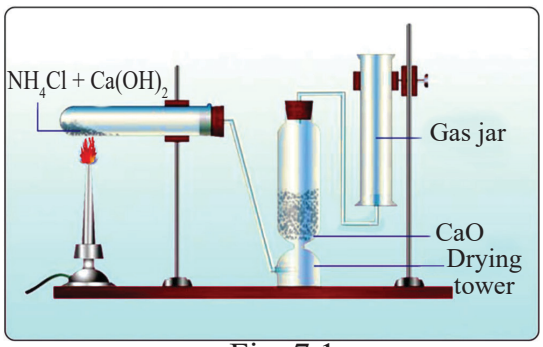


Fig. 7.1

.....

Let us carry out an experiment using ammonia gas.

Collect ammonia in a round bottomed flask. Arrange the apparatus as shown in Figure 7.2. Dip the jet tube in the beaker containing water mixed with phenolphthalein. Using a syringe, inject a few drops of water into the flask containing ammonia.

What do you observe?

What can be inferred about the solubility of ammonia in water? Why does water rush into the flask?

Why does the water entering the flask change its colour?

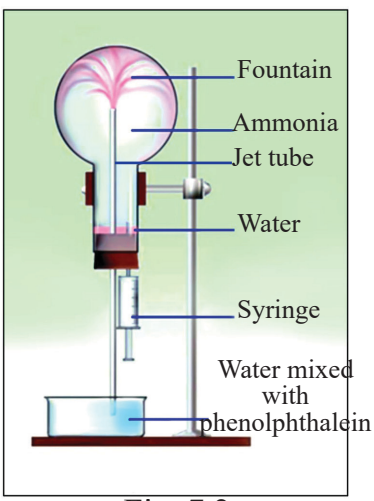


Fig. 7.2

.....

You know that phenolphthalein is an indicator which is colourless when comes into contact with neutral / acidic substances and gives pink colour with alkaline substances.

Which property of ammonia is responsible for this change in colour?

.....

Ammonium hydroxide is the product obtained when ammonia dissolves in water. Find its chemical formula by completing the chemical equation given below.

$$NH_3 + H_2O \rightarrow \text{.....}$$

Industrial preparation of ammonia (Haber process)

In this process, nitrogen and hydrogen, in the ratio 1:3, are made to combine at very high pressure and temperature to produce ammonia. Sponge iron is used as the catalyst.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{heat}$$

Atmospheric air is the source of nitrogen. Petroleum products like naphtha are used as sources of hydrogen. Hydrogen obtained by the electrolysis of water is also used.

Haber process

Fritz Haber
(1868-1934)

Carl Bosch
(1874-1940)

The German scientists Fritz Haber and Karl Bosch played a major role in the development of Haber process for the industrial production of ammonia in the first decade of the 20th century. Both of them are Nobel Prize winners. As ammonia was produced industrially, its importance as a raw material for the production of fertilizers and other chemicals increased. Haber process also led to the production of nitrogenous fertilizers, which helped several countries to achieve food security through Green Revolution.

The ammonia produced by Haber process is liquefied under high pressure and stored as liquid ammonia.

Liquor ammonia is the concentrated aqueous solution of ammonia. Ammonia gas can be easily liquefied by applying pressure. Liquefied ammonia is known as liquid ammonia.

Uses of ammonia

- For the preparation of chemical fertilizers such as ammonium sulphate, ammonium phosphate and urea.
- As refrigerant.
- For the production of artificial fibres such as nylon and rayon.
- In the refining of petroleum.
- As the main raw material in the industrial preparation of nitric acid by Ostwald process.

Take some ammonium chloride in a test tube. Add a little sodium hydroxide solution to the test tube. Observe the colour and odour of the gas produced. Bring a moist red litmus paper to the mouth of the test tube. Heat the test tube gently. Then, introduce a glass rod dipped in con. hydrochloric acid to the mouth of the test tube. Observe the experiment well and complete the following table. Conduct the experiment according to your teacher's instructions.

Colour of the gas produced.	
Odour of the gas produced.	
The change in colour of the moist red litmus paper when shown to the mouth of the test tube.	
Nature of the gas produced.	
What did you observe when the glass rod dipped in con. hydrochloric acid was shown to the mouth of the test tube?	
Write the chemical equation of this reaction.	$NH_3 + HCl \rightarrow$ .....

Table 7.2

Let us do an experiment showing the chemical reaction between ammonia and hydrogen chloride in a glass tube, as shown in the picture.

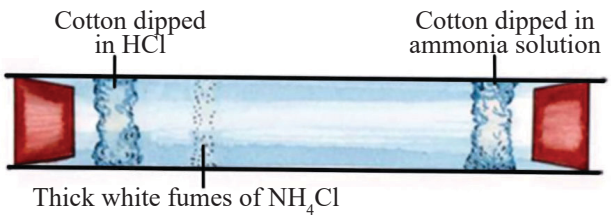


Figure 7.3

Place cotton dipped in HCl at one end and another piece of cotton dipped in ammonia solution at the other end of the glass tube, such that these are well inside the glass tube. Close both ends of the glass tube using cork. Observe the changes inside the glass tube.

Did you observe the thick white fumes formed? It is due to the formation of ammonium chloride by the combination of HCl gas and NH_3 gas which sticks on the walls of the glass tube.

When the glass tube is heated, the ammonium chloride decomposes.

Write the chemical equation of the formation of ammonium chloride.

.....

What are the reactants in this reaction?

.....

What is the product? .....

A reaction in which reactants are converted to products is called a forward reaction.

Write the chemical equation of the decomposition of ammonium chloride.

.....

A reaction in which products are converted to reactants is called backward reaction.

Let us write these chemical equations together.

$$NH_3 + HCl \rightleftharpoons NH_4Cl$$

The sign '$\rightleftharpoons$' indicates that the reaction takes place in both directions.

Reactions taking place in both directions simultaneously are called reversible reactions.

Examine the reversible reactions given in the following table and complete it.

Reversible reaction	Forward reaction	Backward reaction
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$		
$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$		
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$		

Table 7.3

Examine the chemical reactions given below.

$NaOH + HCl \rightarrow NaCl + H_2O$

$C + O_2 \rightarrow CO_2$

$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

In all these reactions, reactants react to give products. However, at the same conditions, the products do not change to reactants. Such type of reactions are called irreversible reactions.

The formation of ammonia by the reaction of nitrogen and hydrogen is a reversible reaction.

A graph related to rate of reaction is given (Figure 7.4). Analyse the graph and answer the questions given.

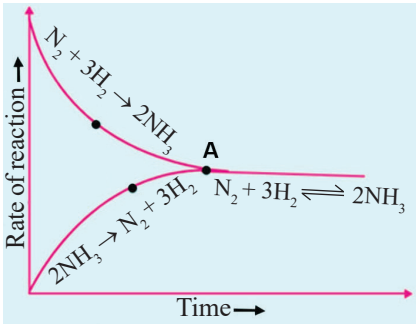


Fig. 7.4

Only the reactants are present at the beginning of the reaction. Then, in which direction does the reaction progress?

Forward reaction / backward reaction

What happens to the rate of the forward reaction as time proceeds?

.....

What change occurs in the concentration of the product, as the chemical reaction proceeds?

.....

Then, what happens to the rate of backward reaction?

.....

Identify the point at which the rates of forward and backward reactions become equal?

.....

The stage at which the rate of forward reaction becomes equal to the rate of backward reaction in a reversible reaction is called chemical equilibrium.

The scientist Le Chatelier has proposed an important principle related to chemical equilibrium.

> "When the concentration, pressure or temperature of a system at equilibrium is changed, the system will readjust itself so as to nullify the effect of that change and attain a new state of equilibrium." This is Le Chatelier's principle.

Characteristics of equilibrium

- At equilibrium, both the reactants and the products coexist.
- The rates of forward and backward reactions are equal at equilibrium.
- Even after attaining equilibrium, the reactant molecules react to form product molecules and, at the same rate, the product molecules react to form reactant molecules. Hence, chemical equilibrium is a dynamic equilibrium at the molecular level.
- When nothing new is added to a system and nothing is removed from the system, such a system is called a closed system. Equilibrium is possible only in a closed system.

Influence of concentration on equilibrium

Examine the chemical equation given below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

If the concentration of one of the reactants, nitrogen, is increased in this system at equilibrium, what changes are made by the system to rearrange itself according to Le Chatelier's principle? Tick (✓) only the correct ones in the Table (7.4).

More ammonia will be formed	✓
More hydrogen will be used	
Rate of forward reaction will increase	
Rate of backward reaction will increase	

Table 7. 4

Analyse the effect of change in concentration in the above equilibrium system and complete Table 7.5.

Action	Change in concentration	Change in rate
More hydrogen is added	Increases the concentration of reactant	Rate of forward reaction .....
More ..... is added	Increases the concentration of product	Rate of backward reaction increases
Ammonia is removed	Concentration of product	Rate of forward reaction increases
More nitrogen is added	Concentration of reactant increases	Rate of forward reaction .....
Nitrogen is removed	Concentration of reactant decreases	Rate of forward reaction .....
Hydrogen is removed	Concentration of reactant	Rate of backward reaction .....

Table 7.5

According to Le Chatelier principle, if the concentration of reactants is increased in a system at equilibrium, the rate of forward reaction increases. If the concentration of product is increased, the rate of backward reaction increases.

Pressure and chemical equilibrium

Examine the chemical equation of the formation of ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

In which state do the reactants and products exist?

Gaseous state / Liquid state / Solid state

……

Which physical state is influenced by pressure? …….....

Observe the above chemical equation and complete Table 7.6.

How many moles of reactant molecules are present?	.....
How many moles of product molecules are present?	.....
Change that takes place in forward reaction	..... moles of reactant molecules react to form ..... moles of product molecules.
Change that takes place in backward reaction	..... moles of product molecules decomposes to form …… moles of reactant molecules.

Change in volume in forward reaction	Volume …… (decreases / increases)
Change in volume in backward reaction	Volume …… (decreases / increases)

Table 7.6

At fixed volume, what happens to the pressure of a gaseous system if the number of molecules is increased?

Increases / Decreases .....

According to Le Chatelier principle, when the pressure of a system at equilibrium is increased, the system will try to attain equilibrium by reducing the pressure. This is achieved by increasing the reaction in the direction where number of moles of molecules decreases.

Identify the influence of pressure in the production of ammonia and complete Table 7.7.

Number of molecules (at the beginning of chemical reaction)	**Action**	**Change in rate of chemical reaction**
Total number of reactant molecules …… (more / less)	Increase the pressure	Rate of forward reaction ……..... (Increases / Decreases) Rate of backward reaction …..... (Increases / Decreases)
Total number of product molecules …… (more / less)	Reduce the pressure	Rate of forward reaction ……..... (Increases / Decreases) Rate of backward reaction ……..... (Increases / Decreases)

Table 7.7

Examine the following chemical equation.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

- What is the total number of reactant molecules?
- What is the total number of product molecules?
- What is the relation between the total number of reactant molecules and the total number of product molecules?
- Does pressure influence this reaction?

In a reversible reaction, if there is no change in the number of molecules of reactants and products in gaseous state, pressure will have no effect on the chemical equilibrium.

Temperature and equilibrium

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{heat}$$

Here, which is the endothermic reaction?

Forward reaction / Backward reaction

.....

On increasing the temperature, the system tries to reduce it by increasing the rate of endothermic reaction. As a result, the rate of backward reaction increases. So, temperature has to be reduced in order to increase the rate of forward reaction. But at low temperature, the number of molecules having threshold energy will be less. Therefore, the rates of forward and backward reactions get significantly reduced and hence the system will take more time to attain equilibrium. So, in the manufacture of ammonia, 450^{o}C is taken as the optimum temperature.

In a system at equilibrium, increase in temperature will increase the rate of endothermic reaction. Decrease in temperature will increase the rate of exothermic reaction.

Catalyst and equilibrium

You know that catalysts are substances which increase the rate of reactions. In a reversible reaction, catalysts increases the rate of both forward and backward reactions to the same extent. As a result, the system reaches equilibrium very fast.

What happens to the rate of reaction of a system at equilibrium when a catalyst is added? .....

- What is the catalyst used in the manufacture of ammonia?
  .....
- The manufacture of ammonia is a reversible reaction. Which conditions are favourable to obtain more product? Record them in your science diary.

Sulphuric acid (H_2SO_4)

Sulphuric acid is an important chemical used in the production of many substances like chemical fertilizers, paints, fibres, medicines, fabrics, detergents etc and in petroleum refining. Sulphuric acid is often called the 'King of Chemicals' because it is an industrially important chemical.

Sulphuric acid is manufactured by Contact process.

Important steps in Contact process

- Molten sulphur is burnt in purified and moisture free atmospheric air and converted to sulphur dioxide.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

- Sulphur dioxide formed in the first step combines with oxygen, in presence of the catalyst vanadium pentoxide (V_2O_5), to form sulphur trioxide.

$$2SO_2(g) + O_2(g) \overset{V_2O_5}{\rightleftharpoons} 2SO_3(g)$$

- SO_3 is dissolved in concentrated sulphuric acid to produce oleum ($H_2S_2O_7$).

$$SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$$

- The oleum thus obtained is dissolved in water to produce sulphuric acid.

$$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$$

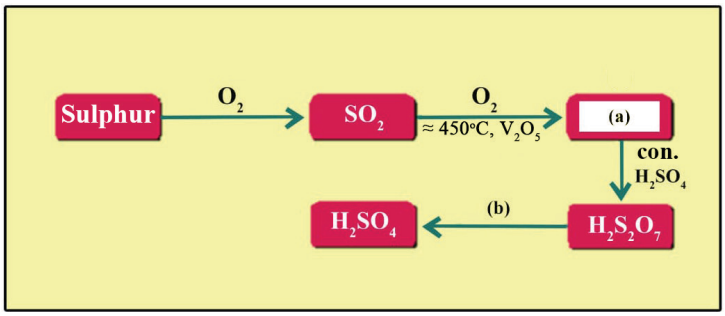
Complete the chemical equation given below to find out the product formed when sulphur trioxide dissolves in water.

$$SO_3 + H_2O \rightarrow .....$$

It is clear that dissolving sulphur trioxide in water gives sulphuric acid. Yet, why is sulphur trioxide not dissolved directly in water in the industrial production of sulphuric acid?

Since the dissolution of SO_3 in water is an exothermic process, the sulphuric acid initially formed turns into fog like particles (smog) which will hinder further dissolution.

The flow chart of industrial production of sulphuric acid is given. Identify (a) and (b) in this and write it down.



Physical properties of sulphuric acid

- Colourless
- Viscosity is higher than that of water.
- Denser than water.
- Dissolves in water.

Solubility in water

Take 5 ml water in a test tube and slowly add a few drops of concentrated sulphuric acid to it. Touch the bottom of the test tube. What do you feel?

Is the reaction exothermic or endothermic?

.....

While diluting sulphuric acid, the acid has to be added to water in very small quantities by stirring. If dilution is done by adding water to acid, the chance of splashing out of acid leading to accident is very high.

Lead chamber process

The Lead chamber process was used for the industrial production of sulphuric acid in early days. In this process, sulphuric acid is manufactured by passing sulphur dioxide obtained by burning sulphur or by the thermal decomposition of pyrite ores, steam and nitric oxide obtained by thermal decomposition of nitrates, into a large chamber coated with lead. Later the more efficient Contact process was discovered. The Contact process is now used in most sulphuric acid manufacturing industries.

Chemical properties of sulphuric acid

Dehydrating property

Take a little sugar in a watch glass and add a few drops of concentrated sulphuric acid. Observe the changes. Analyse the chemical equation of this experiment.

$$C_{12}H_{22}O_{11} \xrightarrow{\text{con.}H_2SO_4} 12C + 11H_2O$$

What is the black substance that remains? .....

What is the ratio of number of atoms of hydrogen and oxygen in a molecule of sugar? .....

What is the role of sulphuric acid in the chemical reaction?

It is clear that sulphuric acid absorbed the elements hydrogen and oxygen from sugar in the same ratio as in water.

Dehydration is the process of absorbing chemically combined water, or hydrogen and oxygen in the same ratio as in water from substances. Concentrated sulphuric acid is a strong dehydrating agent.

Perform the following activities which demonstrate the dehydrating properties of sulphuric acid and record your observations.

Activity	Observations
Add a little con. sulphuric acid to glucose taken in a beaker.	.....
Add con. sulphuric acid drop by drop to blue copper sulphate taken in a watch glass.	.....

Table 7.8

Drying property

Drying agents are substances capable of absorbing the moisture present in a substance.

Concentrated sulphuric acid is used as a drying agent in the preparation of CO_2, SO_2 and HCl.

Concentrated H_2SO_4 is not used as a drying agent in the preparation of NH_3. Why? .....

Reaction with salts

Concentrated sulphuric acid reacts with chlorides to form hydrogen chloride and with nitrates to form nitric acid. Chemical equations of these reactions are given.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$$

$$KNO_3 + H_2SO_4 \rightarrow KHSO_4 + HNO_3$$

Concentrated sulphuric acid can displace acids from their salts.

This method is employed in the preparation of hydrochloric acid, nitric acid etc.

Oxidising nature

Analyse the following chemical equation.

$$C + 2H_2SO_4 \rightarrow CO_2 + 2SO_2 + 2H_2O$$

What is the oxidation state of elemental carbon? .....

What is the oxidation state of carbon in carbon dioxide?

.....

What happened to carbon in this reaction?

Oxidised / Reduced

Have a look at the chemical equation of the reaction between concentrated sulphuric acid and copper.

$$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$$

Here, what change has occurred to copper? Examine by writing the oxidation state.

Oxidised / Reduced

Concentrated sulphuric acid reacts with metals as well as non metals and oxidise them. Concentrated sulphuric acid is a good oxidising agent.

Basicity of acids

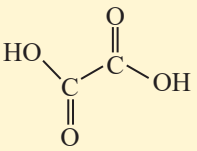
You know that the presence of H^+ ions is the basis for the characteristic properties of acids. Complete the following table by writing the equation of ionisation.

Acid	Equation of ionisation
HNO_3	$HNO_3 \rightarrow H^+ + NO_3^-$
HCl	.....
HBr	.....
HF	.....

Table 7.9

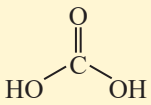
Oxalic acid ($H_2C_2O_4$)

Oxalic acid is present in the leaves and fruits of certain types of plants. Oxalic acid is present in spinach, brocoli, cabbage, tomato and avocado.



Carbonic acid (H_2CO_3)

Carbonic acid is prepared by dissolving CO_2 in water. It is a weak acid. Carbonic acid plays an important role in controlling the pH of blood.



How many hydrogen ions are liberated when each of the acid in the table ionises?

.....

The basicity of an acid is the number of hydrogen ions that the molecule of the acid can donate. If basicity is 1, the acid is called monobasic acid.

Examine the equation of ionisation of sulphuric acid.

$$H_2SO_4 \rightarrow H^+ + HSO_4^-$$

$$HSO_4^- \rightarrow H^+ + SO_4^{2-}$$

How many hydrogen ions are liberated when a molecule of sulphuric acid is ionised?

If so, what is the basicity of sulphuric acid?

.....

If the basicity of an acid is 2, it is called dibasic acid.

Complete the following table by writing the equation of ionisation.

Acid	Equation of ionisation
$H_2C_2O_4$ (HOOC-COOH)	$H_2C_2O_4 \rightarrow$ ..... + ...
H_2CO_3	$H_2CO_3 \rightarrow$ ..... + ...

Table 7.10

Complete the equation of ionisation of phosphoric acid..

$$H_3PO_4 \rightarrow \text{.....} + PO_4^{3-}$$

What will be the basicity of H_3PO_4 ? .....

If the basicity of an acid is 3, it is called tribasic acid.

You have learnt that alkalies are bases that dissolve in water. Write the chemical formula of sodium hydroxide.

.....

Examine the equation of the reaction that takes place when sodium hydroxide dissolves in water.

$$NaOH \rightarrow Na^+ + OH^-$$

Complete the given table 7.11.

Chemical name of alkali	Chemical formula	Equation of ionisation in water
Sodium hydroxide	NaOH	$NaOH \rightarrow Na^+ + OH^-$
Calcium hydroxide	.....	.....
Ammonium hydroxide	.....	.....

Table 7.11

What is the common ion liberated when alkalies dissolve in water?

.....

Alkalies are substances which increase the concentration of hydroxide ions in aqueous solutions.

Arrhenius stated that when acids and bases dissolve in water, they dissociate into ions. According to Arrhenius theory, acids are substances which liberate H^+ ions and bases are substances which liberate OH^- ions in aqueous solutions.

Sodium hydroxide

Sodium hydroxide is industrially produced by chlor-alkali process. In this, concentrated aqueous solution of sodium chloride (brine) is

Svante Arrhenius (1859-1927)

Svante Arrhenius was a Swedish scientist who won the Nobel Prize for Chemistry in 1903. He was a physical chemist who presented a scientific theory about acids and bases. He also proposed the concept of activation energy.

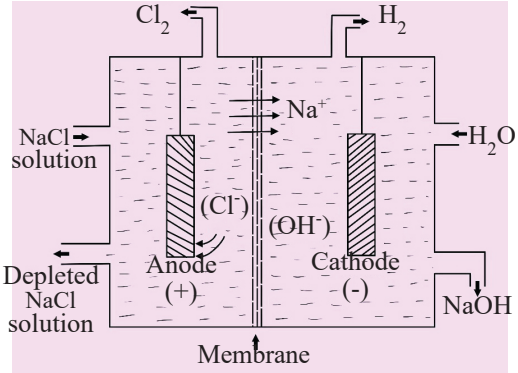


Fig. 7.5

subjected to electrolysis. In modern industries, membrane cell is used for the electrolysis of brine. A diagram of the membrane cell is given in Figure 7.5. In this, the two chambers are separated using a membrane which allows the passage of specific ions only.

What are the ions formed when sodium chloride dissolves in water? .....

Which ion undergoes oxidation at the anode?

.....

Complete the oxidation equation.

$$2Cl^- \rightarrow \text{.....} + \text{.....}$$

Which gas is liberated in the left chamber? .....

Electrodes in chlor-alkali process

In chlor-alkali process, platinum-iridium alloy rod acts as anode and steel or nickel is used as cathode in membrane cell. The membrane which allows the passage of certain specific ions only is made using the polymer nafion.

Na^+ ions in the left chamber move to the right chamber through the membrane.

Water molecules undergo reduction at the cathode in the right chamber.

Complete the reduction equation.

$$2H_2O + 2e^- \rightarrow \text{.....} + 2OH^-$$

Which gas is liberated here? .....

Sodium hydroxide is formed in the right chamber by the combination of Na^+ ions and OH^- ions.

$$Na^+ + OH^- \rightarrow NaOH$$

In this process, hydrogen and chlorine are also formed in addition to sodium hydroxide. Sodium hydroxide is also known as caustic soda.

Uses of sodium hydroxide

- For the preparation of soaps and detergents.
- For the purification of bauxite in the manufacture of aluminium.
- To produce paper.
- For the production of rayon.
- To manufacture medicines like aspirin.

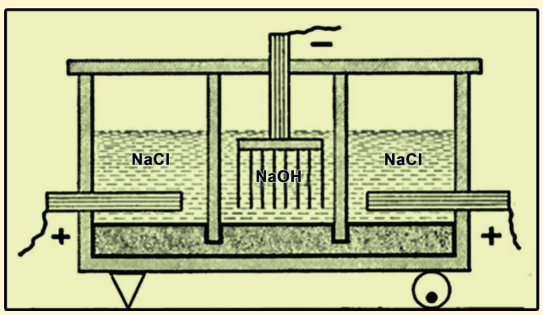
Hydrochloric acid (HCl)

What is the product obtained when hydrogen and chlorine react? Write the balanced chemical equation.

.....

Hydrogen chloride is manufactured by the direct combination of hydrogen and chlorine. Since it is an exothermic process, the reactor where the process takes place will always be hot. Hence the reactor is known as 'HCl oven' or 'HCl burner'. The hydrogen chloride formed in the HCl burner is dissolved in deionised water to produce concentrated hydrochloric acid.

Castner-Kellner Process



The Castner-Kellner process is also used to produce sodium hydroxide industrially. In this process also, sodium hydroxide is produced by the electrolysis of sodium chloride solution. In Castner–Kellner cell, graphite rod acts as anode and mercury acts as cathode (intermediate electrode).

Uses

- To refine table salt.
- To prepare dyes.
- For manufacturing PVC.
- To prepare aquaregia which is used to dissolve metals like gold and platinum.
- For preparing organic and inorganic compounds.
- To produce fertilizers.
- For refining metals.

Salts

We have learnt about neutralisation reactions in previous classes. Which is the salt formed when sodium hydroxide reacts with hydrochloric acid?

.....

After dissolving sodium chloride in water, use litmus papers to test whether the solution has acidic or basic nature. Write down your observation.

Examine whether the solutions of the salts given below are acidic or basic in nature and complete Table 7.12.

Salt solution	Change in the colour of blue litmus paper when it is in contact with the solution	Change in the colour of red litmus paper when it is in contact with the solution	Nature of solutions (Acidic nature / basic nature / neutral)
NaCl	No change in colour	No change in colour	Neutral
NH_4Cl			
Na_2CO_3			

Table 7.12

Certain salts when dissolved in water do not exhibit acidic or basic nature. Such salts are called neutral salts.

Salts that undergo hydrolysis when dissolved in water to give an acidic solution are called acid salts.

Eg. NH_4Cl, $(NH_4)_2SO_4$

Salts that undergo hydrolysis when dissolved in water to give a basic solution are called basic salts.

Eg. Na_2CO_3, CH_3COONa

Salt hydrolysis is the process by which the anions, cations or both of a salt react with water to form a solution that has acidic or basic nature.

Which acid and base react to produce NaCl?

.....

Here acid and base are strong. The salt formed by the reaction of a strong acid and a strong base will be neutral.

Strong acids and bases

Strong acids and bases completely decompose into ions in a solution. Hydrochloric acid (HCl), nitric acid (HNO_3), sulphuric acid (H_2SO_4), perchloric acid ($HClO_4$) etc. are strong acids.

Sodium hydroxide (NaOH), potassium hydroxide (KOH), calcium hydroxide ($Ca(OH)_2$) etc. are strong bases.

Weak acids and bases decompose into ions only partially in a solution.

Acetic acid (CH_3COOH), formic acid (HCOOH), oxalic acid ($H_2C_2O_4$) etc. are weak acids. Ammonium hydroxide (NH_4OH) is a weak base.

Which acid and base react to produce NH_4Cl?

.....

Which of these is stronger, the acid or the base?

.....

The salt formed from strong acid and weak base will be acidic.

Which acid and base react to produce Na_2CO_3 ?

.....

Which of these is stronger, the acid or the base?

.....

The salt formed from weak acid and strong base will be basic.

Fertilizers

Natural or artificial substances that provide nutrients to plants are called fertilizers.

What are the elements present in water and carbon dioxide?

.....

These elements are available to plants from nature itself. They can be absorbed from air and water. These three elements are called natural nutrients.

Nitrogen (N), phosphorus (P) and potassium (K) are the three elements that plants need in large quantities. These are called primary nutrients.

The soil contains low amounts of calcium (Ca), magnesium (Mg) and sulphur (S). Plants need these only in small amounts. These three elements are called secondary nutrients. Some elements are needed to plants only in very small amounts. Hence they are called micro nutrients.

Eg. Iron, manganese

Which are the elements needed for the growth of plants?

Carbon, hydrogen, oxygen, potassium, phosphorus, nitrogen, calcium, magnesium, sulphur, zinc, boron, copper, manganese, molybdenum, chlorine, iron, nickel etc are the elements needed for the growth of plants. About sixty elements are found in various plants. Continuous cultivation in the same area leads to the loss of nutrients in the soil. Therefore, nutrients have to be supplied to the soil as biofertilizers or chemical fertilizers.

Can plants utilise fertilizers that are insoluble in water?

.....

If a fertilizer decomposes too quickly, will it be beneficial to plants?

.....

Essential qualities of fertilizers

- The elements present in the compounds in fertilizer should be easily available to plants.
- The fertilizer should be soluble in water.
- The compounds in fertilizer must be stable and remain in the soil for a long time, making them available to plants
- They should not cause significant variations to the pH of the soil.
- They should not be toxic to plants.

Chemical fertilizers are used to make the primary nutrients available to plants in the right quantities. Such fertilizers are classified as nitrogenous feritlizers, phosphate fertilizers and potash fertilizers.These are combined to produce mixed fertilizers. These are also called NPK mixed fertilizers.

Types of fertilizers	Effect of fertilizer on plants	Examples
Nitrogenous fertilizers	• Accelerates the growth of plants.	Ammonium sulphate, calcium cyanamide, urea, sodium nitrate, calcium nitrate, potassium nitrate
Phosphate fertilizers	• Helps the growth of plants • Increases productivity	Ammonium phosphate, triple super phosphate
Potash fertilizers	• Helps the growth of plants • Increases productivity • Boosts immunity	Potassium chloride (Muriate of potash), potassium sulphate, potassium – magnesium sulphate

Table 7.13

Let us assess

1. Chemical formula of certain salts are given below.

KCl, $(NH_4)_2SO_4$, $AlCl_3$, CH_3COONa

Choose the correct ones from the given statements related to them and write it down.

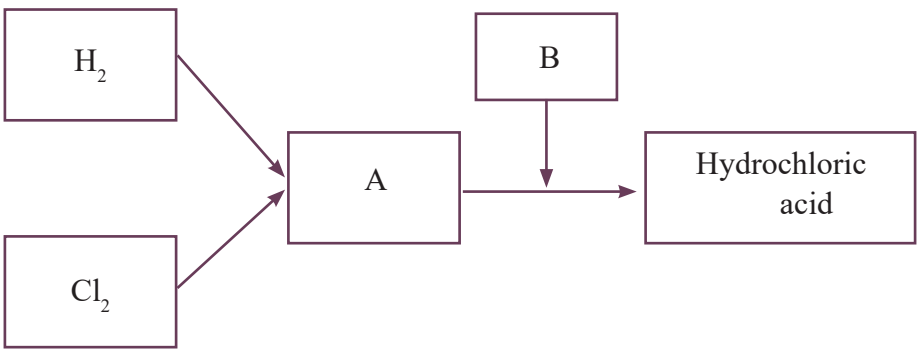
(i) KCl does not undergo hydrolysis.

(ii) $(NH_4)_2SO_4$ is an acidic salt.

(iii) $AlCl_3$ is a basic salt.

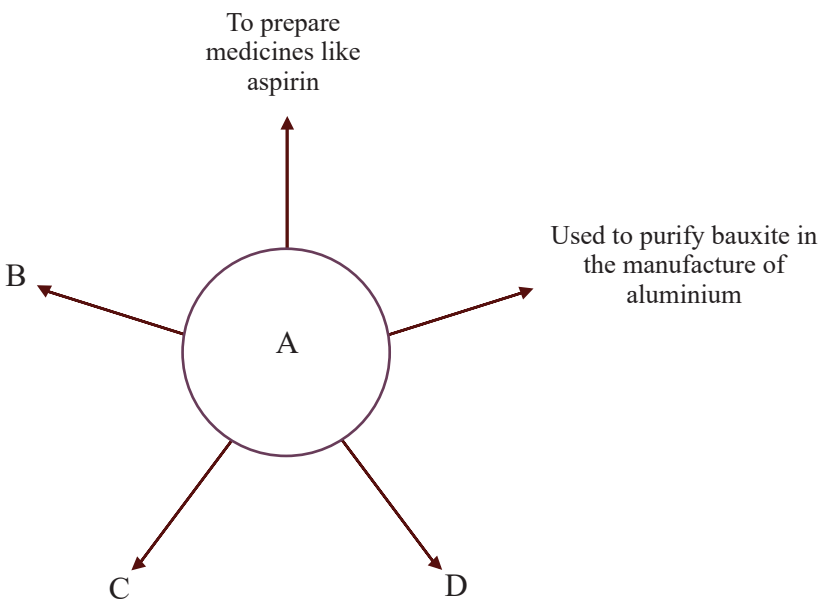
(iv) CH_3COONa is used to increase the basicity of an aqueous solution.

3. A flow chart of the industrial production of hydrochloric acid is given below.



What is A and B?

3. A word web indicating the uses of a compound is given. Complete it by adding A, B, C and D.



4. Explain with chemical equations of the chemical reactions that take place in the left and right chambers of the membrane cell during the chlor-alkali process.

   (Hint : Type of reaction, chemical equation, the gas liberated, compound formed)

5. The basicity of phosphoric acid (H_3PO_4) is 3.

   (i) Write the ionisation equations of phosphoric acid.

   (ii) Write the possible salts that can be formed when phosphoric acid react with sodium hydroxide.

6. Explain the effect of pressure on the following reversible reactions.

   (i) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

   (ii) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

7. $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) + heat$

   Complete the table given below by indicating the possible measures to increase the amount of NO_2 in this chemical reaction.

Temperature	..... (Increase / decrease)
Pressure	..... (Increase / decrease)
Amount of oxygen	..... (Increase / decrease)
Amount of NO	..... (Increase / decrease)

8. Haber process is an exothermic process. What changes can be done in the system to increase the amount of the product?

9. Complete the table.

Chemical name of the compound present in fertilizer	**Calcium nitrate**	**Ammonium sulphate**	**Calcium phosphate**	**Potassium sulphate**
Primary nutrient in the fertilizer				
Secondary nutrient in the fertilizer				

10. Examine the following statements related to Contact process. Write which among A, B, C or D is correct.

    (i) Contact process is the process used for the industrial production of sulphuric acid.

    (ii) In Contact process, the reaction between SO_2 and O_2 is endothermic .

(iii) Increasing the pressure will produce more SO_3.

(iv) Increasing the amount of oxygen will decrease the amount of the product.

(v) Increasing or decreasing the amount of SO_2 does not change the amount of SO_3.

(vi) V_2O_5 is used as a catalyst.

(vii) Here, the catalyst does not affect the chemical equilibrium.

A. (i), (ii), (iv) and (vi) are right and (iii), (v) and (vii) are wrong.

B. (i), (iii), (vi) and (vii) are right and (ii), (iv) and (v) are wrong.

C. (i), (ii), (iii) and (iv) are right and (v), (vi) and (vii) are wrong .

D. (i), (iii) and (vi) are right and (ii), (iv), (v) and (vii) are wrong.

11. (i) Which substance is used as the drying agent in the laboratory preparation of ammonia?

(ii) Can concentrated sulphuric acid be used as a drying agent in this process? Write the chemical equation that occurs if it is used.

12. Certain fertilizers are given.

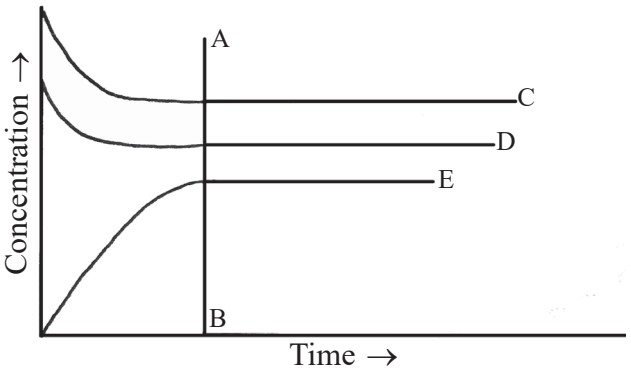
Urea, sodium nitrate, ammonium phosphate, potassium chloride

Complete the table.

Function in plants	**Fertilizers that can be used**
To accelerate plant growth.	
To increase productivity.	
To boost immunity of plants.	

Extended activities

1. A graph of the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ is given below.



At the start of this chemical reaction (time = 0), the concentration of hydrogen is greater than that of iodine.

(i) What do the curves C, D and E indicate?

(ii) What is the nature of the chemical reaction from the time indicated by the line AB?

2. Discuss with farmers and agriculture officer and prepare a note on the fertilizers used for any four crops at different stages of their growth.

3. Some chemical reaction that attain chemical equilibrium are given below. Explain the effect of pressure on these. (Hint : The effect of pressure on compounds that exist in the solid and liquid states is so small that it cannot be considered.)

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g)$$

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

4. If sodium acetate is added to very dilute vinegar, will the resulting solution be more or less acidic than the dilute vinegar? Justify.

5. The main components of a chemical fertilizer are ammonium phosphate $\left((NH_4)_3PO_4\right)$ and ammonium sulphate $\left((NH_4)_2SO_4\right)$.

(i) What is the minimum number of raw materials needed to manufacture it industrially?

(ii) What are these raw materials?

(iii) Explain the industrial preparation of these raw materials that are described in the unit.

CONSTITUTION OF INDIA

Part IV A

FUNDAMENTAL DUTIES OF CITIZENS

ARTICLE 51 A

Fundamental Duties- It shall be the duty of every citizen of India:

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wild life and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievements;

(k) who is a parent or guardian to provide opportunities for education to his child or, as the case may be, ward between age of six and fourteen years.

CHILDREN'S RIGHTS

Dear Children,

Wouldn't you like to know about your rights? Awareness about your rights will inspire and motivate you to ensure your protection and participation, thereby making social justice a reality. You may know that a commission for child rights is functioning in our state called the ***Kerala State Commission for Protection of Child Rights.***

Let's see what your rights are:

- Right to freedom of speech and expression.
- Right to life and liberty.
- Right to maximum survival and development.
- Right to be respected and accepted regardless of caste, creed and colour.
- Right to protection and care against physical, mental and sexual abuse.
- Right to participation.
- Protection from child labour and hazardous work.
- Protection against child marriage.
- Right to know one's culture and live accordingly.
- Protection against neglect.
- Right to free and compulsory education.
- Right to learn, rest and leisure.
- Right to parental and societal care, and protection.

Major Responsibilities

- Protect school and public facilities.
- Observe punctuality in learning and activities of the school.
- Accept and respect school authorities, teachers, parents and fellow students.
- Readiness to accept and respect others regardless of caste, creed or colour.

Contact Address:

Kerala State Commission for Protection of Child Rights

'Sree Ganesh', T. C. 14/2036, Vanross Junction

Kerala University P. O., Thiruvananthapuram - 34, Phone : 0471 - 2326603

Email: childrights.cpcr@kerala.gov.in, rte.cpcr@kerala.gov.in

Website : www.kescpcr.kerala.gov.in

Child Helpline - 1098, Crime Stopper - 1090, Nirbhaya - 1800 425 1400

Kerala Police Helpline - 0471 - 3243000/44000/45000

Online ***R. T. E Monitoring : www.nireekshana.org.in***